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nx2-Amplifier

A 100W CFA High Fidelity Amplifier

An updated and improved version of the venerable nx-Amplifier, launched in 2012, the new nx2 features components readily available in 2025, lower distortion and noise, and a more capable output stage.

Contents

1. WARNING DISCLAIMER

This project is intended for experienced DIY constructors.

This project involves wiring up mains voltages.

Do NOT attempt this project unless you are completely aware of the dangers of mains voltages and fully understand mains voltage wiring safety practices and conventions.

A wiring mistake can be lethal. Do not take any risks.

Seek professional advice if you are not sure.

Always adhere strictly to the electrical regulations in your country.

WARNING DISCLAIMER

Never work on the amplifier wiring with power connected. When wiring or debugging with the lid off, always unplug the amplifier from the mains

2. The nx2-Amplifier: Some Background

- In 2012, shortly after I published the sx-Amplifier, a very simple pared-down class A CFA, I tweaked the design to come up with the nx-Amplifier that delivered 100 Watts RMS into an 8 Ohm load and simulated at 0.007% distortion at 80 Watts RMS.
- Like the sx-Amp it was based on, the idea was to keep the amplifier simple, and easy to build but still have good overall results and sound.
- The transimpedance stage (aka VAS) was a simple single transistor implementation preceeded by a standard CFA diamond buffer input stage, while the OPS was an EF2.
- Two iterations of the nx-Amp board were made - the initial release in 2012 and then a further small update in 2016. About 150 sets of each release were sold through Jim's Audio* and from what I can tell, most of those were built.
- Accompanying the amplifier boards was a rather complex and unwieldy power supply and protection board that I called the 'PSU +Prot' that offered +-50V DC rails, DC offset and overload current protection, and power ON/OFF muting. The Zobel network for the amplifier modules was, unusually and not very cleverly, incorporated onto the PSU +Prot Board.
- I received lots of excellent feedback about the sound which builders loved. However, in retrospect, I think some aspects of the design were idiosyncratic as will be made apparent on the next two slides.
- Fast forward 13 years to 2025, I've learned a lot, had much feedback, and so it is time for an upgrade . . .
- This can be approached in two ways: start with a blank sheet of paper and a brand-new design or start with what is a good basic amplifier and improve it, ending up with something altogether better than the original. I decided on the latter course of action, adhering to the 'if it ain't broke, don't fix it, just upgrade it' dictum.

*Kindly note, I make/made no financial benefit from the sx, nx or kx2 Amplifiers and associated PSU boards. The Gerbers for the PCBs were ceded to Jim's Audio who then sold the PCB's through his online shop. The nx2-Amplifier will however be sold through the ww.hifiSonix.com store. The small profit I make funds new designs and the Hifisonix.com website

3. The nx2-Amplifier: Upgrades over the original nx-Amp (1 of 2)

Refer to slides 8 and 9 for the original nx-Amplifier circuit diagrams

1. Output DC Offset adjustment. In the original nx-Amp design, the offset trimming current was injected into the low-impedance inverting input of the CFA Diamond Buffer (‘DB’) via R1 (10k). In badly h_{FE} and V_{be} mismatched DB and TIS transistors, this would necessitate injecting large offset currents into the inverting input and in extreme cases, changing R1 from 10k to 4.7k. This in turn loaded the +10V Zener references, sometimes exacerbating the problem. On the nx2-Amp, the offset adjust is moved to the high impedance non-inverting input, like the kx2-Amplifier, requiring only +-300 uA to be injected into the offset nulling node to provide up to +- 1V offset adjustment at the amplifier output.

2. On the original amplifier, the diamond buffer transistors Q9 and Q11 collectors were tied directly to the +-50V rails via R33 and R32 leaving each of these transistors with about 45V collector to emitter voltage. Due to the Early effect, these transistor collector currents were higher than the input transistor collector currents by about 30-40uA and larger offsets than necessary arose because the Early voltage (V_A) is markedly different between the N and P devices, with LTspice models showing 82V for the BC546 vs 39V for the BC556. In the nx2-Amplifier, these problems are solved by cascoding Q3 and Q4 (see the nx2 schematic), reducing input offsets and associated drift and keeping the input stage in better thermal balance. Note, this problem is not apparent on the kx2 and its progenitor, the sx-Amp, because of their dramatically lower supply voltages.

3. The DB on the original design used 150 Ohm (R36 and R37) and 120 Ohm (R28 and R29) emitter degeneration resistors, in the latters cae, to ensure an adequate voltage drop across the DB output transistor load resistors R32 and R33 (1k). The nx2 uses all 100 Ohm resistors and the upshot is a very significant improvement in output offset voltage drift (which was already very good on the original).

4. Another criticism with the original nx-Amplifier was the direct coupled input, with many builders fitting their own DC blocking caps. Further, the HBR on the original nx-Amp was incorrectly configured although this did not seem to cause any problems in practice – the nx-Amp and sx-Amps were noted for being exceptionally hum-free. The nx2 remedies both these issues.

5. The original nx loop gain was low as a consequence of the single transistor transimpedance stage or TIS (aka VAS) (Q6 and Q7) and meant distortion at full power was not much lower than 0.01% (1 kHz). The 1 kHz Loop gain on the nx2 is ~63 dB (vs 42 dB on the original nx) which has been accomplished by adding a beta helper to the TIS transistors Q6 and Q7 in the nx2 (see the nx2 schematic). This in amongst other things has lowered the measured 100W full power distortion to <30ppm (see the measurements starting at slide 35).

6. Compensation. The compensation used on the original nx-Amp used a single ‘light touch’ 68pF capacitor from the VAS to the inverting input and exploited most of the available HF loop gain. However, given the additional loop gain from introducing a beta helper in the nx2 as outlined in (5) above, more advanced Transitional Miller Compensation (TMC) can now be employed, dramatically lowering HF distortion. This has also increased the loop gain bandwidth from c. 6 kHz on the original to ~20 kHz on the nx2. In the compensation design discussion later, we will go into this in more detail.

The nx2-Amplifier: Upgrades over the original nx-Amp (2 of 2)

7. The Zobel on the original design was off-board on the PSU +Prot board. This meant users were tied to the PSU +Prot board and the solution was in any event sub-optimal. The Zobel loop area has to be as small and tight as possible around the OPS (output stage) for maximum effectiveness. By correctly locating the Zobel on the amplifier module board, inter-module wiring is further reduced and builders can opt for their own power supply if they so wish.
8. The speaker protection switched the speaker return and not the amplifier output. While this saved on 2 photovoltaic couplers and allowed very fast protection switching, it did not work if the speaker return was accidentally shorted to the amplifier chassis. Other than that, the protection board worked well.
9. Wiring to the PSU +Prot board was overly complex and the terminal layout sub-optimal, making a neat build and wiring difficult for all but the most persistent builders. The nx2 uses the existing Hifisonix speaker protection board for easier wiring. Builders can also use their own protection board if they so wish.
10. The OPS bias current adjustment was coarse, allowing the OPS to be turned completely off, through to over 400mA, which was trimmed down to about 200mA in the 2016 update. An adjustment range of 0mA to about 130mA per pair to cater for device spreads would be an improvement and that is what has been done on the nx2.
11. On the original nx Amp, the power supply reservoir capacitors were rated at 50V so the maximum supply voltage was 50V and to get the rated 100W out, the amplifier needed close to +-50V rails. This meant on some implementations, the capacitors were stressed if mains overvoltages were encountered. On the nx2, all rail to 0V connected electrolytic caps are rated at 63 volts and the supply voltage can therefore be raised to ~55V, giving a little more headroom and tolerance for mains overvoltages
12. The new nx2 uses SMD components extensively on the front end to keep the PCB compact and future-proof the design.
13. The nx2 uses 3 pairs of 200W output devices, offering a dramatic improvement in SOA, and allowing the amplifier to drive more difficult loads with ease.
14. Finally, and very importantly, the PCB layout on the new nx2-Amplifier incorporates all the learnings I have accumulated over the last 12 years and that has dramatically lowered the full power mains hum and related harmonics peaks to no more than -110 dBr, or a measured THD+N of -88dB. For a simple CFA like this, these are very good figures.

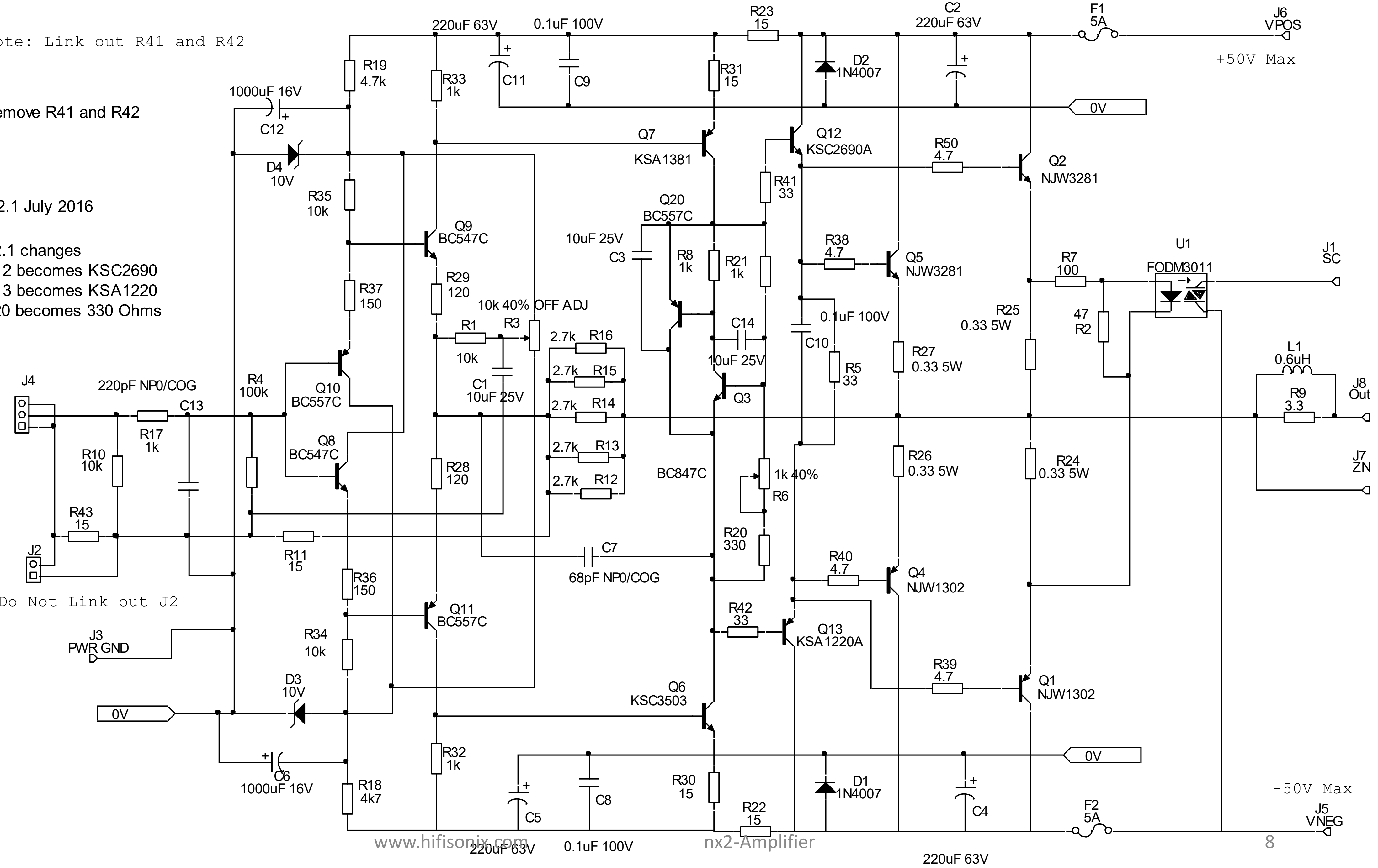
Original nx-Amplifier Circuit Diagram (2012)

Note: Link out R41 and R42

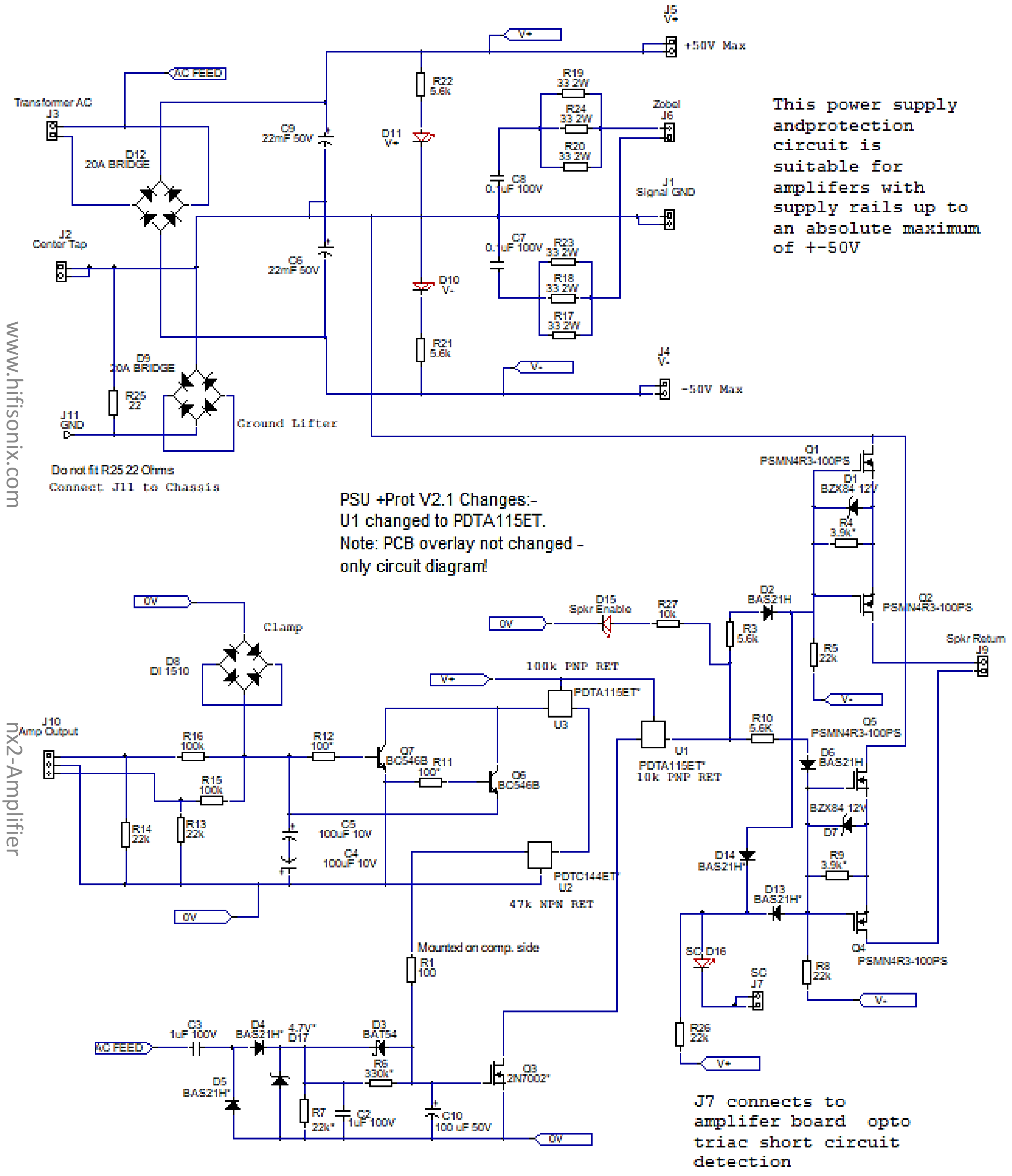
Remove R41 and R42

V2.1 July 2016

V2.1 changes
Q12 becomes KSC2690
Q13 becomes KSA1220
R20 becomes 330 Ohms



Original nx-Amplifier PSU + Protect Circuit Diagram (2012)



All Components marked with astersik (*) are SMD and mounted on BOTTOM of PCB

4. nx2-Amplifier specifications - July 2025

Output power and distortion	Both channels driven: 100 W RMS into 8 ohms at <0.003% distortion; 200 W RMS into 4 ohms at 0.004% distortion (1 kHz)
Maximum short term power	single Channel driven: 300 W into 2 ohms for 1 minutes or less
IMD 19+20 kHz at full power	-90 dB below fundamental tones at 2 x 25 W RMS into 8 ohms
Peak output current	>20 Amps for 50 ms
Output stage standing current	40 to 80 mA per OPS pair recommended
OPS configuration	3 pairs 200 W 15A transistors in Locanthi 'T' EF2
Frequency response	2 Hz to 340 kHz +0 dB -3 dB; 20 Hz to 20 kHz +0 dB -0.1 dB
Rise/fall time	~700 ns in both directions at 75 V pk~pk into 8 ohms; equivalently ~100 V/us slew rate*
Gain	31x or 29.9 dB
Input sensitivity	1.35V for rated output power into 8 ohms
Input Impedance	22k at 1 kHz
Small signal stability	Any capacitance up to 2.2 uF in parallel with any resistance from 2 ohms to ∞
Output offset	+-20 mV worst case over temperature; typically +-5 mV or better
PSRR	All peak mains fundamental and harmonic components <-110 dBr at all rated powers
Damping factor 1 kHz	130
Loop gain	65 dB at 1kHz
Loop gain bandwidth	-3 dB at 19 kHz; ULGF 2.19 MHz
Compensation	Transitional Miller Compensation (TMC)
Weight	12kg
Dimensions	Modushop Mini Dissipante housing 300 mm wide x 300 mm deep x 190 mm high (including feet)

* CFA amplifiers do not slew rate limit, so its better to characterise them in terms of rise/fall time; For a practical amplifier, this is primarily set by the input bandwidth limiting filter; nevertheless, an indicative slewrate figure has been included in the nx2-Amp spec of >100 V/us

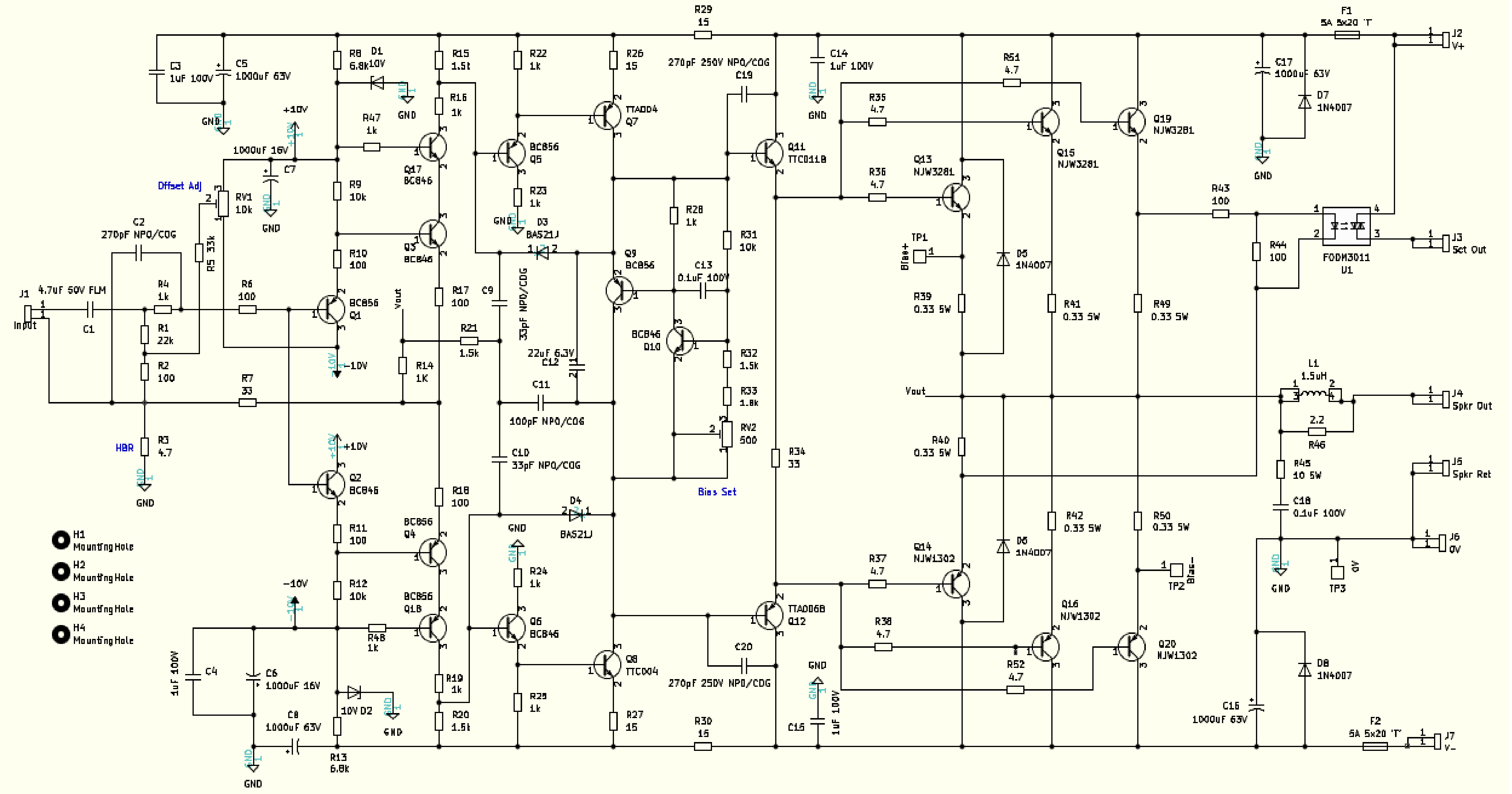
5. nx-2 Amplifier Circuit Description

- ***Input Stage.*** The nx2-Amplifier is a Current Feedback Amplifier (CFA). The unbalanced (aka 'single-ended') input is fed in via J1 with pin 1 (signal HOT) going to C1, the DC blocking capacitor (4.7uF Film). R1 and R2 (22k and 100 Ohms respectively) provide DC bias for the input transistors Q1 and Q2 (BC856B and BC846B). R4 and C2 form a low pass filter with a cut-off frequency of c. 340 kHz. This acts to limit RFI, and bandwidth limits the input signal – a point that will be discussed further under 'Compensation'. R6 (100 Ohms) acts as a base stopper since the input pair are emitter followers which can under some circumstances suffer from instability. About +-1V of output voltage offset adjustment is provided by injecting a small current of up to ±300uA into the junction of R1 and R2 via R5 (33k) which is connected to the wiper of RV1 (10k 25 turn trimmer) which in turn taps off the +-10V front-end supply created by 10V Zener diodes D1 and D2. This offset technique is much more elegant and more reliable than the original nx-Amp where the offset was injected into the low-impedance input at the output of the diamond buffer (DB).
- ***Input diamond buffer stage.*** Q1, Q4 (BC856B), and Q2 and Q3 (BC846B) form the input stage diamond buffer. The bases of Q1 and Q2 are the high-impedance non-inverting input, whilst the junction of R17 and R18 (100 Ohms) coming from the emitters of Q3 and Q4 is the low-impedance inverting input. The emitter load for the input DB devices is provided via R9 and R12 (10k) which are connected to D1 and D2 which form the front-end regulated supply. R10, R11, R17, and R18 are all set at 100 Ohms and thus in conjunction with the reference current derived from the +-10V supply through R9 and R12, provide an emitter stand-off voltage of around 100mV on all four DB devices. This stabilizes all the DB DC operating currents at ~950uA. Further, since there may be substantial differences of up to 20mV in the transistor Vbe's due to normal device production spreads, the 100mV stand-off swamps these, ensuring all the devices operate at around the same current, give or take a few 10's of uA. If the 100 mV stand-off resistors are omitted, it would require all four of the front-end transistors to be very closely Vbe and hFE matched to ensure correct operation, something that can really only be achieved on an IC. The output of the diamond buffer is a complementary current at the collectors of Q3 and Q4, with a nominal DC level of ~950uA. Note that the zener references D1 and D2 are heavily decoupled with 1000uF capacitors C7 and C6. In conjunction with R8 and R13, this ensures that on power-up, the amplifier comes up slowly, minimizing output thumps.
- The output of the DB is coupled to the respective rail referenced load resistors R15 and R20 via cascode transistors Q17 and Q18. These derive their base bias from the reference diodes D1 and D2 via R47 and R48 1k base stoppers. Without cascoding, the collector currents of Q3 and Q4 would be about 20% higher and highly imbalanced due to the Early effect, and the fact that the Early voltage for BC846 and BC856 are quite different. By operating all 4 DB transistors at the same collector currents and the same voltages, the offset voltage spread is minimised, and DC offset drift is very low. On the two prototypes builds, I measured <5mV difference between 2 minutes after switch on, and 30 minutes later after running at full power output. No doubt, the use of SMD devices and a compact front end layout also contribute to this.
- ***Transimpedance aka Voltage amplifier stage.*** R15 and R20, the cascode collector load resistors, develop ~1.45V across them which provides the DC bias for the complementary, or balanced, transimpedance stage (TIS) also referred to in some texts as the VAS. Q5 beta helper (BC856B) and Q7 (TTA004 PNP) form the upper amplifier stage with the lower stage formed by Q6 beta helper (BC846B) and Q8 (TTC004 NPN). The volt drops across R15 and R20, in conjunction with R26 and R27 (15 Ohms) set up the TIS standing current in Q7 and Q8 at circa 20mA and maintain thermal stability of the stage's operating current. R26 and R27 also provide local AC feedback (aka degeneration), improving the open-loop linearity of the TIS. Since this is an EF2 amplifier and not an EF3 or MOSFET OPS, the current demanded by the output stage is higher, hence the higher TIS operating current. R22 and R25 (1k) load the beta helpers to their respective rails, while R23 and R24 (1k) are included to ensure the beta helpers cannot suffer from any HF instability, a problem mentioned earlier with emitter followers. Diodes D3 and D4 (very low reverse capacitance BAS21J 300V devices) form Baker clamps and prevent rail sticking and limit the peak current in the VAS on gross overdrive to just a few mA above the standing current. Without them, the TIS transistor current can peak at over 300mA, almost certainly failing in the process.

nx-2 Amplifier Circuit Description (cont.)

- ***Voltage Amplifier Stage (cont.)*** The TIS output appears at the collectors of Q7 and Q8 which are tied together by the Vbe multiplier bias control circuit formed by Q9 (BC856B) and Q10 (BC846B) and associated components. Under normal operating conditions, the volt drop across the bias controller is around 2.4V, so ±1.2V measured with respect to 0V with the amplifier input shorted and the offset dialled out. C12 (10 uF) provides decoupling for the stage, while C13 (0.1uF) provides compensation, ensuring the Vbe multiplier circuit is free from oscillation. Q10 is mounted in close thermal proximity to Q9's collector and this provides fast, accurate bias control compensation over the amplifier's operating temperature range.
- ***Output Stage.*** Q13, Q15 and Q19 form the top half of the class AB push-pull output stage, and Q14, Q16 and Q20 form the bottom half of the output stage. Q11 (TTC011B NPN) and Q12 (TTA006B PNP) are the drivers whose emitters are tied together by R34 (33 Ohms), setting the driver standing current at 36mA. 4.7 Ohm resistors (R35, R36, R51 and R37, R38 and R52) act as base stoppers to ensure there is no chance of any OPS instability. The emitters of all 6 devices are coupled to the output rail via 0.33 Ohm 5W resistors (R39, R41, R40, R42, R49 and R50) which provide local AC feedback to the output devices and in conjunction with the bias controller circuit, help stabilize the output stage standing current.
- The junction of these 6 resistors is coupled to the output at J4 by L1, a 1.5uH inductor, in parallel with a 2.2 Ohm damping resistor R46. This network very effectively isolates the output stage from any speaker and interconnect cable capacitive load. R45 (10 Ω 5W) and C18 (0.1uF 100V film) form a Zobel network (sometimes called a 'Boucherot cell') that ensures at HF the amplifier load impedance (which typically rises with frequency above a few kHz) as seen from the output terminal J4, remains fairly flat and resistive. Without it, the amplifier could break into HF parasitic oscillation with (typically) reactive speaker loads. D5 and D6 (1N4007) provide a path to the supply rails for inductive energy dump from the speaker and cabling.
- **Short circuit protection.** A random phase opto-triac (U1) is used to implement output current overload detection. R43 and R44//R53 measure the voltage across emitter degeneration resistors R49 and R40 and if exceeding 7A peak (so >20A for all 3 output transistor pairs), the triac is triggered and pulls J3 ('Sct Out') to the V+ rail. This output is used by the Hifisonix speaker protection PCB to rapidly disable the speakers. Note that the amplifier will have to be powered fully down and the main reservoir capacitors fully discharged before the triac and the speaker protection board will reset. If this ever does happen, it is a good opportunity while the amplifier is reseting to check speaker wiring etc or any short circuits. The response time to a gross overload is in the region of 5 to 10 millseconds to disengage the speakers. Note, if you use the Hifisonix speaker protection board, you must change R7 on that board from 1k to 33k – details given in the assembly instructions later.
- ***Power and Power Rail decoupling*** The power rails are generously decoupled with 1000uF 63V capacitors (C16, C17) which are further paralleled by 1uF 50V MLCC capacitors (C14, C15) to ensure the power rail impedance at HF remains low. R29 and R30 (15 Ωs) with C5 and C6 (1000uF 63V) form power rail low pass filters with a corner frequency of c. 10 Hz, isolating the voltage gain stage from the main power rails and further improving HF PSRR. C3 and C4 (1uF 100V) provide HF bypassing for the large electrolytics. The Amplifier PSRR with this set-up is in excess of 75 dB at 100Hz, and increases so that between 1 kHz and 20 kHz it is better than 85 dB, decreasing again so that at 1 MHz it approaches 50 dB. At 200W per channell in to 4 ohms, all peak mains harmonics remain below -107 dBr, and at 100W into 8 ohms, they are not more than -110 dBr.
- Diodes D7 and D8 (1N4007) ensure that if one of the fuses blows, none of the semiconductor junctions becomes excessively reverse-biased, causing possible damage. The rails are fused with 5 x 20 mm 5A 'T' fuses – these will safely allow short term peak currents in excess of the rated 20A peak current outputs and are incorporated as a final protection mechanism in case of a catastrophic failure, for instance of both output halves go short (highly unlikely).

nx-2 Amplifier Schematic



Notes about matching the transistors

- It is recommended you hFE and Vbe match to within 10% the following device pairs

  Q1 and Q2

  Q3 and Q4

  Q7 and Q8

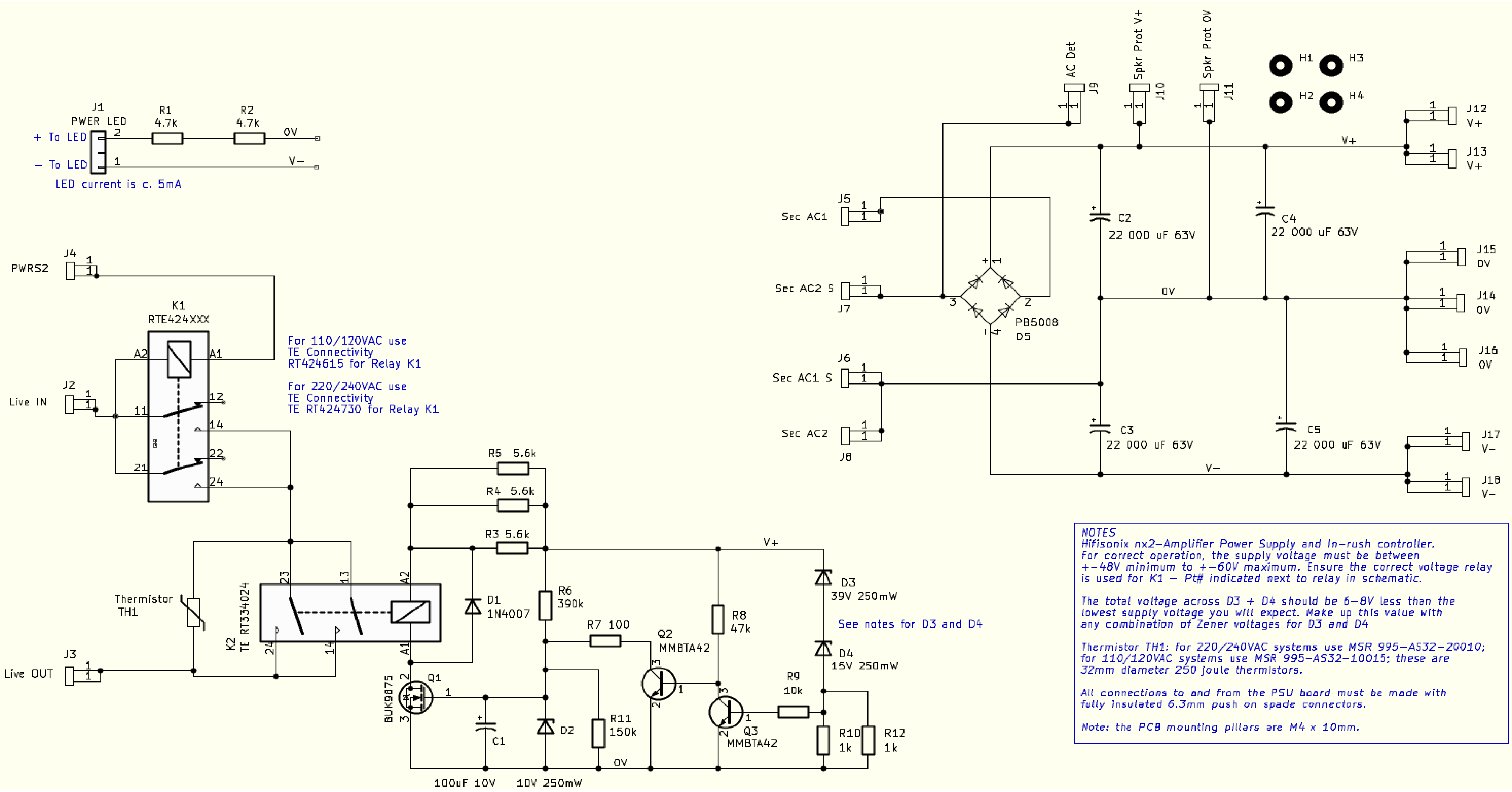
- If you cannot get tight matching, a good option is to simply measure the Vbe and then use the closest matched pairs in each amplifier module.

Please note, if you do not match the transistors, you amplifier will still work, but matching them will give you a little lower distortion, and it will make a big improvement to the offset adjustment range.

6. nx-2 Amplifier PSU Circuit Description (see next slide for the schematic)

- **Power transformer.** I used a very high quality 500VA transformer from Tiger Toroids with dual 41 VAC secondaries to provide ±56V output (no load). The transformer includes a GOSS band and interwinding screen. The transformer secondaries feed into the PSU board on J5 through J8 before passing through a single 45A rated bridge rectifier D5 (PB5008). This is followed by 2 x 22 000uF 63V filter capacitors on each rail (C2 and C4 for V+ and C3 and C5 for V-). The output connectors are J12 through J18. The power section of the board is carefully laid out to minimize loop areas, and thus EM radiation. The power supply and AC Detect connections (J9~J11) for the Hifisonix speaker protection board are conveniently located together which facilitates a neat wiring job during final assembly of the amplifier.
- **Power ON/OFF control.** A 110VAC or 220VAC Relay is used (K1). The coil current at mains AC voltage is in the region of 15-20mA allowing the use of an attractive front panel mounted anti-vandal switch (see the schematic for the relevant AC voltage dependent Mouser part numbers).
- **Inrush delay circuit.** Zener diodes D3 and D4 ensure that transistor Q3 (MMBTA42) only conducts when the supply voltage exceeds their total series voltage plus about 1V. Prior to Q3 conducting, Q2 (MMBTA42) is conducting with base bias being provided by R8 (47k), which in turn holds the delay timing capacitor C1 (100uF 10V) at 0V. Once Q3 starts to conduct, Q2 is turned off, and C1 begins to charge via R6 (390k). When the voltage across C1 reaches ~2.5V, Q1 switches on, energizing K2 (24V relay), which bypasses the thermister TH1. When the amplifier is powered down, as soon as the voltage drops below the combined volage of D3 plus D4, Q3 turns off, allowing Q2 to conduct again which then resets the timing capacitor C1.
- R11 reduces the maximum voltage across C1 and helps increase the delay time without recourse to a larger value C1 timing cap. R7 (100 ohms) reduces the peak current into Q2 collector to ~100mA while D2 is included to protect the mosfet gate from potentially excessive voltages. R3-R4 are the voltage dropper resistors that allow the 24V relay to be used on the amplifier’s 55V rails and D1 is the relay coil flyback clamp diode.
- While TH1 is in circuit, the inrush current is limited to about 15A peak which prevents mains dips, and limits the peak current through relay K1’s contacts
- **Front panel power switch**. The front panel anti-vandal switch indicator LEDs are powered of the negative rail of the amplifier and R1 and R2 (4.7k each) set the LED current to about 6mA. Note that the indicator LED will remain illunated for a few minutes after power down as the power supply discharges.
- The anti-vandal switch contacts must be rated for 250 VAC and 30 mA minimum. Do not use switches that only have a low voltage DC rating – this is important for safety reasons! See slides in the construction and assembly section for examples of suitable switches.
- **Important notes.** Note carefully that relay K1 and the thermistor must be selected per the mains operating voltage in your region for either 110/120 VAC or 220/240 VAC. The thermistor (a 250J devices) is set for 10 ohms for 110/120 VAC or 20 ohms for 220/240 VAC devices.
- **Selecting D3 and D4**. The total voltage across D3 + D4 should be 6-8V less than the lowest supply voltage you will expect. Make up this value with any combination of Zener voltages for D3 and D4. For my build, I used what I had available which was 39V and 15V. The devices should be rated for 400mW or greater.
- Finally, since the power supply board has mains voltages present on it, exercise extreme caution during testing, wiring and debugging. If you are unsure of how to deal with mains voltages, seek professional help, or use another power supply.

nx-2 Amplifier PSU Schematic



7. nx2-Amplifier Compensation

The nx2 uses Transitional Miller Compensation aka TMC. On the next slide, the uncompensated (red trace) and compensated loop (teal trace) gains are plotted.

There are two feedback networks on the nx2 amplifier. The first is the main feedback network via Rf (1k R14 in the schematic) and Rg (33 Ohm R7 in the schematic) setting the closed loop gain to 31x. The second is the TMC network comprising C9, 10, 11 and R21.

Due to the output stage pole, the ULGF has to be closed at a suitable phase margin of 60 degrees or more, and that is at about 2.2 MHz in the EF2 design. This is accomplished with -40 dB/decade slope (the combined slopes of both feedback networks) which manifests between about 25kHz and 200kHz as depicted on the plot, allowing the extra loop gain at 20kHz to be extracted.

At LF, the output stage is enclosed by both the overall feedback network via R14 and R21 and C9 and C10 (33pf each) with R21 at 1.5k effectively bypassing high reactance of C11 (100pF). The combination of these two feedback paths results in additional loop gain over and above that of conventional Miller compensation (MC) in the upper half of the audio band and a -40 dB/decade gain slope after 25 kHz. This is accomplished by utilizing, or extracting, the available open loop gain at HF which you can see on the open loop plot. With MC, a much more basic scheme, this valuable additional loop gain is wasted.

However, the penalty for TMC is the phase margin at HF approaches 180 degrees and if the loop is closed with this -40 dB/decade slope, the amplifier will almost certainly be unstable. To remedy this, the slope beyond 200 kHz is returned to -20dB/decade so that by the time it intersects the targeted ULGF, the phase margin is returned to a figure that ensures stability – usually ~60 degrees in an amplifier design like this. This is accomplished as the reactance of C11 reduces, shunting R21 and in so doing, taking the OPS out of the TMC network. This has the effect of returning the amplifier to straight MC compensation (which is -20 dB/decade and 90 degree phase shift) at HF by transitioning the gain slope from -40 dB/decade to -20 dB decade, along with the attendant phase margin shift back towards 90 degrees. This transition takes place from about 400kHz up 1MHz after which the slope is -20dB/decade up to the ULGF at 2.2 MHz.

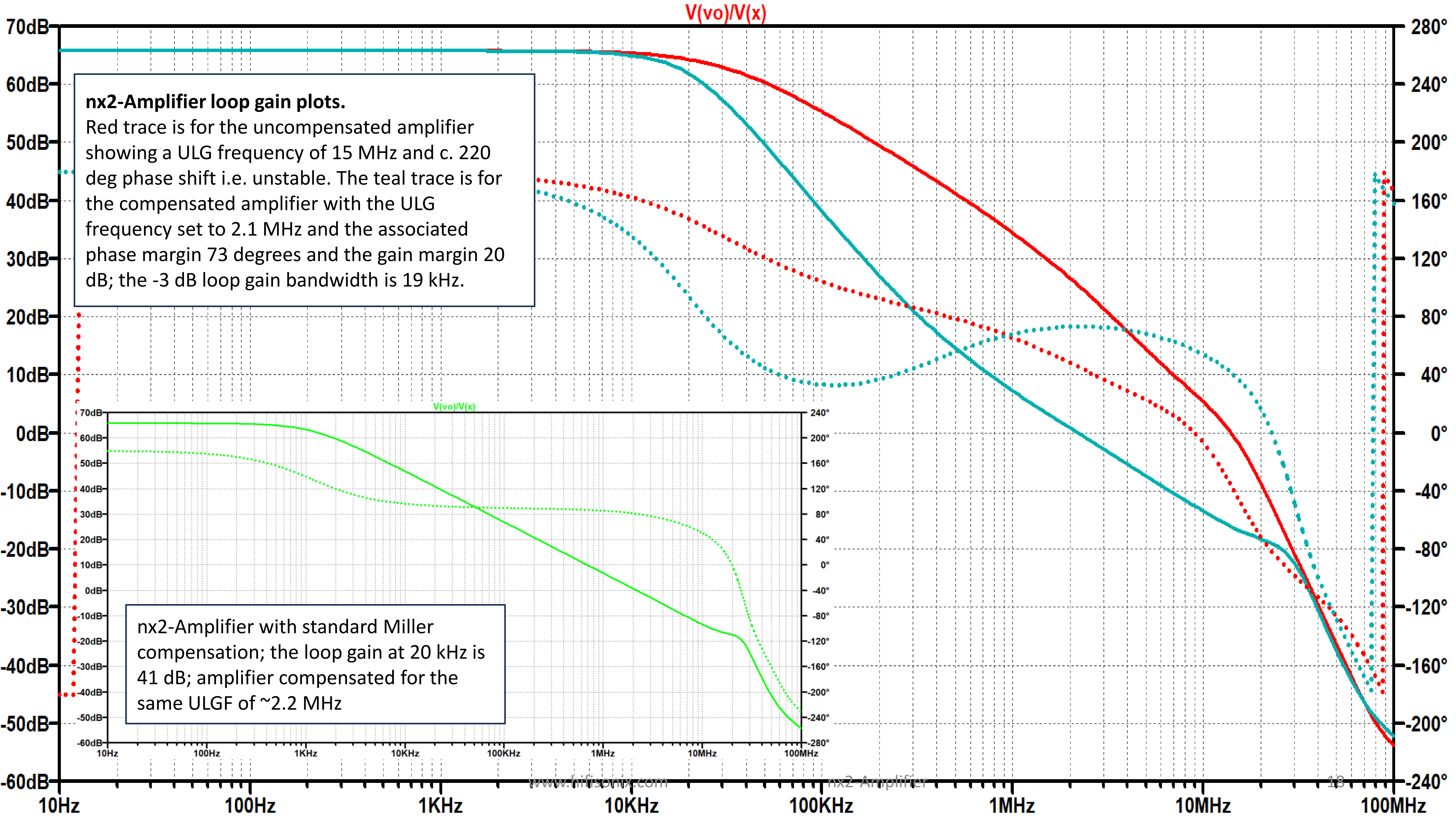
Thus, compared to straight MC, TMC allows an additional 20 dB loop gain to be extracted at 20 kHz in this design, resulting in lower HF distortion. Looking at 1 kHz distortion, the advantages of TMC are not readily apparent because the loop gain is usually flat across much of the audio band (for example, on the sx-Amp, the loop gain bandwidth was 60 kHz, while the original nx-Amplifier, it was 6 kHz). However, IMD tests using 19+20 kHz tones readily highlight the HF distortion reduction improvement over MC. The full power IMD distortion using 19+20 kHz tones is -90 dB on the nx2 Amp – an excellent result given the comparatively low overall loop gain of this design and directly attributable to the use of TMC.

A further advantage of TMC compared to Two Pole Compensation aka TPC, which offers similar distortion reduction levels, is that it does not suffer from the closed loop gain HF peaking that TPC does, often requiring more aggressive front end bandwith filtering to mitigate HF gain peaking, clearly visible as overshoot on square wave stimulus tests.

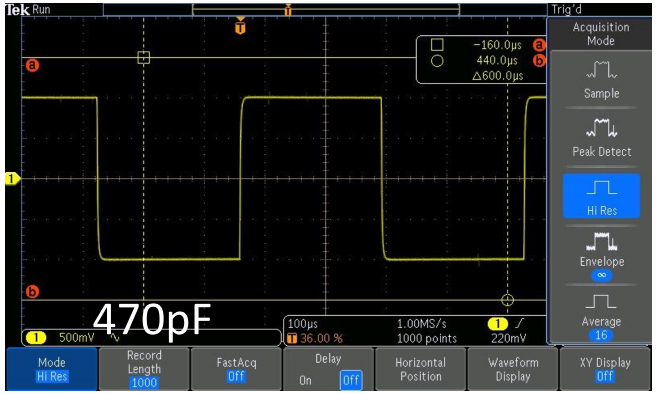
The input filter(R4 and C2 at 1k and 270pF) set the input bandwidth to about 600 kHz and with 1us rise fall times (much faster than any possible music transient) always ensures the diamond buffer remains in class A. It usefully also blocks any series mode RF ingress to the input stage.

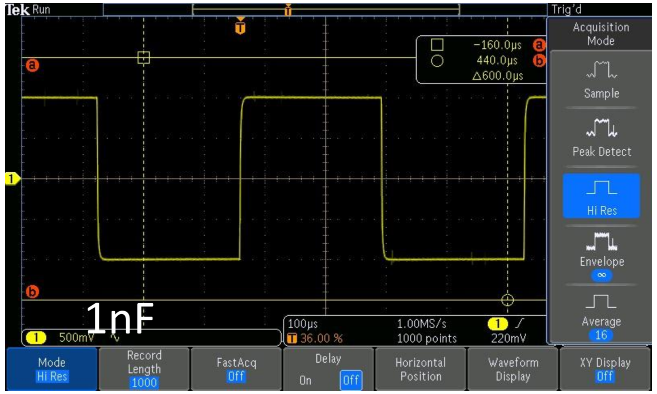
Although L1 in parallel with R46 does not form part of the compensation scheme proper, it nevertheless plays a vital role in ensuring the amplifier output stage is not exposed to heavy capacitive loads at HF which would cause the OPS pole to migrate down in frequency but increase in magnitude with the attendant phase lag, leading to oscillation – a problem all amplifiers have to contend with. In other words, the compensation scheme described above works contingent upon the amplifier output not being exposed directly to excessive capacitive loading, which is the function of the L1//R46 network. You can read more about this specific problem in ‘Output Coupling Inductors'

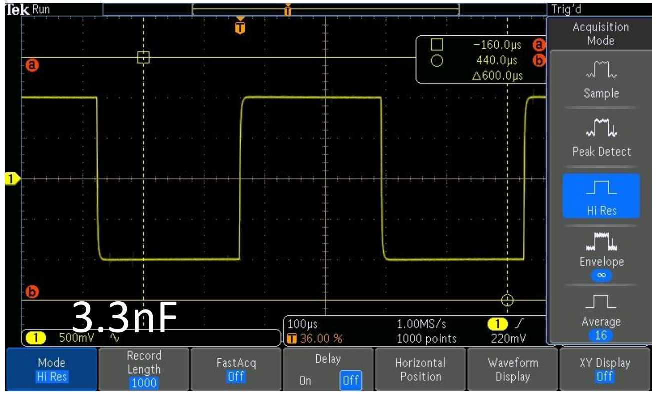
The nx2-Amp small signal stability tests (2V pk~pk) show it can drive any load from 2 ohms and up in parallel with any capacitance up to 2.2uF. Slides 19 and 20 depict the amplifier stability performance into capacitive and resistive loads.

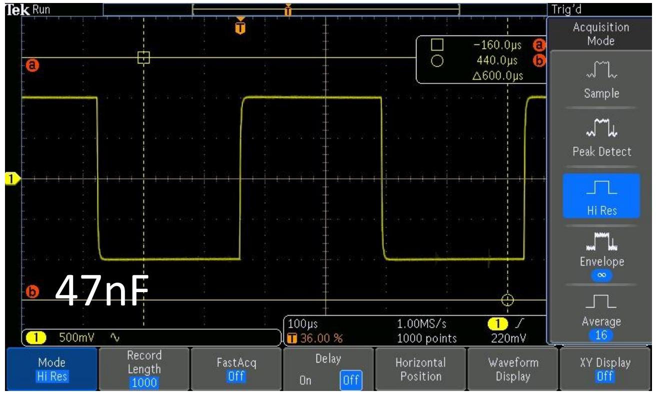

V(vo)/V(x)
70dB
60dB
50dB
40dB
30dB
20dB
10dB
0dB
-10dB
-20dB
-30dB
-40dB
-50dB
-60dB
280°
240°
200°
160°
120°
80°
40°
0°
-40°
-80°
-120°
-160°
-200°
-240°
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
nx2-Amplifier loop gain plots.
Red trace is for the uncompensated amplifier showing a ULG frequency of 15 MHz and c. 220 deg phase shift i.e. unstable. The teal trace is for the compensated amplifier with the ULG frequency set to 2.1 MHz and the associated phase margin 73 degrees and the gain margin 20 dB; the -3 dB loop gain bandwidth is 19 kHz.
V(vo)/V(x)
nx2-Amplifier with standard Miller compensation; the loop gain at 20 kHz is 41 dB; amplifier compensated for the same ULGF of ~2.2 MHz

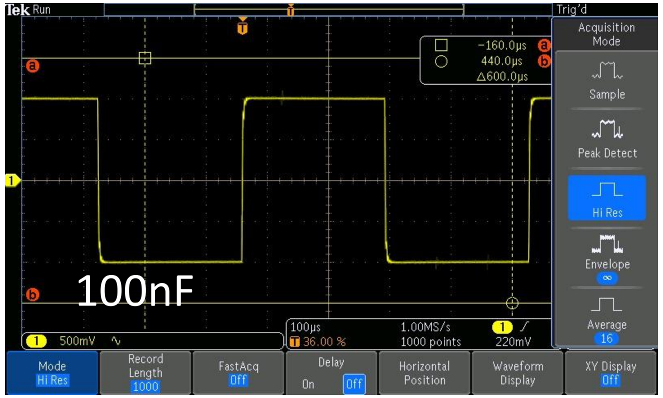
nx-2 Amplifier - stability measurements on Prototype #1

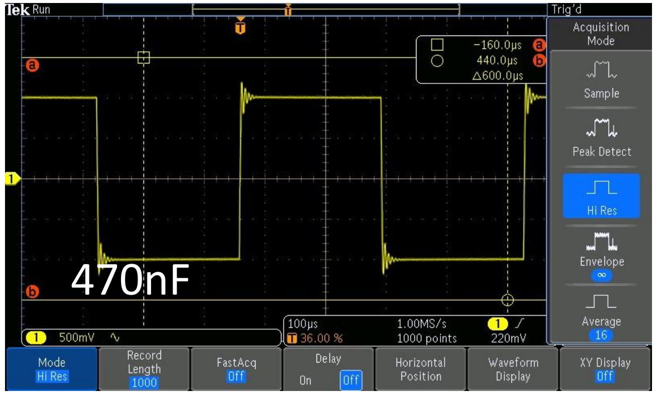


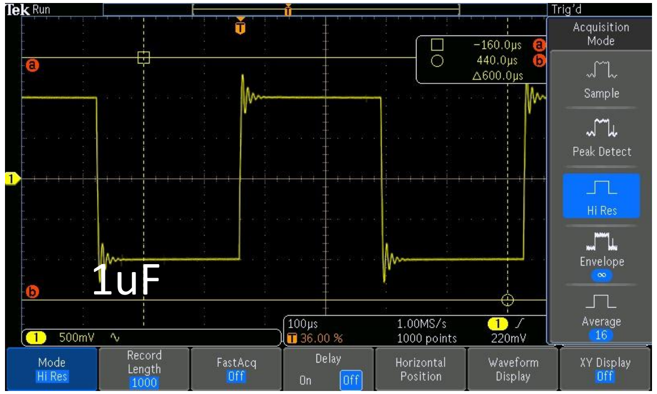


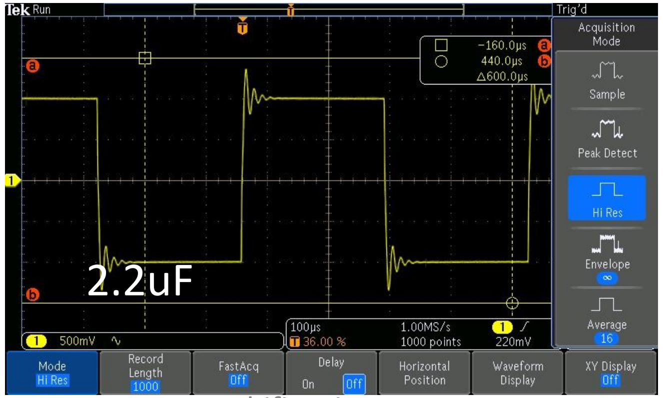






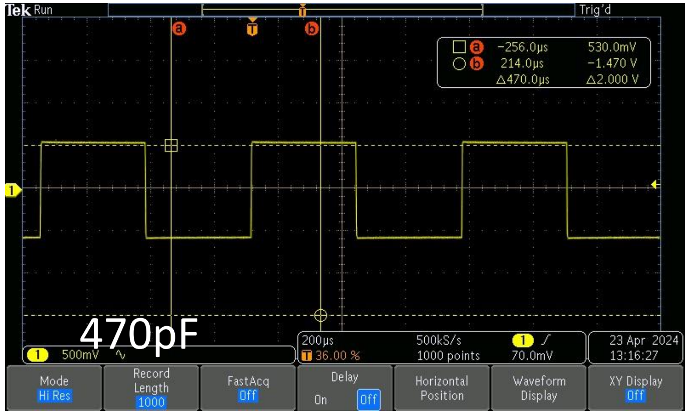


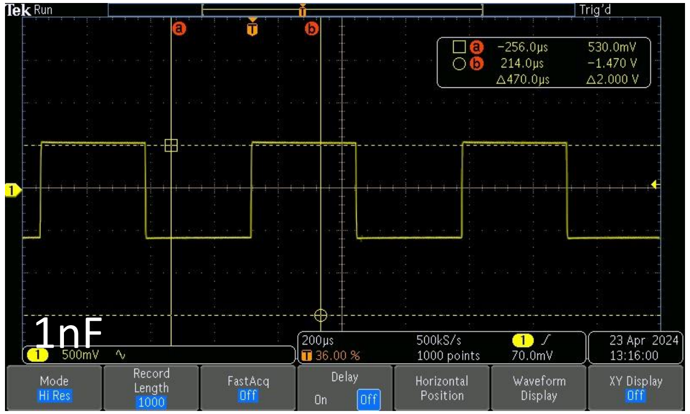


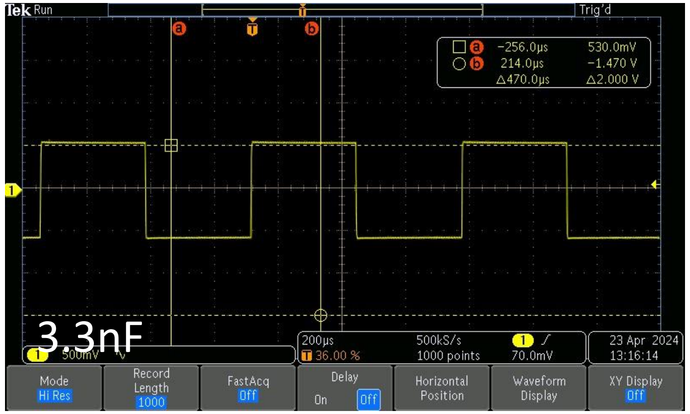


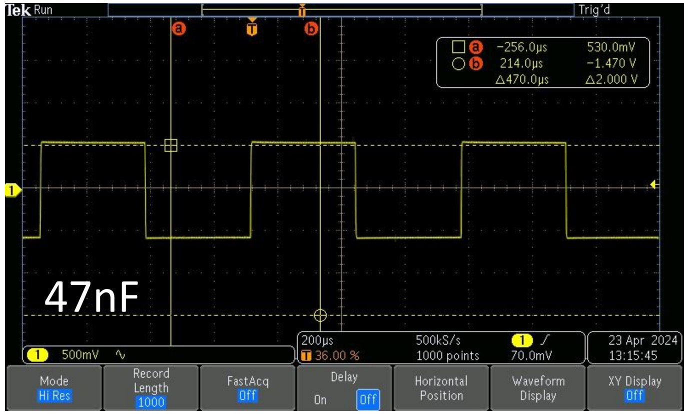
Load is 2 Ohms in // with capacitor

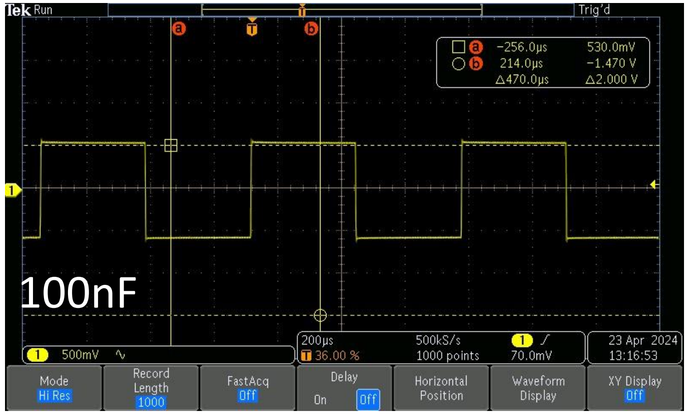
nx-2 Amplifier - stability measurements on Prototype #1

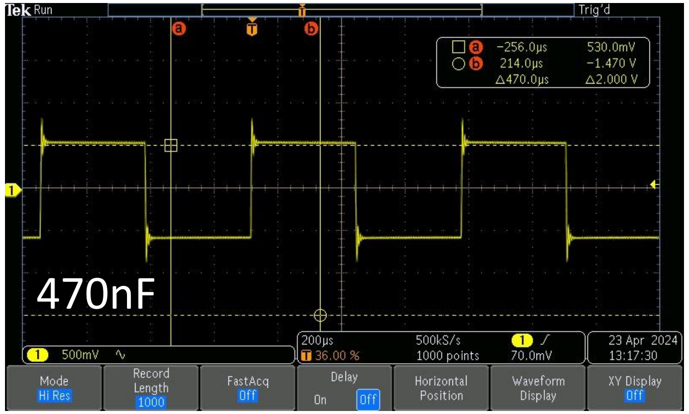


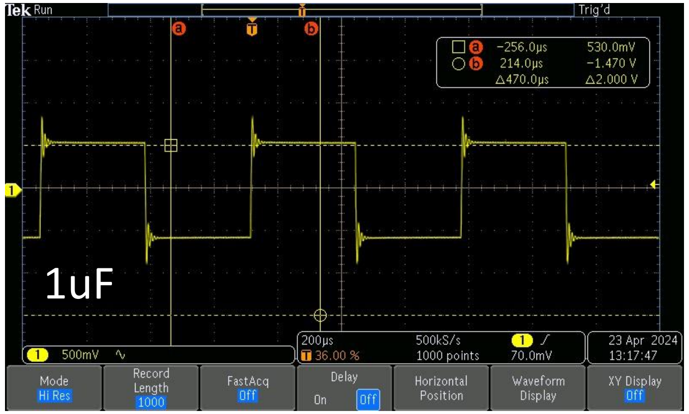


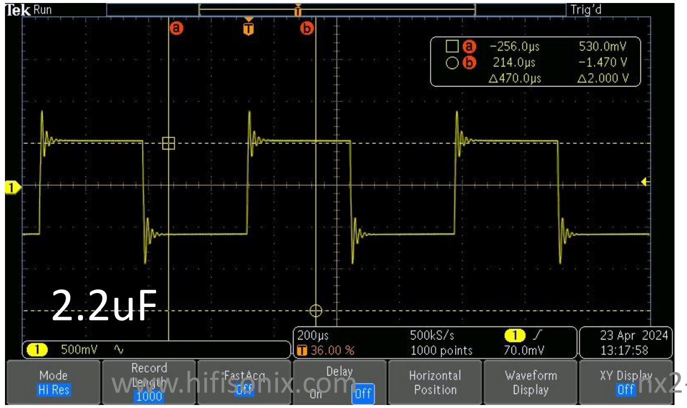












Load is ∞ Ohms in // with capacitor

8. Assembly and Testing

This assembly and test procedure assumes you are using the Modushop

Mini Dissipante housing pre-drilled to the Hifisonix heatsink spec and rear panel with IEC power entry cutout, speaker protection board and speaker terminal drilling.

Do NOT assemble your amplifier without first checking the individual boards first.

Step 1: Preapare the heatsinks and housing

- There may be a small ridge of 0.1-0.2mm around the machined heatsink holes.
- This can cause thermal issues in severe cases.
- Use a 8-10mm drill bit to slightly countersink the holes and remove the ridge. Note: do this manually by just rolling the bit back and forth between your thumb and index fingers.
- Do not over countersink the holes because this removes valuable thermal coupling area under the transistor tabs.
- Locate the PSU on the baseplate and the transformer. Make sure you leave enough space between the transformer and the PSU so that the bridge rectifier D5 can be screwed to the baseplate. Also make sure you leave some space between the IEC power entry module and the PSU board.
- Mark the hole positions using the template at the end of this presentation and drill the 4 off PSU mounting holes out to 4.5mm and D5 mounting hole out to 3.5mm.
- Debur all the holes.
- For the front plate, decide where to mount the power ON/OFF control switch. Make sure it is kept well away from the power transformer – for this reason it might make sense to offset it to the side and not too far up from where the baseplate butts up against it.
- Do not assemble the amplifier housing – you will need the heatsinks for testing.

Step 2: Assemble the PSU

- The assembly of the board is straightforward, but note the following with respect to the power supply and inrush controller PCB.
- Mount all the components except the main bridge rectifier D5.
- Tightly screw the M4 x 10mm + M4 lock washer standoffs to the PCB using 4 off M4 x 8mm machine screws. Do not use longer or shorter screws. The lock washer must go to the component side of the PCB.
- Next, bend D5 leads up at 90 degrees towards the front of the rectifier at the point on the lead frame where the leads thin
- Feed D5 leads into the mounting hole from the bottom.
- Place the PCB with the loose D5 on one of the amplifier heatsinks, locating D5’s mounting hole over one of the transistor mounting holes and then securing it tightly with an M3 x 10mm machine screw
- Make sure the M4 standoffs are flat on the heatsink, and then ensure D5 is parallel to the edge of the PCB – just move the PCB on its M4 standoffs around on the heatsink surface to accomplish this.
- Next, solder the rectifier leads and then clip off any excess leads protruding through on the component side of the board.
- Set the power supply board aside, being careful not to inadvertently move or twist the rectifier under the PCB.

- Next step is to assemble the Speaker Protection Board

Step 3: Assemble the speaker protection board

To use the speaker protection module with the nx2-Amplifier, on +-48 to +-60V supply rails, fit the following resistor values

R1, R2 = 1k

R4 = 33k

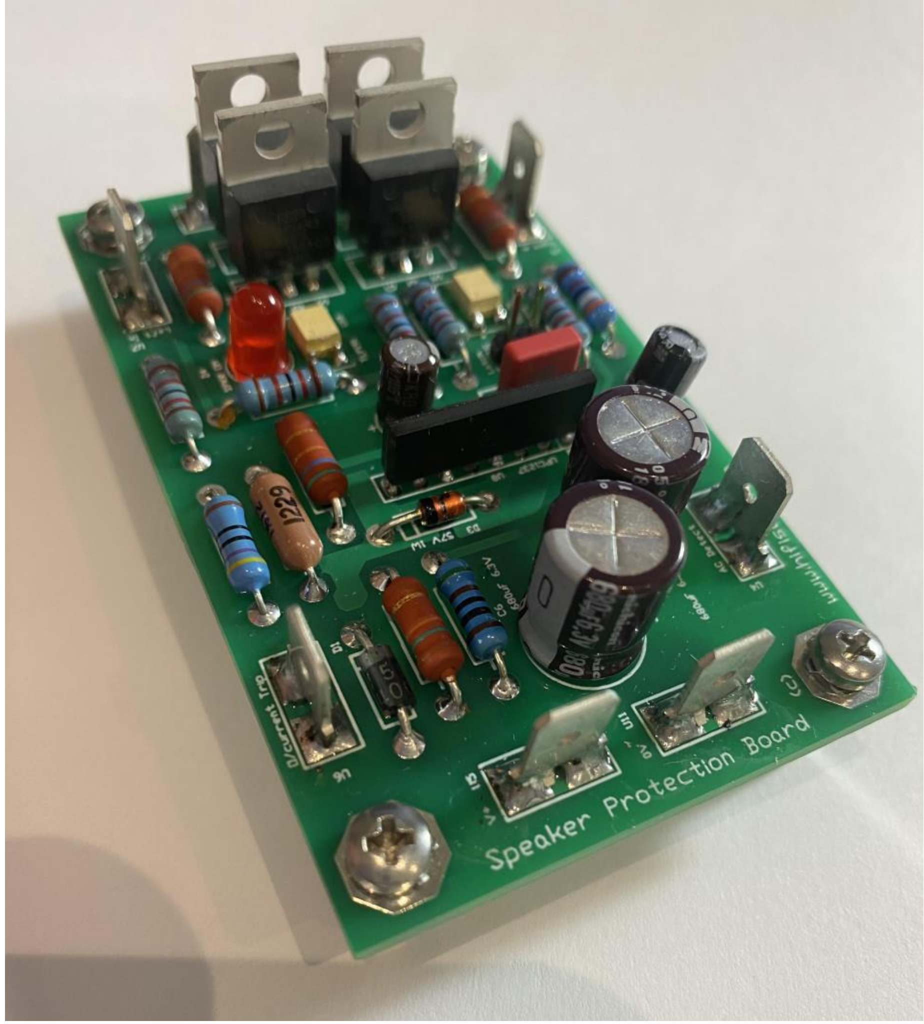
R5 = 18k

R10 = 10k

R7 = 33k (change from 1k listed in the build document)

Here is a link to the speaker protection board documentation.

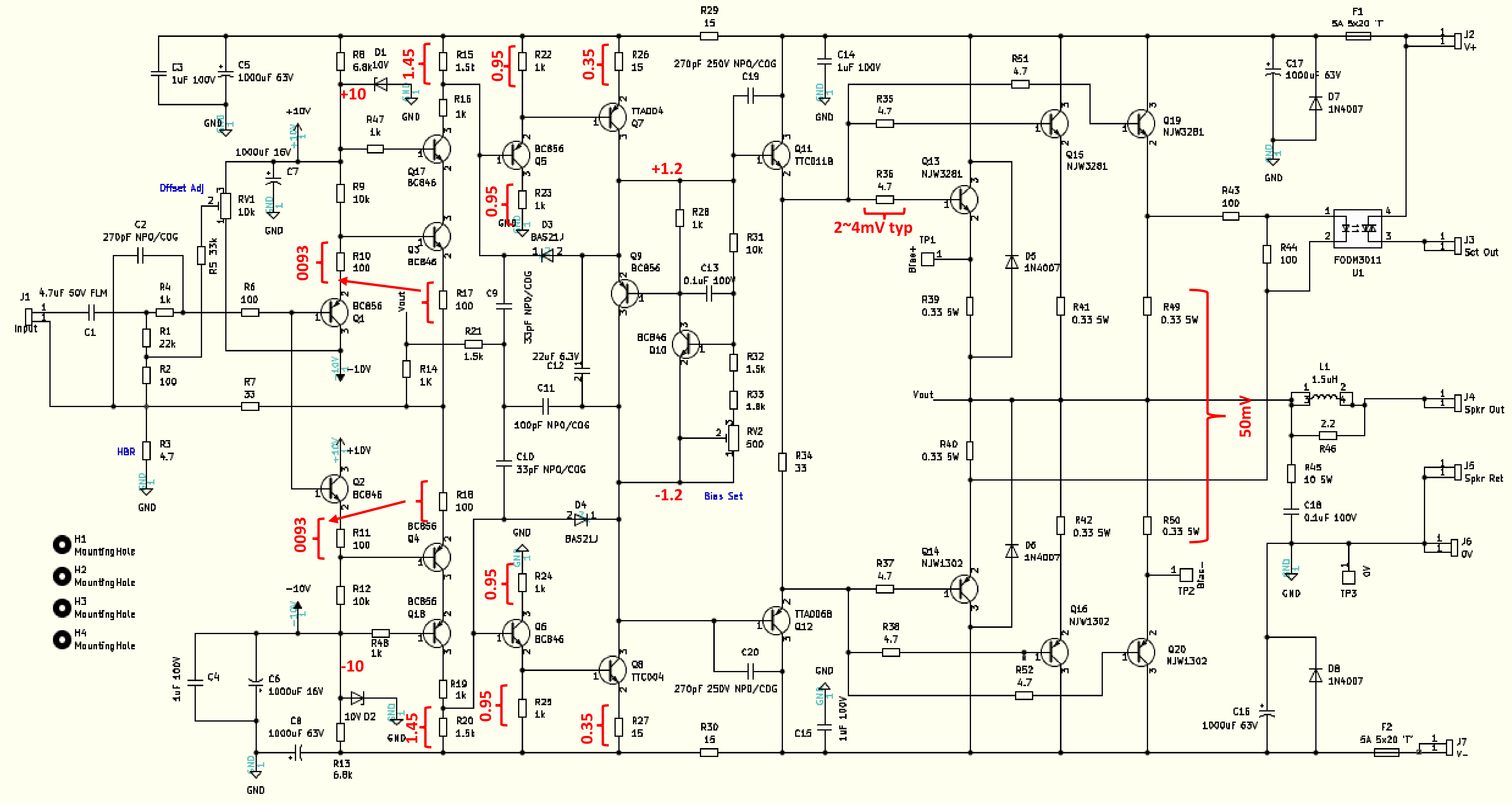
Follow the test procedure for the board given in the documentation link above.

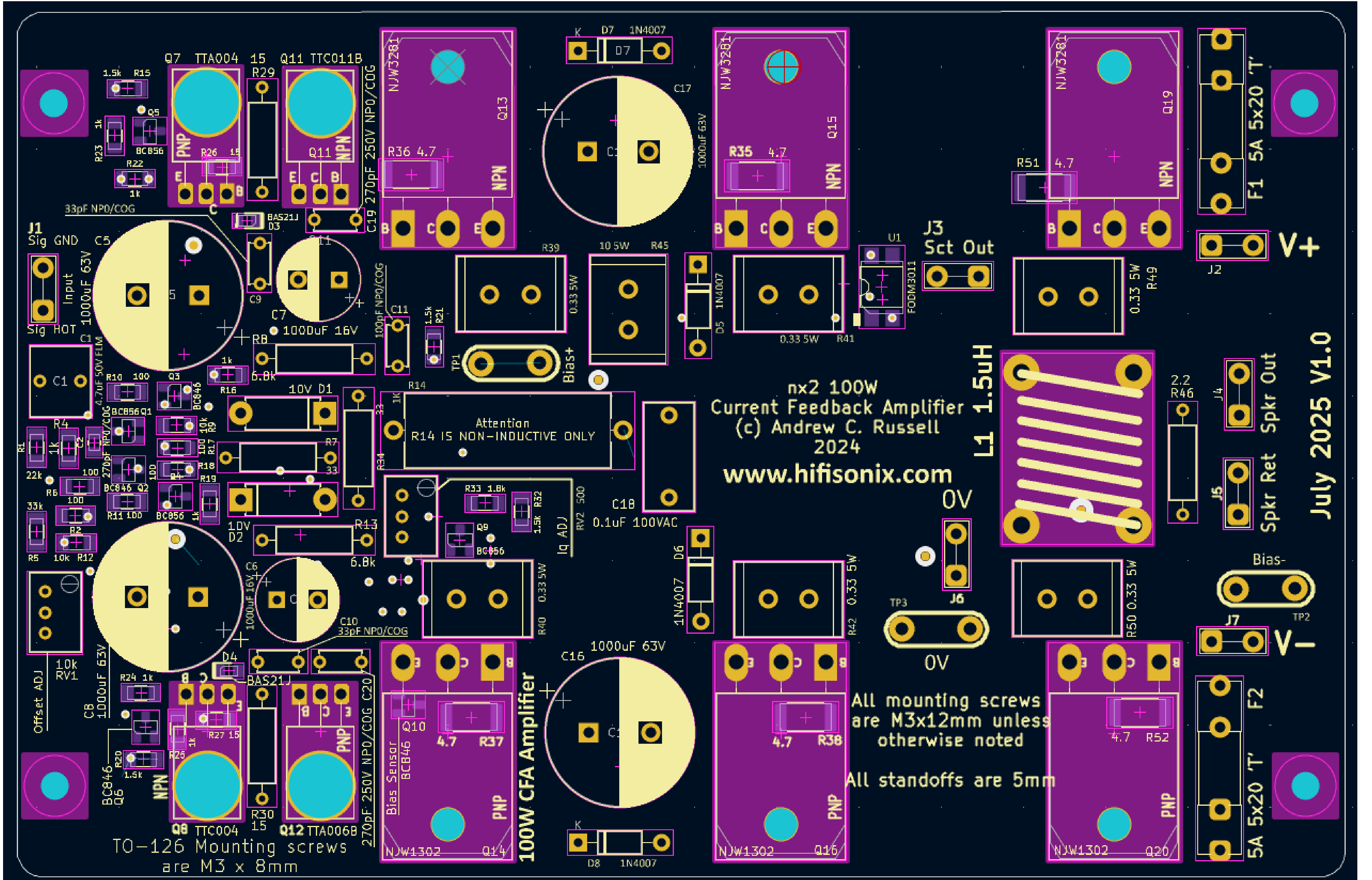


Step 3: Assemble the amplifier module PCBs

1. DO NOT mount any of the TO-3P power transistors or any of the TO-126 transistors
2. Assemble both power amplifier modules, starting with the SMD components on the rear side, and then the top side, then the through hole resistors and finally the electrolytic capacitors.
3. Make sure to run 1mm diameter single core wire on the underside of the amplifier along the white silk screen traces. Use Sellotape to hold the wires flat to the PCB, and then a spot of superglue at regular intervals to secure it. Let the glue harden for 2-3 hours before moving on to the next step.
4. Once you have checked that all the components are correctly located etc, the next step is to mount the power devices. Have the 12 x heatsink thermal pads for the TO-3P devices to hand – we will use those a little later in the assembly process.
5. Fit but do not solder the TO-3P devices. Start by bending the leads up at 90 degrees at the point the leads thin. The leads must be bent up towards the front of the devices
6. Insert the devices into their respective positions on the PCB. Double check the device type and the PCB location, as once soldered in, they can be difficult to remove if you have made a mistake (Tip: 'check twice and solder once')
7. You can keep them from falling out by bending the outer two leads slightly apart
8. Next, turn the board over and using 6 off M3 x 12mm machine screws, loosely screw the PCB to the heatsink through the TO-3P mounting holes on the PCB. Do not tighten the screws yet.
9. Get the transistors nice and square under the heatsink and then tighten the screws and solder all 18 leads and clip off the excess lead on the component side of the PCB.
10. Carefully remove the PCB from the heatsink. Next, bend the TO-126 transistor leads up by 90 degrees in the same manner as you did with the TO-3P devices, making sure the distance between the centre of the device mounting hole and where the leads bend up is 11mm.
11. Insert the devices into the PCB in their respective locations, again checking carefully to have the right device in the right location. As with the TO-3P devices, bend the outer two leads slightly apart to prevent them from falling out.
12. Next locate the TO-3P thermal pads over the heatsink mounting holes. If you put a drop of water on the underside of the thermal washer, they tend to stay in place. Note: the TO126 devices do NOT need a thermal pad.
13. Locate the PCB over the TO-3P mounting holes and loosely screw the board in place. Align the TO-126 devices up with their respective mounting holes screw them loosely in place with 8 x M3 x 8mm + 1 x M3 lock washer.
14. Once confirmed that all the TO-126 devices are neatly aligned and square, you can tighten all the screws – but do not overtighnten as you run the risk of stripping the heatsink thread, or cracking the transistors.
15. Solder the TO-126 device leads and clip off any excess lead protruding through on the component side.
16. Finally, remove the board and put a small dab of heatsink grease on the underside of each of the TO-126 devices.
17. Remount the board, making sure the TO-3P thermal pads are correctly posisitioned under the device collector tabs and then tighten all the screws as before. We can now move to testing.

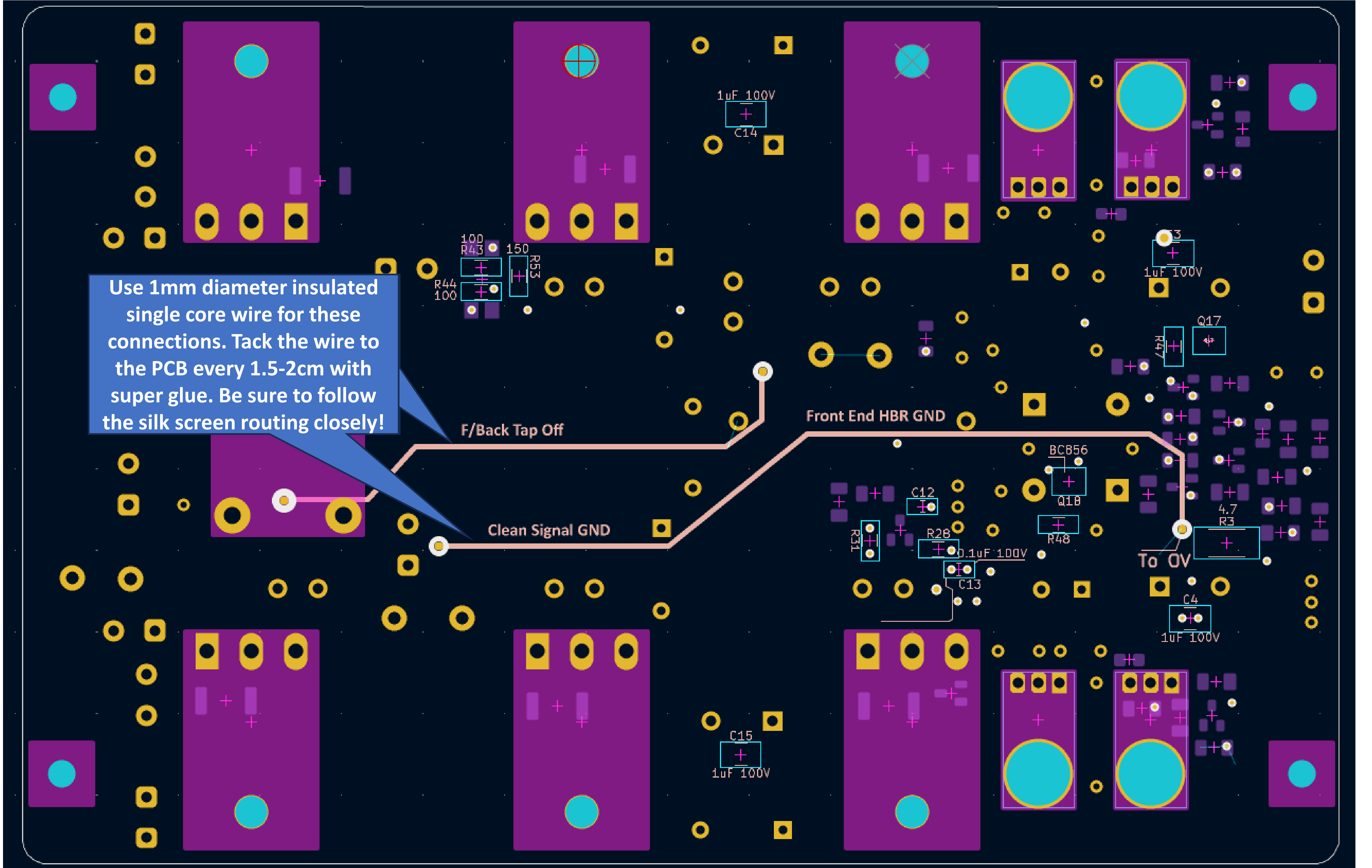
nx-2 Amplifier Schematic – annotated for debugging. Input shortedand output at 0.00V.



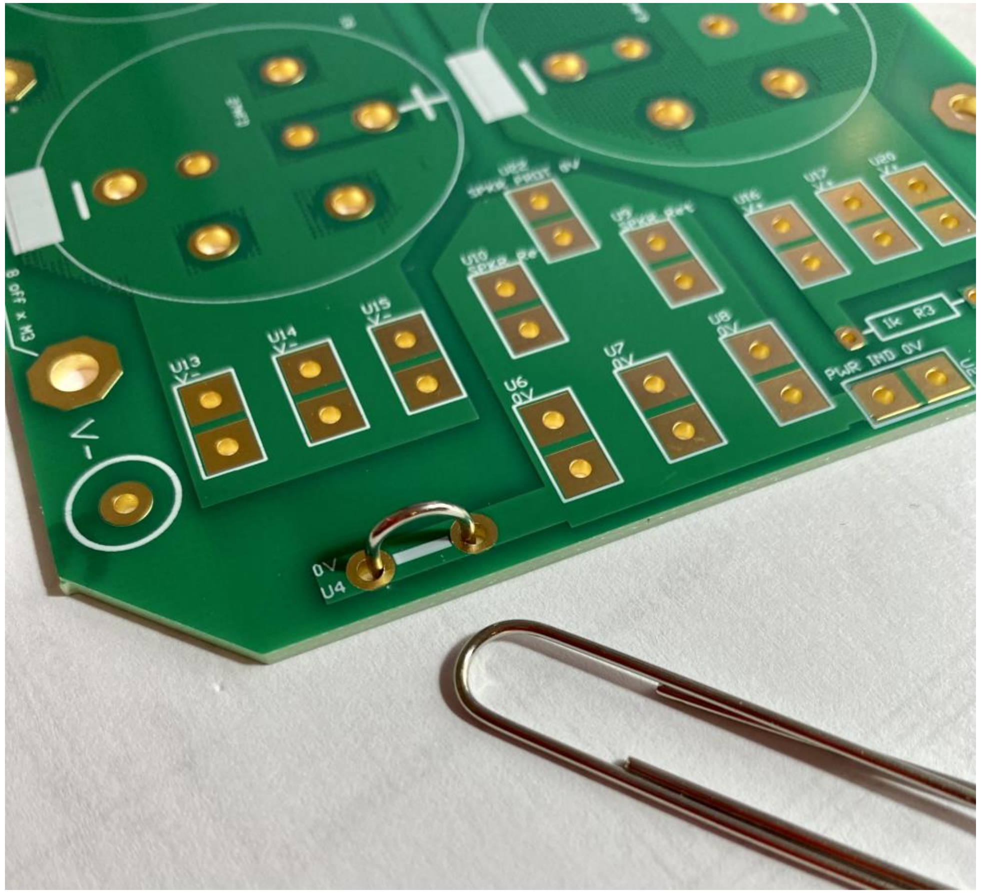


PCB Layout top side

PCB Layout bottom side



A Quick Tip



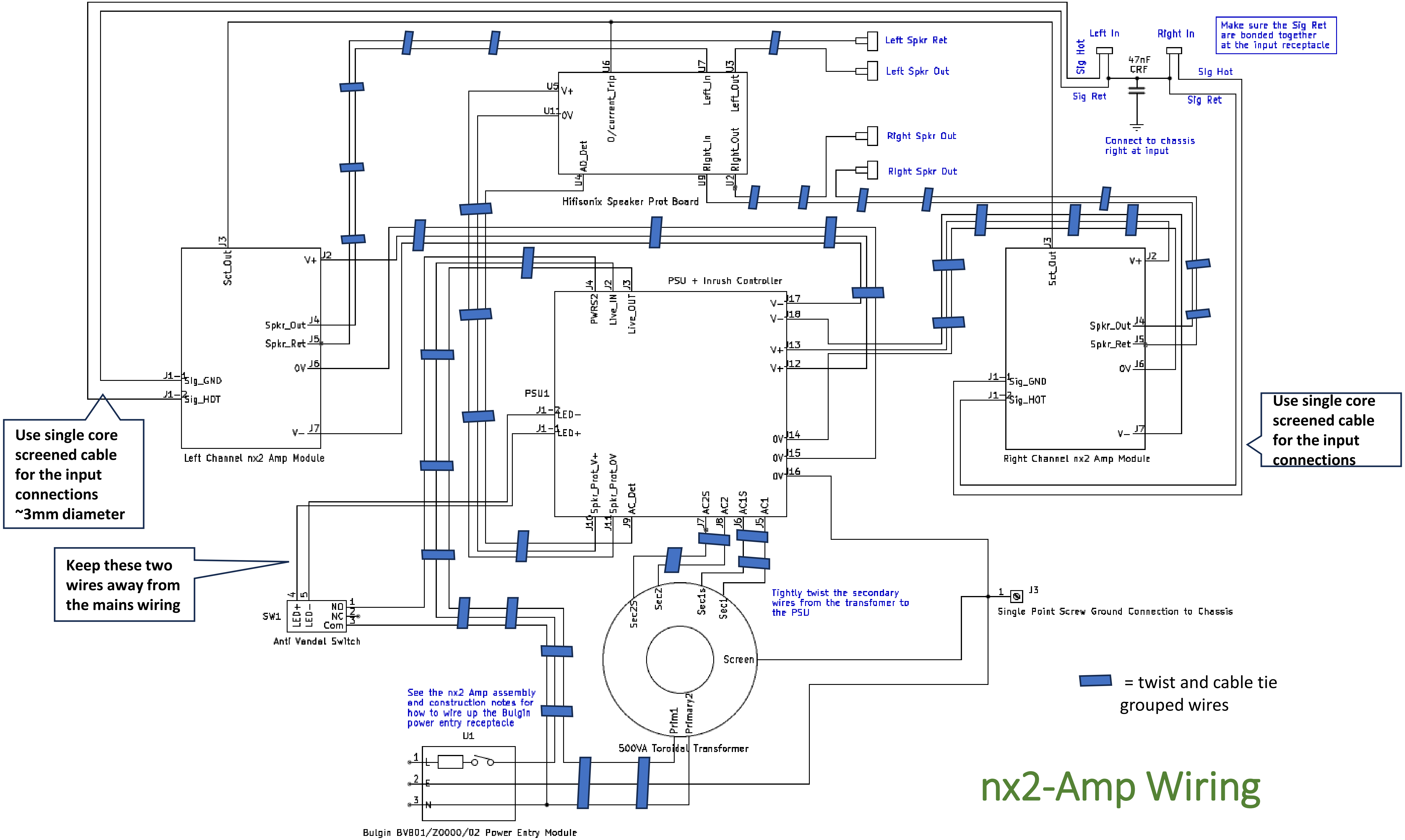
- For the various monitoring straps around the amplifier e.g. Bias+ and Bias-, I use a good quality chromed paper clip as shown.
- You can get 3 monitoring straps per paper clip
- When using croc clips, the connection is secure and will not inadvertently come off, potentially causing problems or a short while testing and setting up.

Step 4: Test the PSU

- Use you meter and check that the connections between J2 J3 and J4 to to J12 (V+), J14 (0V) and J17 (V-) are all open circuit; check that J9 (AC Detect) to J2, J3 and J4 is open circuit
- Measure from J4 to J2 – it should read between 30k and 33k ohms
- Measure between J2 and J3 – it must be open circuit
- Measure from J14 to J12 – it should start at a low ohm value and increase as the capacitors charge – most important is to make sure it is not a short circuit
- Measure from J14 to J17 – it should behave in a similar manner to the previous step – make sure it is not a short circuit.
- If all of the above steps are ok, set the board aside until you do the wiring etc.

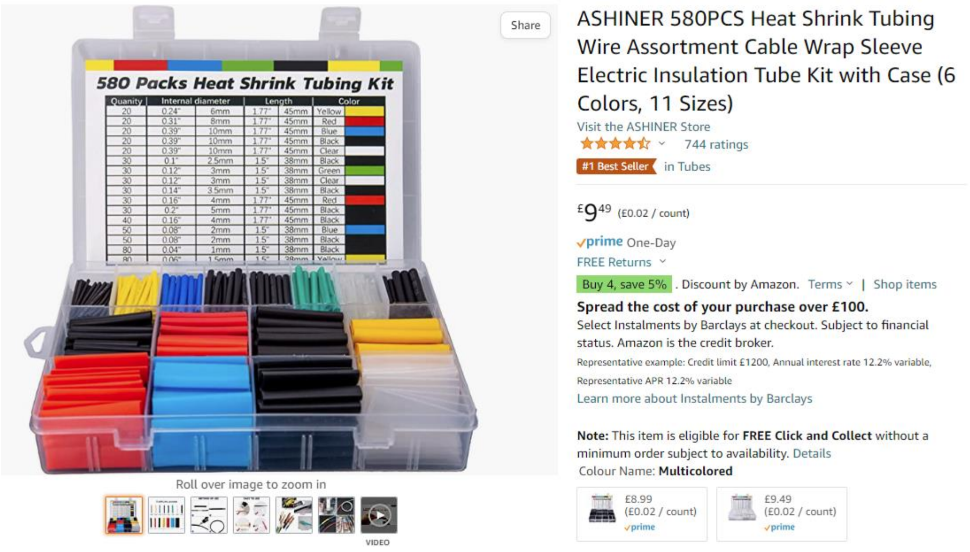
Step 5: Test and set-up amplifier module PCBs

1. Wire the transformer secondaries up to the PSU board. Wire the transformer mains side to a suitable cable and plug. Make sure the transformer primaries are connected as required for your local AC mains voltage i.e. 120 VAC or 240 VAC if using a split primary transformer. Apply power and check the output voltage. It should read between 50 and 60 Volts, with 55V ideally between 0V and the V+ rail and 0V and the V- rail. Disconnect the PSU and discharge the capacitors so the output voltages on both rails are close to 0V
2. Fit the amplifier modules with 500mA T1 fuses in preparation for testing; do not connect a load to the amplifier output at this stage.
3. Connect the PSU to the amplifier module and apply power
4. Measure the voltage across Bias- and Bias+ on the module and adjust Iq ADJ (RV2) to get 50mV
5. Adjust RV1 ‘Offset Adjust’ for 0.00V at ‘Speaker Out (J4)
6. Check all the key voltages around the board using the voltage reading annotated circuit diagram on slide **“$$ £^^**
7. Recheck the voltage across Bias+ and Bias- and readjust Iq ADJ (RV2) to 50mV if required; readjust Rv1 for 0.000 V out at J4
8. Power down and make sure the power rails are fully discharged.
9. Replace the 500mA fuses with 5A T1 devices
10. Connect a high power (100 W) 8 Ohm load to the amplifier module.
11. Apply power
12. Using a signal generator, set the amplifier output to 44V pk~pk and leave the module to run for about 30 minutes, allowing the heatsink temperature to maximise. It should not in any event be more than 55 Celsius.
13. After 30 minutes, repeat steps 4 and 5
14. If all is ok, the amplifier modules are tested and we can proceed to assembly and wiring



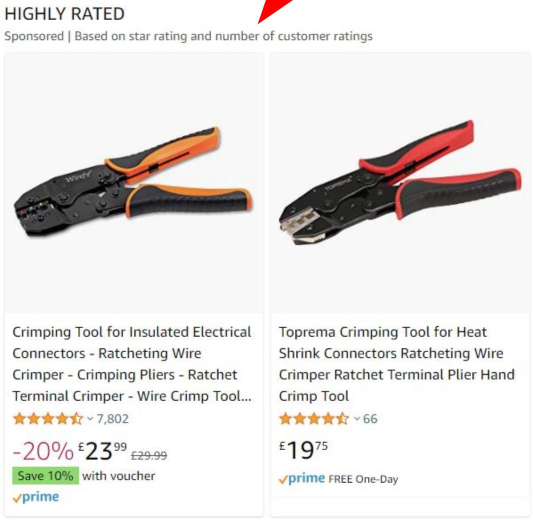
nx2-Amp Wiring

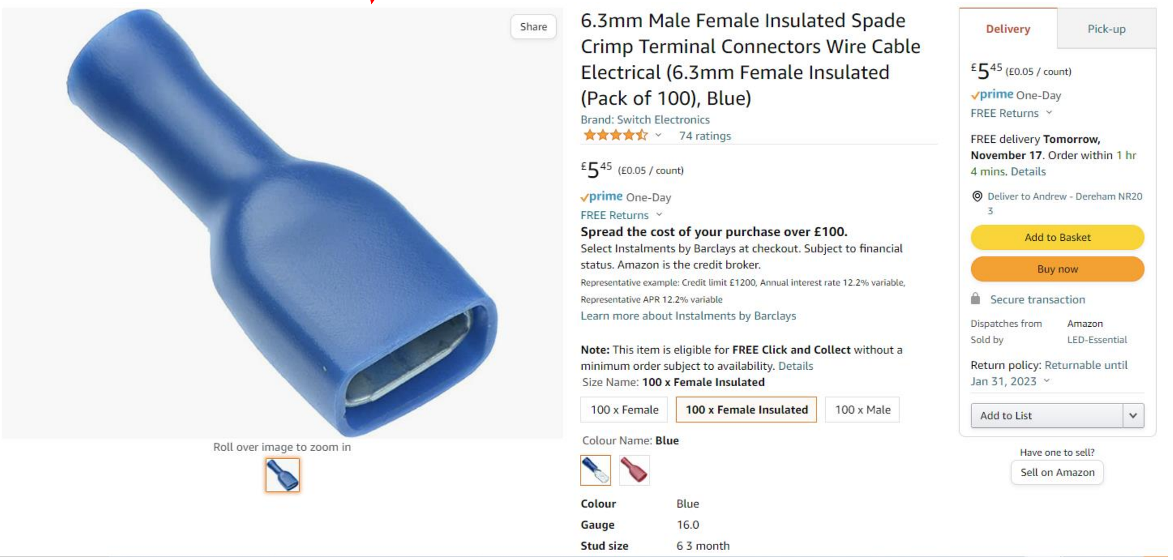
Examples of consumables from Amazon required for wiring up.



Invest in a 6.3mm crimping tool!

Attention: only use fully insulated 6.3mm spade connectors!



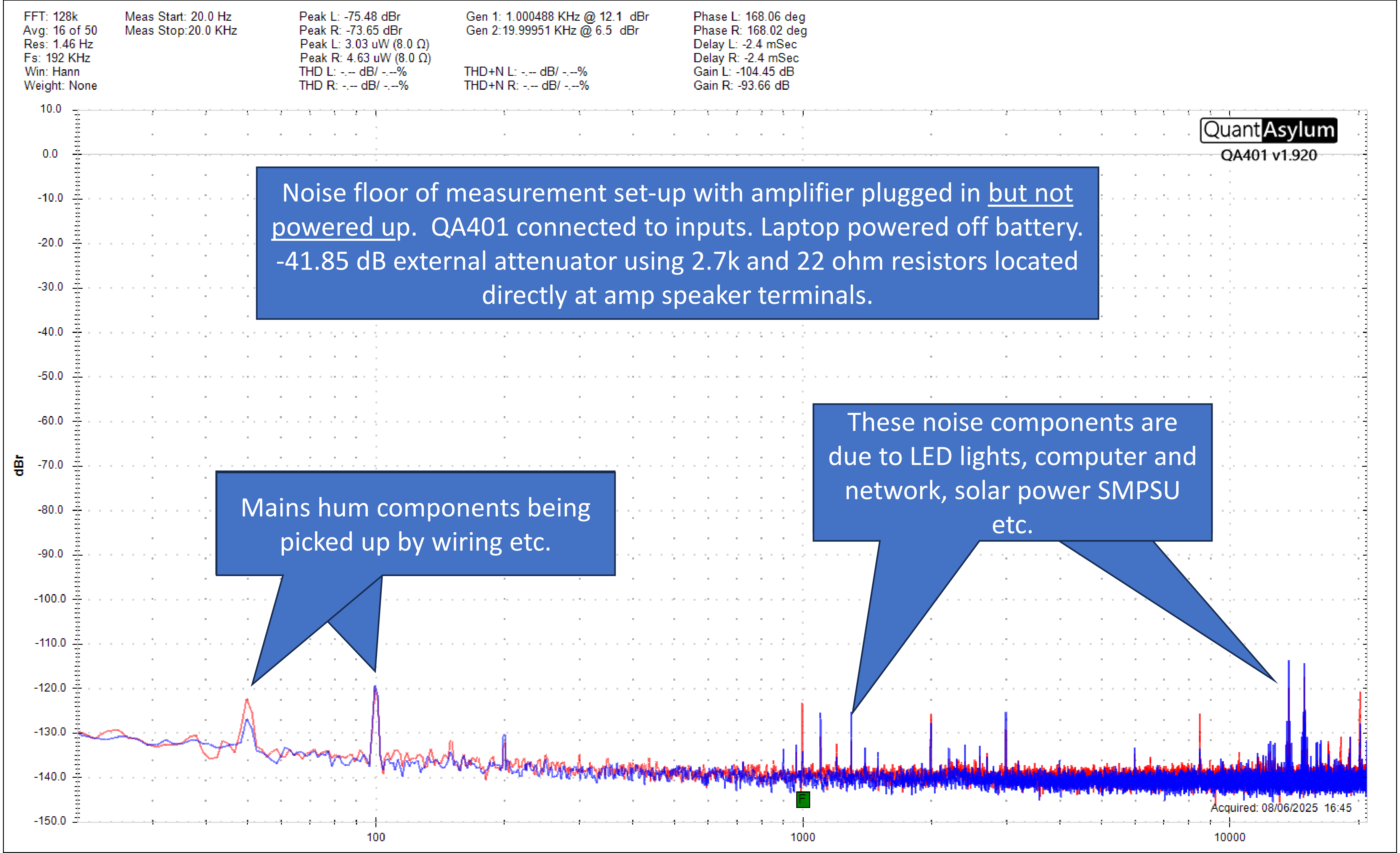


Anti-vandal switch

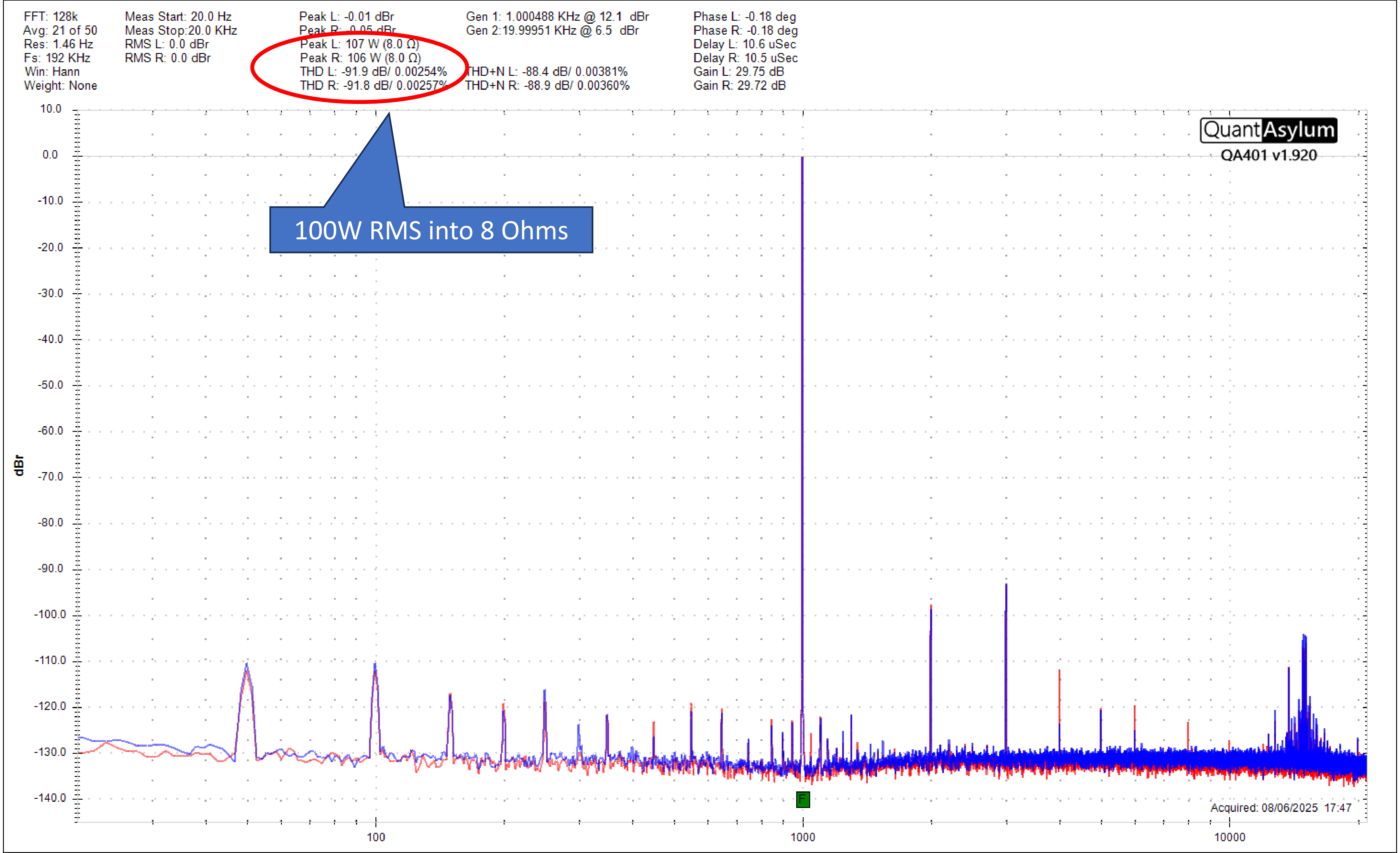
Ensure the switch is latching with changeover contacts and they are rated for 250VAC and at least 30mA. I used a 19.2mm diameter switch.

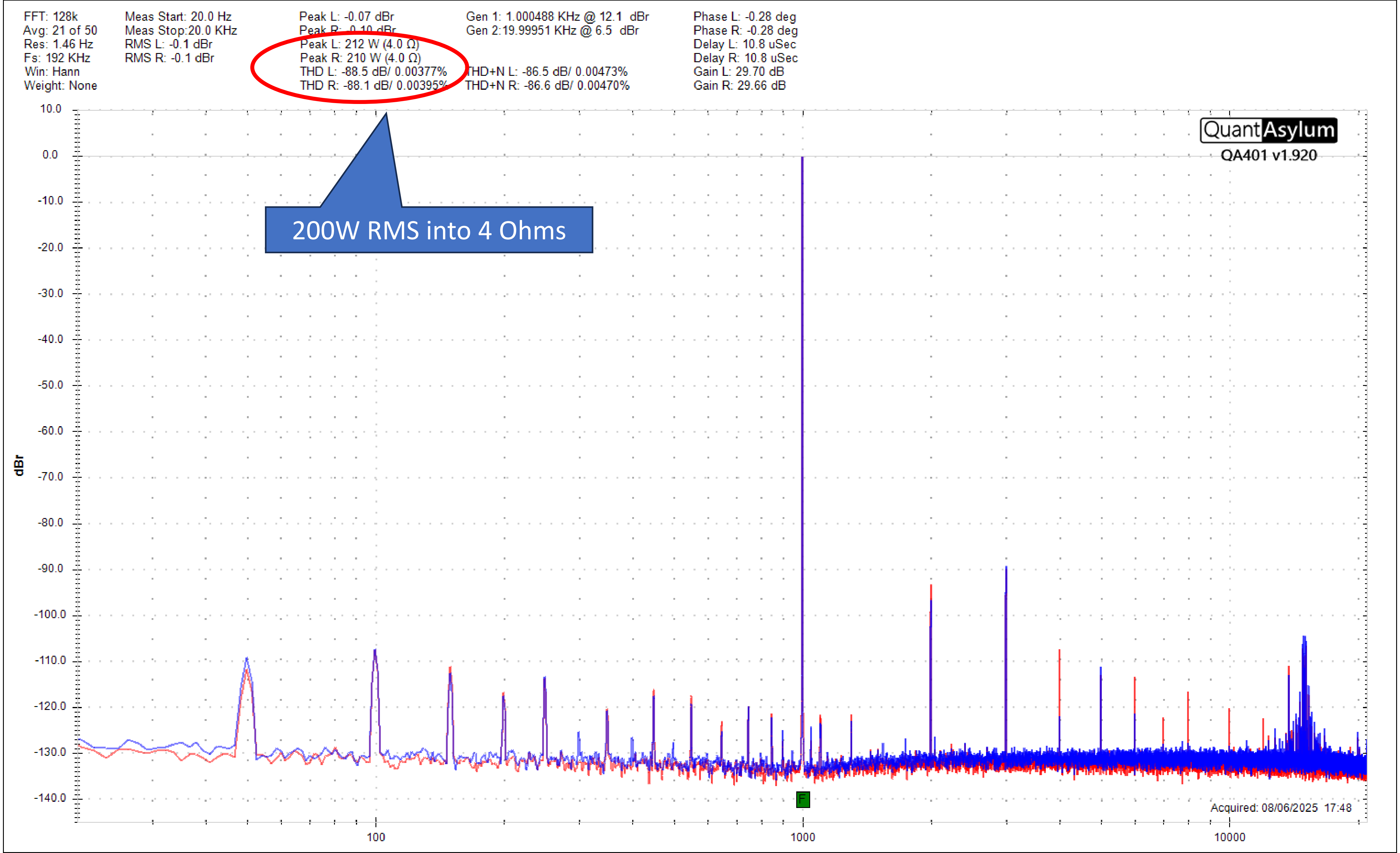
9. nx2-Amplifier Measurements
08 June 2025

For these measurements, an external attenuator was used that dropped the QA401 noise floor c. 20-30 dB, allowing a deeper look at the noise and distortion components. For all of these tests, the output standing current was set to 76 mA per pair, corresponding to a reading of 50mV across the Bias+ and Bias- test points.

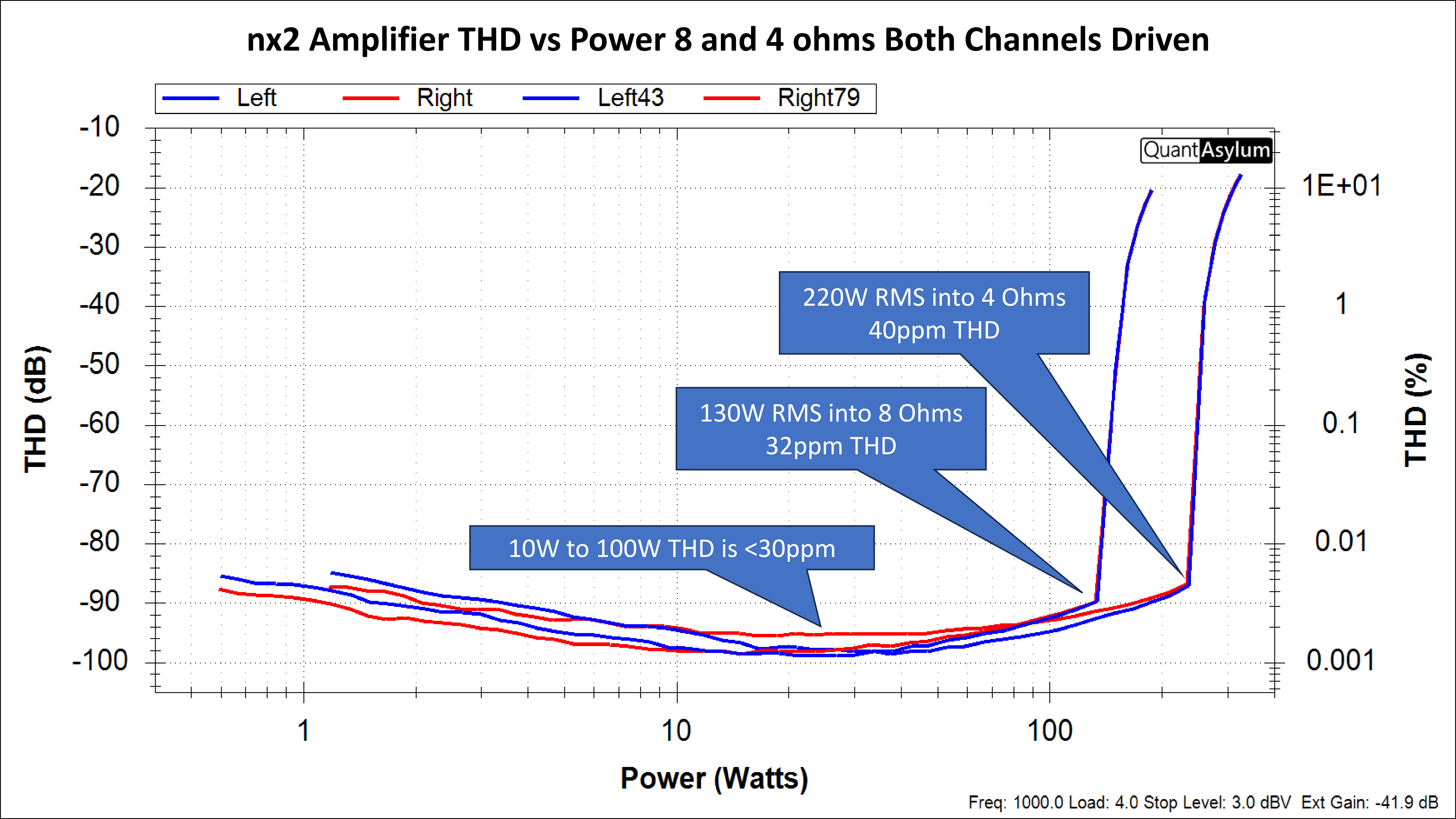


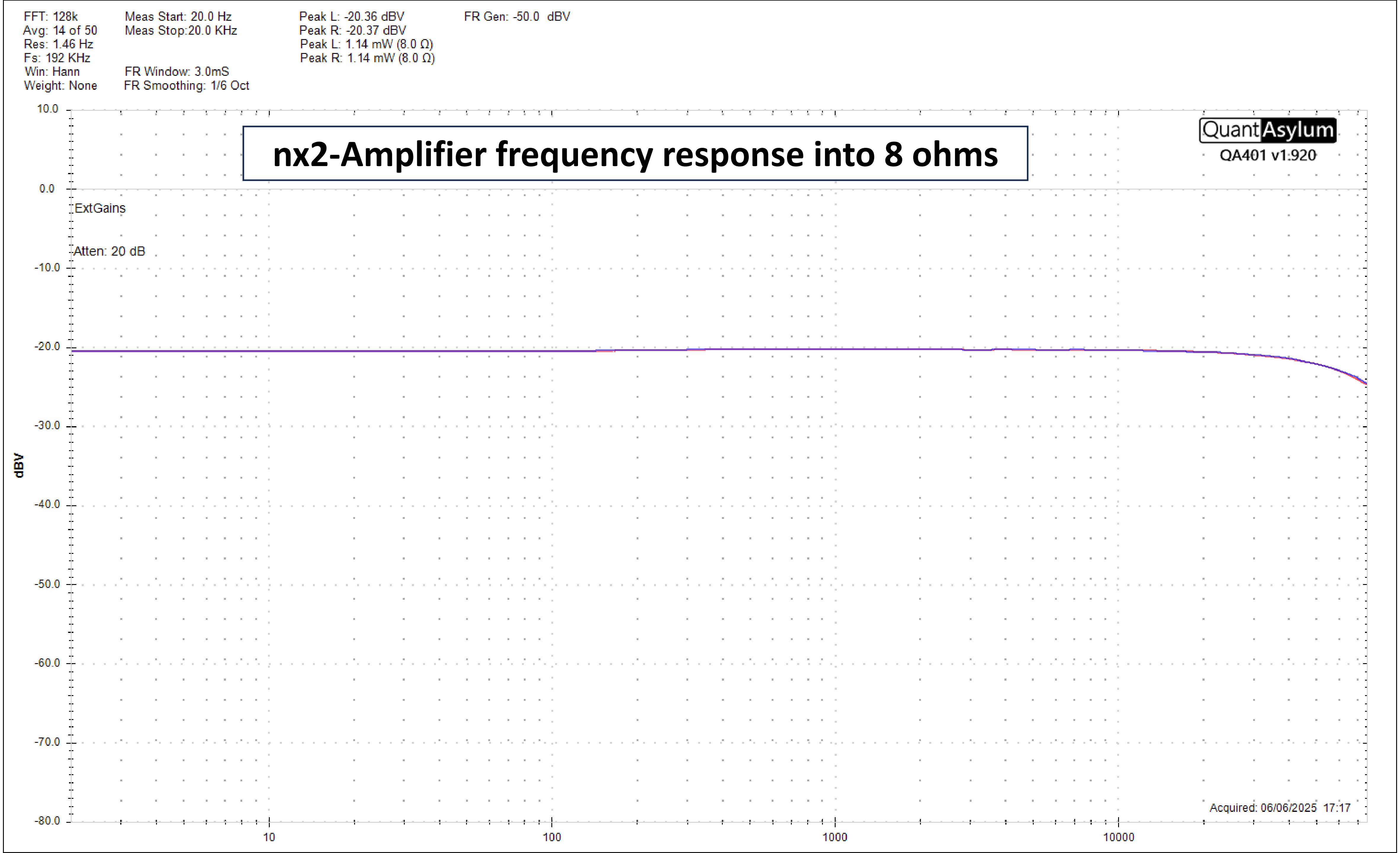
FFT: 128k
Avg: 16 of 50
Res: 1.46 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -75.48 dBr
Peak R: -73.65 dBr
Peak L: 3.03 uW (8.0 Ω)
Peak R: 4.63 uW (8.0 Ω)
THD L: -.-- dB/ -.--%
THD R: -.-- dB/ -.--%
Gen 1: 1.000488 KHz @ 12.1 dBr
Gen 2:19.99951 KHz @ 6.5 dBr
THD+N L: -.-- dB/ -.--%
THD+N R: -.-- dB/ -.--%
Phase L: 168.06 deg
Phase R: 168.02 deg
Delay L: -2.4 mSec
Delay R: -2.4 mSec
Gain L: -104.45 dB
Gain R: -93.66 dB
QuantAsylum
QA401 v1.920
dBr
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
-150.0
100
1000
10000
Acquired: 08/06/2025 16:45
Noise floor of measurement set-up with amplifier plugged in but not powered up. QA401 connected to inputs. Laptop powered off battery. -41.85 dB external attenuator using 2.7k and 22 ohm resistors located directly at amp speaker terminals.
Mains hum components being picked up by wiring etc.
These noise components are due to LED lights, computer and network, solar power SMPSU etc.

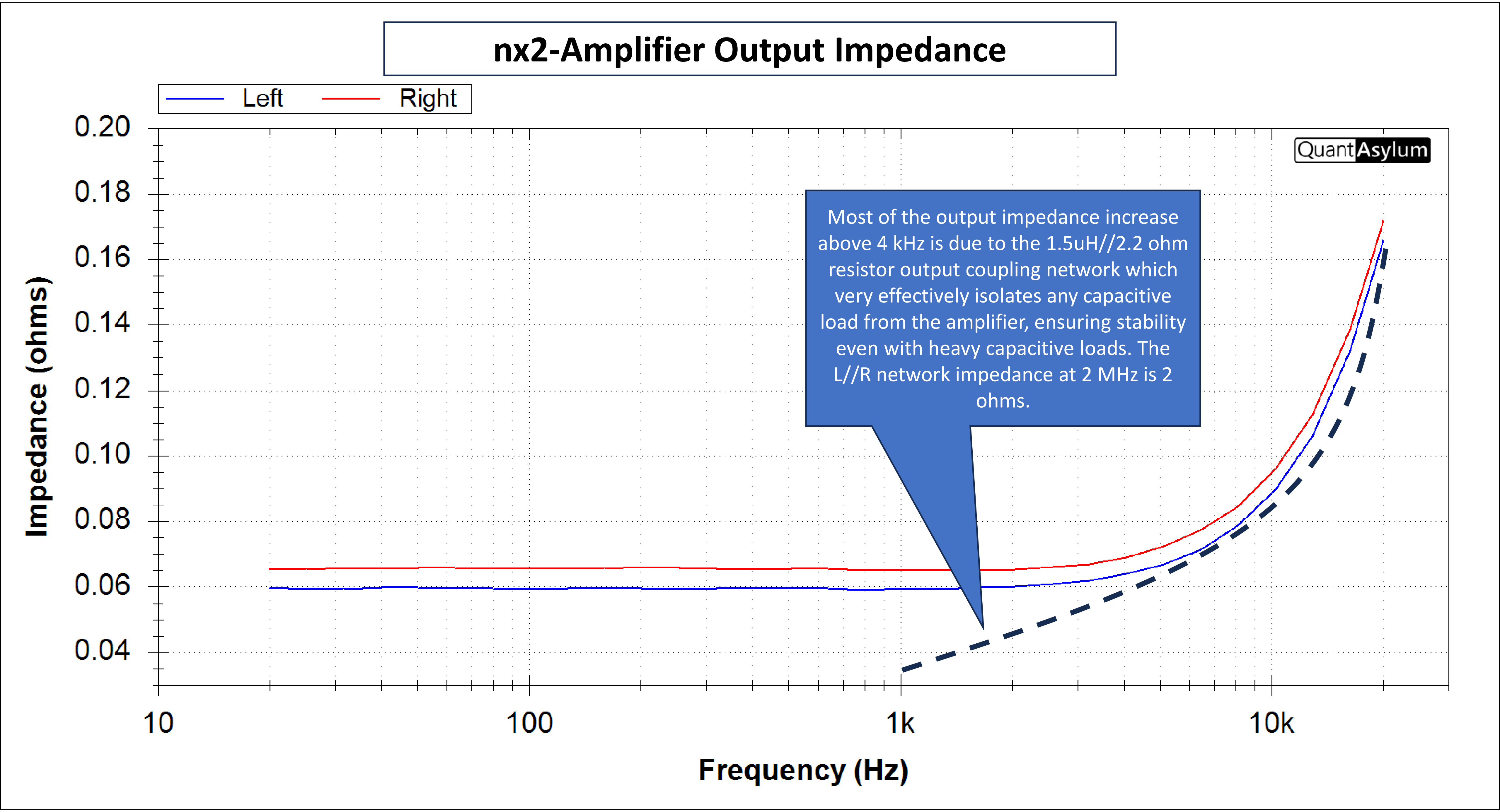

FFT: 128k
Avg: 21 of 50
Res: 1.46 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
RMS L: 0.0 dBr
RMS R: 0.0 dBr
Peak L: -0.01 dBr
Peak R: -0.05 dBr
Peak L: 107 W (8.0 Ω)
Peak R: 106 W (8.0 Ω)
THD L: -91.9 dB/ 0.00254%
THD R: -91.8 dB/ 0.00257%
Gen 1: 1.000488 KHz @ 12.1 dBr
Gen 2:19.99951 KHz @ 6.5 dBr
THD+N L: -88.4 dB/ 0.00381%
THD+N R: -88.9 dB/ 0.00360%
Phase L: -0.18 deg
Phase R: -0.18 deg
Delay L: 10.6 uSec
Delay R: 10.5 uSec
Gain L: 29.75 dB
Gain R: 29.72 dB
100W RMS into 8 Ohms
QuantAsylum
QA401 v1.920
dBr
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
Acquired: 08/06/2025 17:47



FFT: 128k
Avg: 21 of 50
Res: 1.46 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
RMS L: -0.1 dBr
RMS R: -0.1 dBr
Peak L: -0.07 dBr
Peak R: -0.10 dBr
Peak L: 212 W (4.0 Ω)
Peak R: 210 W (4.0 Ω)
THD L: -88.5 dB/ 0.00377%
THD R: -88.1 dB/ 0.00395%
Gen 1: 1.000488 KHz @ 12.1 dBr
Gen 2:19.99951 KHz @ 6.5 dBr
THD+N L: -86.5 dB/ 0.00473%
THD+N R: -86.6 dB/ 0.00470%
Phase L: -0.28 deg
Phase R: -0.28 deg
Delay L: 10.8 uSec
Delay R: 10.8 uSec
Gain L: 29.70 dB
Gain R: 29.66 dB
200W RMS into 4 Ohms
QuantAsylum
QA401 v1.920
dBr
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
Acquired: 08/06/2025 17:48


nx2 Amplifier THD vs Power 8 and 4 ohms Both Channels Driven
Left
Right
Left43
Right79
THD (dB)
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
THD (%)
1E+01
1
0.1
0.01
0.001
Power (Watts)
1
10
100
QuantAsylum
220W RMS into 4 Ohms
40ppm THD
130W RMS into 8 Ohms
32ppm THD
10W to 100W THD is <30ppm
Freq: 1000.0 Load: 4.0 Stop Level: 3.0 dBV Ext Gain: -41.9 dB


FFT: 128k
Avg: 14 of 50
Res: 1.46 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
FR Window: 3.0mS
FR Smoothing: 1/6 Oct
Peak L: -20.36 dBV
Peak R: -20.37 dBV
Peak L: 1.14 mW (8.0 Ω)
Peak R: 1.14 mW (8.0 Ω)
FR Gen: -50.0 dBV
nx2-Amplifier frequency response into 8 ohms
QuantAsylum
QA401 v1.920
ExtGains
Atten: 20 dB
dBV
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
10
100
1000
10000
Acquired: 06/06/2025 17:17


nx2-Amplifier Output Impedance
Left
Right
QuantAsylum
Most of the output impedance increase above 4 kHz is due to the 1.5uH//2.2 ohm resistor output coupling network which very effectively isolates any capacitive load from the amplifier, ensuring stability even with heavy capacitive loads. The L//R network impedance at 2 MHz is 2 ohms.
Impedance (ohms)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
10
100
1k
10k
Frequency (Hz)

10. References and further reading

1. 'Analog Circuit Design', Sergio Franco, 2015
2. 'Designing Audio Power Amplifiers', Robert Cordell, 2011
3. 'The Audio Power Amplifier Design Handbook', Douglas Self, 2008
4. 'Audio Amplifiers', Dr. Arto Kolinummi, 2017
5. 'In Defense of the current-Feedback Amplifier', Sergio Franco, EDN, August 2017
6. Hifisonix nx-Amplifier
7. Hifisonix sx-Amplifier
8. Hifisonix kx2-Amplifier
9. Ground Loops
10. Output Coupling Inductors