# Hifisonix kx2-Amplifier

## A Low Distortion, Wide Bandwidth 25 Watt Class A, class AAB, AB CFA Amplifier

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***Updated November 25 2022***

www.hifisonix.com

Important: This project is strictly for DIY/personal use only. If you wish to use this design, or aspects of this design, for commercial applications and/or resale, kindly contact me via the hifisonix website or at bonsai(at)hifisonix.com

Double sided, silk screened PCB's for the kx2-Amplifier project are available from Jim's Audio on eBay.

# WARNING

**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 practises 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.**


# kx2-Amplifier
# 28 Watt class A Amplifier
# June 2021

# kx2-Amplifier 2021 – Quick Overview of upgrades over the earlier kx-Amplifier design from 2018

- **6 out of 114 builders of the kx-Amp reported 15-20 MHz parasitic oscillation problems at 20 ~ 80mV at the output – this is now completely solved (R4 and R5 changed from 10k to 1k)**
- **Zobel Network now on amplifier PCB allowing alternative power supplies to be used**
- **Improved offset adjustment - done on hi-Z non-inverting input and *non-interactive between channels (it was slightly interactive on the kx-Amplifier)***
- **Improved LF distortion due to the addition of C23 see circuit diagram)**
- **The kx2-Amplifier can be switched between class A, class AAB mode or class AB – details later in this document.**
- **TMC or Miller compensation - jumper selectable vs just TPC on the earlier kx-Amplifier.**
- **-115dBr 15 W RMS into 8 Ωs hum and noise class A; -120 dBr class AB – see specifications for details**

# kx2-Amplifier Specifications (+- 28V Rails)

**General Description:** A low distortion, wide bandwidth class A, class AAB or class AB amplifier specifically designed for driving high efficiency horn speakers, or high performance speakers in small listening spaces. At rated output power (28W peak class A into 8 Ω) all distortion products are at or below -90dB and predominantly low order 2nds and 3rds. There is no output quiescent current adjustment on the kx2 Amp - just a feature to switch between class A, AAB and AB. The compensation can be jumper selected between standard Miller or TMC via J3.

Note: A hifisonix Ripple Eater PSU was used in both build 1 and build 2. All measurements in this document are with the ripple eater PSU fitted with the supply voltages to the modules measured at +-28V under load in class A and +- 30 V in class AB.

**Output power**: 28 W peak class A into 8 Ω = 15 W RMS class A into 8 Ω class A; 50 W RMS into 4 Ω class AB; ~90W RMS class AB into 2 Ω

**Standing current Class A mode**: 1.2 amps (600 mA per output pair); standing current class AAB mode: 700 mA (350 mA per pair); 160mA (80mA per pair) in class AB (these modes are switch selectable)

**Distortion at 1kHz** (measured): typically < 10 ppm up to 10 W RMS into 8 Ωs; <0.0015% at 28W peak into 8 Ω class A; 0.003% at 30 W RMS into 4 Ω with class A mode selected; <0.02% at 50W into 2 Ω with class A mode selected; 85 Watts RMS into 2 Ωs at <1% distortion

**Gain:** 25x = 28 dB

**Hum and Noise Measured (Inputs shorted):** -120 dBr 15 W RMS class AB; -115 dBr 15 W RMS class A

**Input impedance:** 11 k Ω at 1 kHz

**Large Signal Rise/Fall Time*:** ~2us (10%~90%) front end filter enabled; c. 700ns without front end filter

**Closed Loop Bandwidth:** 2 Hz to 400 kHz (-3dB)

**Closed loop bandwidth without front end filter:** 2Hz to 1MHz (-3dB) 2.8V pk~pk into 8 Ω

**Loop Gain:** approx. 63 dB at 1 kHz

**Loop Bandwidth:** 2 Hz to 12 kHz -3 dB; Loop gain at 30 kHz is 45 dB and at 100 kHz ~23 dB (simulation)

**Stability:** Unconditionally stable with any combination from 2 Ω up to ∞Ω in parallel with 0 uF to 2 uF capacitance

*CFA amplifiers do not slew rate limit, therefore rise/fall time is quoted instead

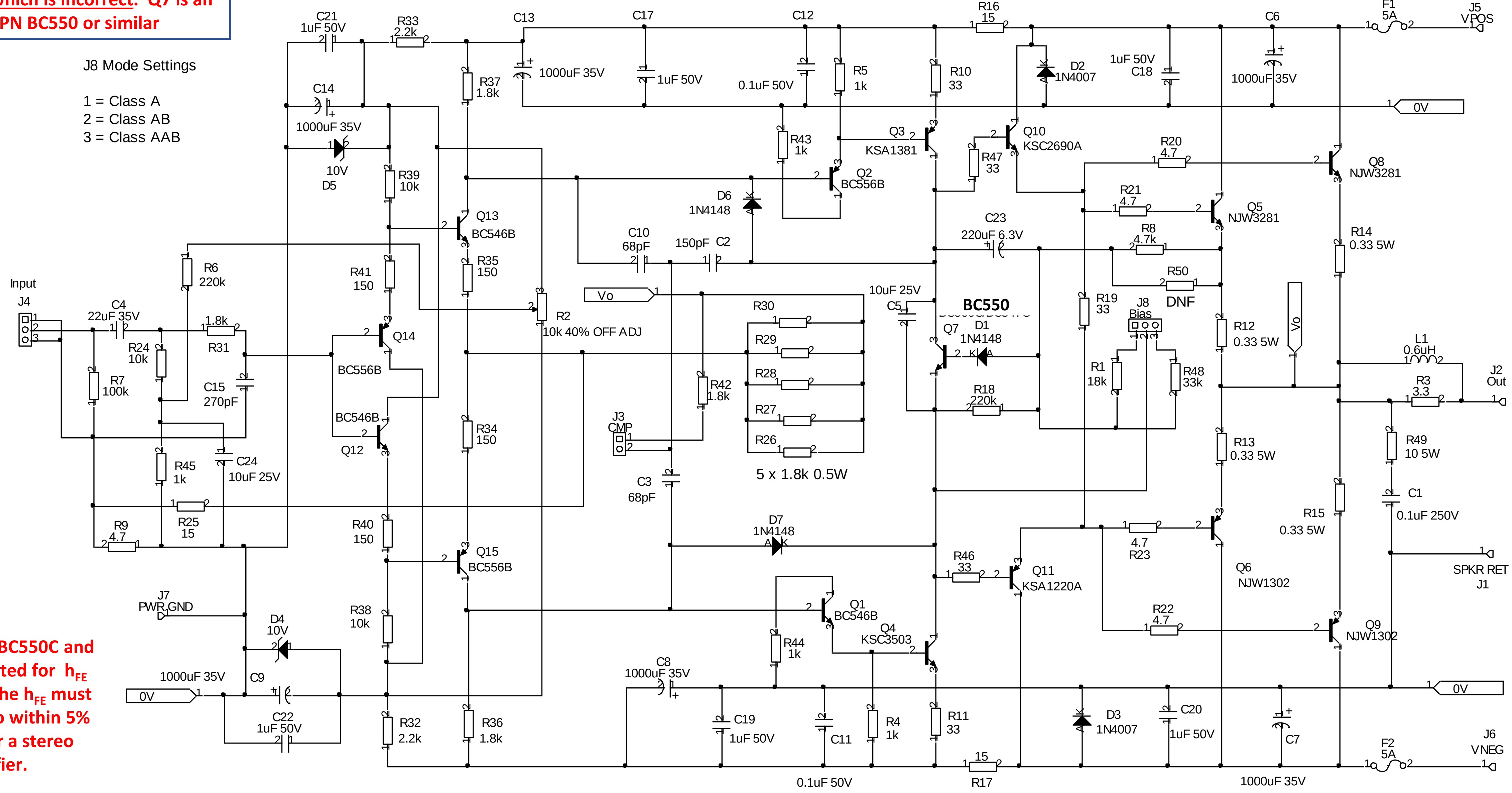
**Errata: Q7 was shown as BC560 in the schematic and on the PCB silk screen which is incorrect. Q7 is an NPN BC550 or similar**

Attention: The 35V 1000uF capacitors have a diameter of 10mm. 13mm diameter capacitors do not fit on the PCB!

For C23 220uF 6.3V electrolytic capacitor only 5mm diamter will fit User Mouser 667-ECA-0JM221I , 80-ESK227M6R3AC3AA or 667-ECA-0JHG221

J8 Mode Settings

1 = Class A
2 = Class AB
3 = Class AAB




**Q7 is BC547C/BC550C and must be selected for $h_{FE}$ of >450 AND the $h_{FE}$ must be matched to within 5% or better for a stereo amplifier.**

**kx2 Amplifier May 2021** **28W class A Amplifier** **www.hifisonix.com** **(c) 2018, 2019, 2021 Andrew C Russell** **June 11th 2021**

# kx2-Amplifier – Circuit Description 1/3 (refer to slide 6)

- ***Input Stage.*** The kx2-Amplifier is a Current Feedback Amplifier (CFA). The input is fed in via J4 where the centre pin is the signal hot and the outer two pins are signal ground. R7 ties the input side of C4 to ground to bleed off any charge build-up on C4 (22uF 35V non-polar electrolytic). R9 (4.7 Ω) is the hum breaking resistor (HBR). The input stage bias current is provided by R24 (10k) in series with R45 (1k). The amplifier offset adjustment from R2 (10k 20 turn potentiometer) is injected into the junction of R24 and R45 via R6 (220k) and allows up to +- 0.9 V adjustment as measured at the amplifier output.

- ***Input diamond buffer error amplifier and feedback.*** Q12, 13, 14 and 15 form the CFA input diamond buffer stage. The bases of Q14 and Q12 are tied together and are the high impedance non-inverting input and the emitters of Q13 and Q15 are tied together via 150 Ω resistors R34 and R35. The junction of these two resistors is the low input impedance inverting input. The input stage operating current is set by R38 and R39 (10k) plus R40 and R41 (150 Ωs) connected to -10V (From D4) and +10V (from D5) respectively. The standing current of *all four transistors* is therefore fixed at c. 985uA. The main feedback loop is via R26 to R30 (5 x 1.8 0.5W resistors) into the low Z input at the junction of R34 and R35 and the gain is set by R25 (15 Ω) to 25x. Since the overall feedback resistor is low (360 Ω), it is made up of parallel 1.8k resistors to minimize self heating.

- R40 and R41 are also 150 Ω and together with R34 and R35 ensure that the volt drop across these 150 Ω resistors swamps any differences in Vbe between the input transistors and further stabilizes the DC operating point of the front end stage. All four transistors operate at the same current density, are in close thermal proximity and their Vbe's and -2mV/K temp coefficients cancel. The DC stability of the amplifier once initial offsets are dialled out is therefore <u>very</u> good, changing by no more than +-10 mV from cold to final operating temperature in class A mode and reached within a few minutes from power up. If other operating modes are used for normal operation, the offset range change is even tighter due to lower heat dissipation in the amplifier. The zener reference diodes D4 and D5 are heavily decoupled by C9 and C14 (1000uF 35V) along with MLCC 's C21 and C22 (1 uF 50 V) and run at about 7mA each at 28V supply rails – the current set by R32 and R33 at 2.2k Ω. At the lowest recommended supply voltage of 22V, the zener diode standing current is about 4.5mA and at 35V rails around 10.5 mA. It is recommended that 2% or better tolerance diodes are used for D4 and D5.

- ***Voltage amplifier stage.*** The output of the front end stage is a balanced complementary current in the collectors of Q13 and Q15 which develop a voltage across R36 and R37 (both 1.8k Ω) and the high impedance parallel load of the input to the main voltage amplifier stage formed by Q2 (BC556B) and Q3 (KSA1381) in the upper half of the amplifier, and Q1 (BC546B) and Q4 KSC3503 in the lower half. The emitters of Q1 and Q2 are loaded with 1k resistors (R4 and R5 respectively). R10 and R11 (33 Ω), provide degeneration for Q3 and Q4, improving the linearity of the voltage gain stage and stabilizing the VAS operating current at around 17mA. R43 and R44, in conjunction with the low value for R4 and R5 act to damp the beta helper stages comprising Q1 and Q2 and prevent any tendencies towards instability.

- ***EF2 Output stage.*** The voltage amplifier stage output appears at the collectors of Q3 and Q4, which are tied together by the bias control servo (Q7 and associated components which we will discuss a bit further on) and feeds into an emitter follower two (EF2) output stage. Although there is a loss in output swing of about 3 volts in total using the EF2 compared to the single output device EF used in the sx-Amplifier and JLH, there is a marked reduction in distortion, and especially so at heavy loads. You can see from the distortion measurements that even at 85W into 2 Ω, the kx2-Amplifier is not more than 1% (see slide 77).

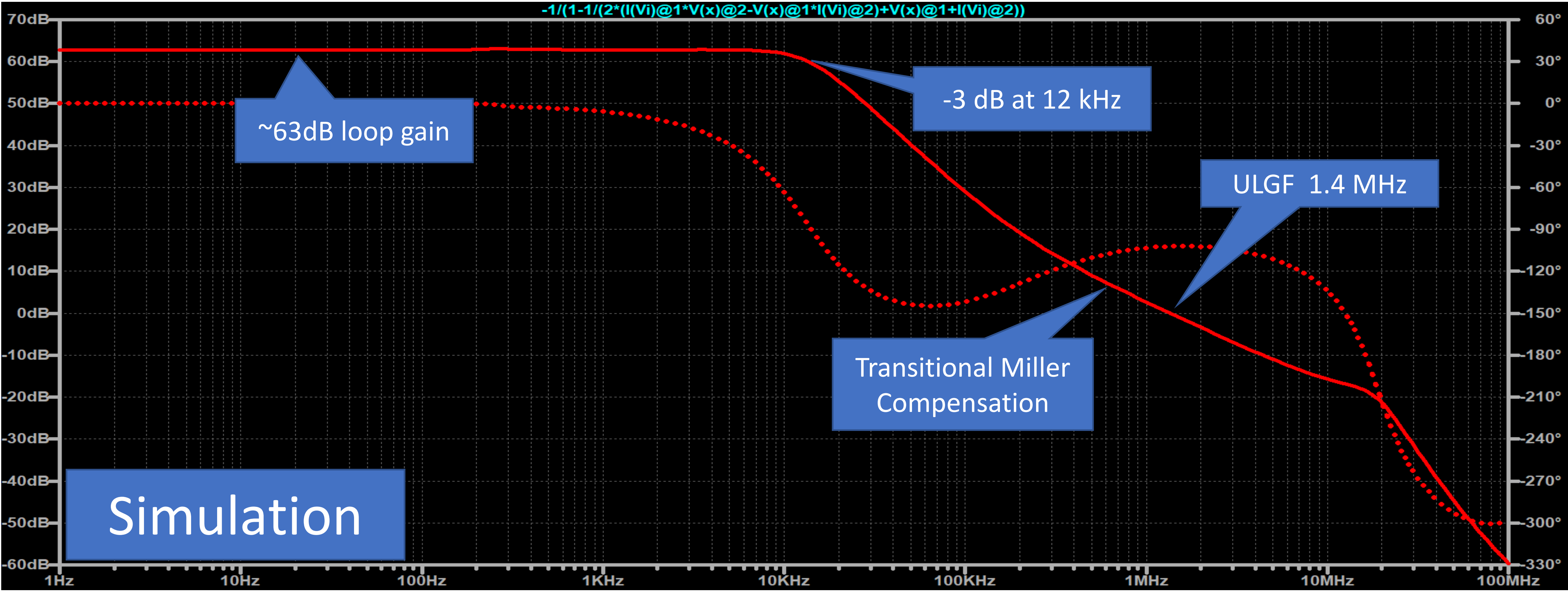
# kx2-Amplifier – Circuit Description 2/3

- ***Output Stage (continued).*** R46 and R47 (33 Ω) in the bases of the driver transistors Q10 (KSC2690A) and Q11 (KSA1220A) isolate the main voltage gain stage from the output stage input capacitance at HF (> 10 MHz) and ensure there will be no HF stability issues – a belt and braces approach. The emitters of the driver transistors are tied together with R19 (33 Ω) setting the driver standing current in class A to c. 38 mA. Even into 2 Ω, the driver standing current hardly changes due to the action of the active bias servo controller Q7.
- The output devices Q5, Q8 (NJW3281 – NPN) and Q6, Q9 (NJW1302 – PNP) are coupled to the driver stage via 4.7 Ω 2512 1W SMD resistors placed in very close proximity to the device base leads. These function as 'base stoppers' and ensure that the chances of output stage parasitic oscillation are essentially zero. Each output device emitter is degenerated with a 0.33 Ω 5W resistor. This helps to linearize the output stage by providing local AC feedback to each transistor, and is used by the bias controller to sense the output current.
- ***Output Coupling network and Zobel.*** The output, labelled 'Vo' in the circuit, couples to the outside world via a L1 (0.6~0.8 µH inductor) paralleled with a damping resistor R3 (3.3 Ω). This network very effectively isolates the output stage from any speaker + cable capacitive load. The kx2-Amplifier will drive any capacitance up to 2uF with any load impedance above 2 Ω (I did not test below 2 Ω). Without this network, capacitive loads cause the 2$^{nd}$ HF pole which by design is located above the unity loop gain frequency (ULGF) but << 0dB in magnitude to migrate down in frequency with the concomitant decrease in phase margin. If it rises above 0 dB and the phase margin severely degraded as a result, the amplifier will suffer from feedback loop stability problems. L1 and R3 ensure this cannot happen.
- R49 (10 Ω 5W) and C1 (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 Vo, remains fairly flat. Without it, the amplifier could break into HF parasitic oscillation with typically reactive speaker loads.
- ***Power Rail decoupling*** The power rails are generously decoupled with 1000uF 35V capacitors (C6, C7) which are further paralleled by 1uF 50V MLCC capacitors (C17, C18, C20, C19) to ensure the power rail impedance at HF remains low. Further HF decoupling is provided by C11 and C12 (0.01 uF 100V). R15 and R16 (15 Ωs) with C13 and C8 (1000uF 35V) from a power rail low pass filter with a corner frequency of c. 10 Hz, isolating the voltage gain stage from the main power rails at HF and further improving HF PSRR.

# kx2-Amplifier – Circuit Description 3/3

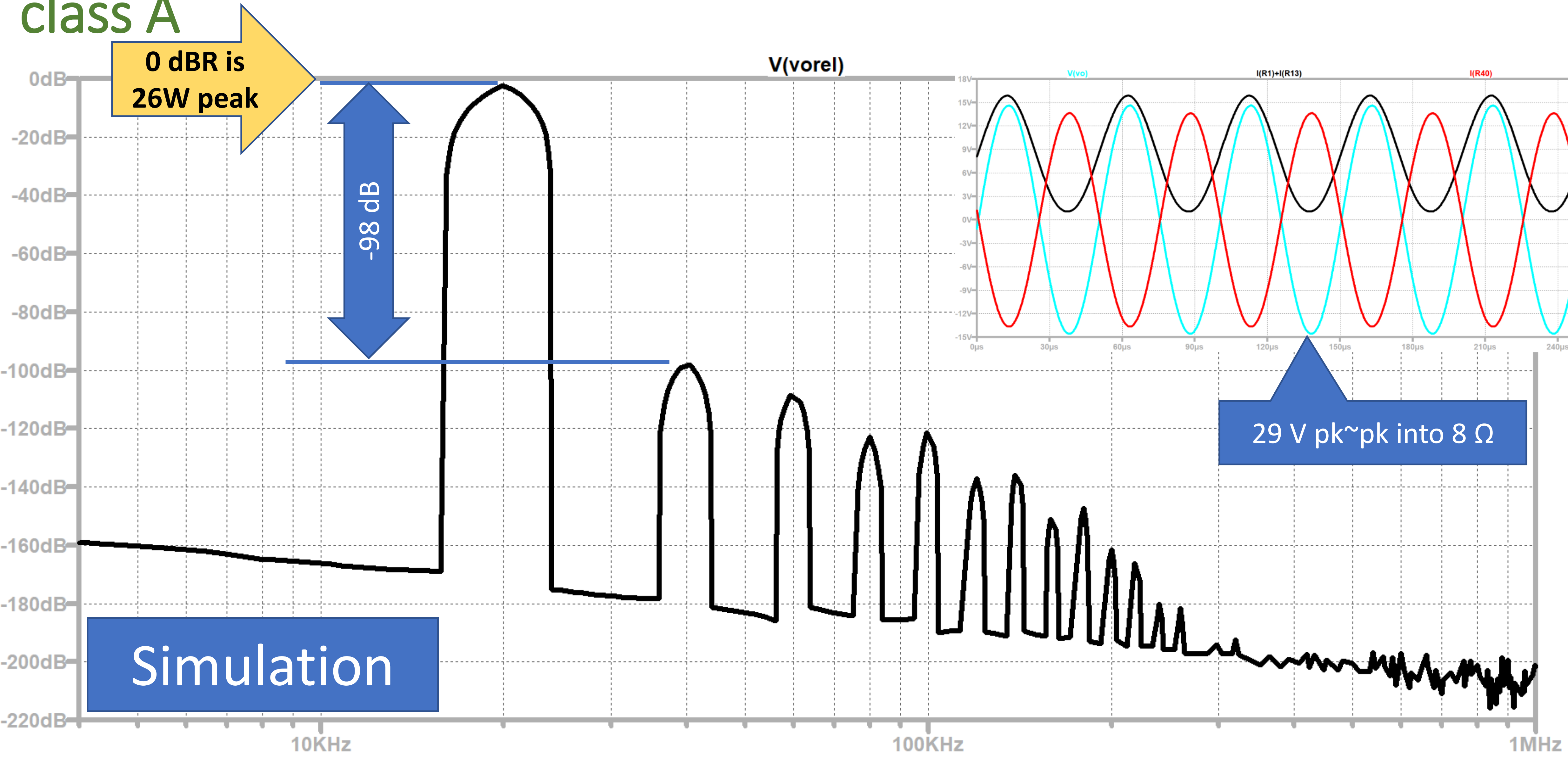
- ***Bias servo amplifier.*** Q7 (BC550 NPN or equivalent) is the bias control servo amplifier. After initial DC adjustment, most Class AB amplifiers, and some class A amplifiers, rely on thermal feedback between the output (and sometimes driver stages) as the main physical mechanism to regulate output stage standing current over temperature. In the kx2-Amplifier (as in the sx-Amplifier and in the class A X-Altra HPA-1 headphone amplifier), Q7 directly measures the voltage drop across the 0.33 Ω output device degeneration resistors (0.66 Ω in total) and then adjusts the voltage across its collector < > emitter terminals to keep the bias voltage, and hence output device standing current, constant. Because the OPS is an EF2, D1 has been added to provide a back-off voltage to compensate for the extra Vbe junction of Q11 in the regulator loop. See important notes later on the $h_{FE}$ requirements for Q7. See slide 19 for class A bias stability.
- C5 (10uF) and C16 (1uF) MLCC capacitors provide decoupling. C23 (220 uF 6.3V electrolytic) dramatically improves distortion performance at LF when the amplifier is swinging close to the supply rails. With out it, as Q3 pulls the collector node of Q7 close to the positive supply, the collector emitter voltage of Q7 collapses, causing the amplifier to enter class B operation earlier than would otherwise be the case. The addition of C23 solves this issue.
- ***Operation class switching***. By connecting a on-off-on toggle switch to J8 as shown in slide 16 and switching in R1 (18k) or R48 (33k) or leaving only R18 (220k) across Q7 + D1, the amplifier can be switched between class A, class AAB or class AB.
- ***Amplifier compensation design (refer to slide 10)***. The earlier kx-Amplifier from 2018 used TPC compensation in order to extract a further 20 dB loop gain at HF, dramatically reducing distortion at 20 kHz. Unfortunately, the closed loop response of TPC does exhibit slight overshoot on square wave testing that is usually mitigated by lowering the input bandwidth filter cut-off frequency, or by bridging the 'T' network with a small capacitor (See Robert Cordell "Designing Audio Power Amplifiers" (2011) pages 177-183). The kx2-Amplifier uses Transitional Miller Compensation (TMC) (developed independently by Peter Baxandall and later Edmond Stuart). TMC offers the same dramatic improvements in HF linearity, but without the slight closed loop peaking evident with TPC.
- C2 (150 pF *film, mica or NP0/COG types only*) feeds into C3 and C10 (68 pF *film, mica or NP0/COG only*). With jumper C3 closed, at LF, the main compensation feedback path is directly from the output to C3 and C10, since the impedance of C2 is high with respect to that of R42 (1.8k Ω). At about 600 kHz, the reactance of C2 equals that of R42 and decreases at 20 dB/decade above this frequency, transitioning the main compensation loop to the voltage amplifier stage output at the collector of Q3. If jumper C3 is left open, the amplifier reverts to plain Miller compensation. Do NOT attempt to wire this link to a front or rear panel switch to select between the two. This is a high impedance node and doing so will create problems – only use the link on the PCB to select one or the other compensation mode.
- Note: The kx2 Basic PSU is discussed in the construction section later in this document.

# kx2-Amplifier Loop Gain

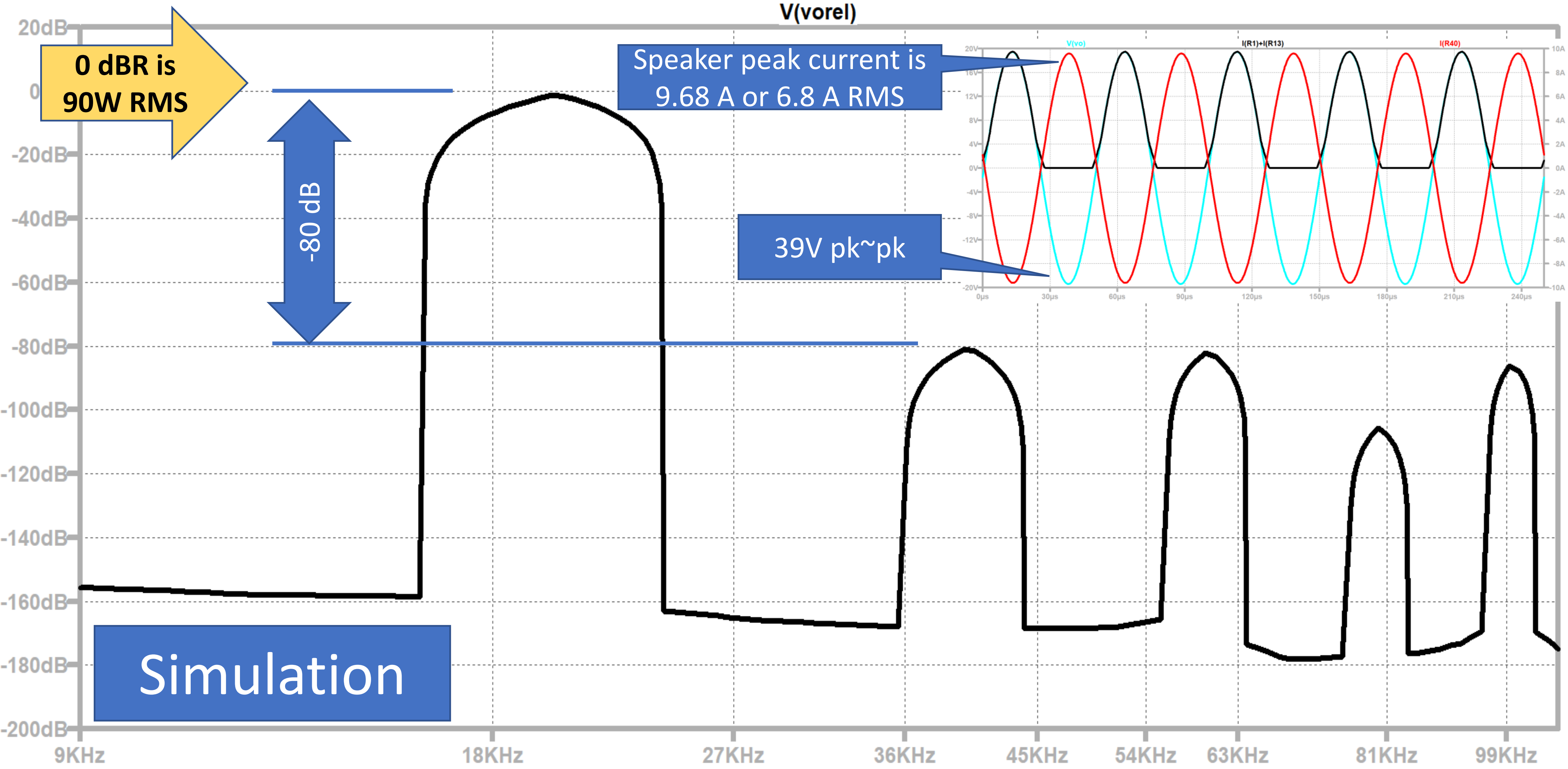


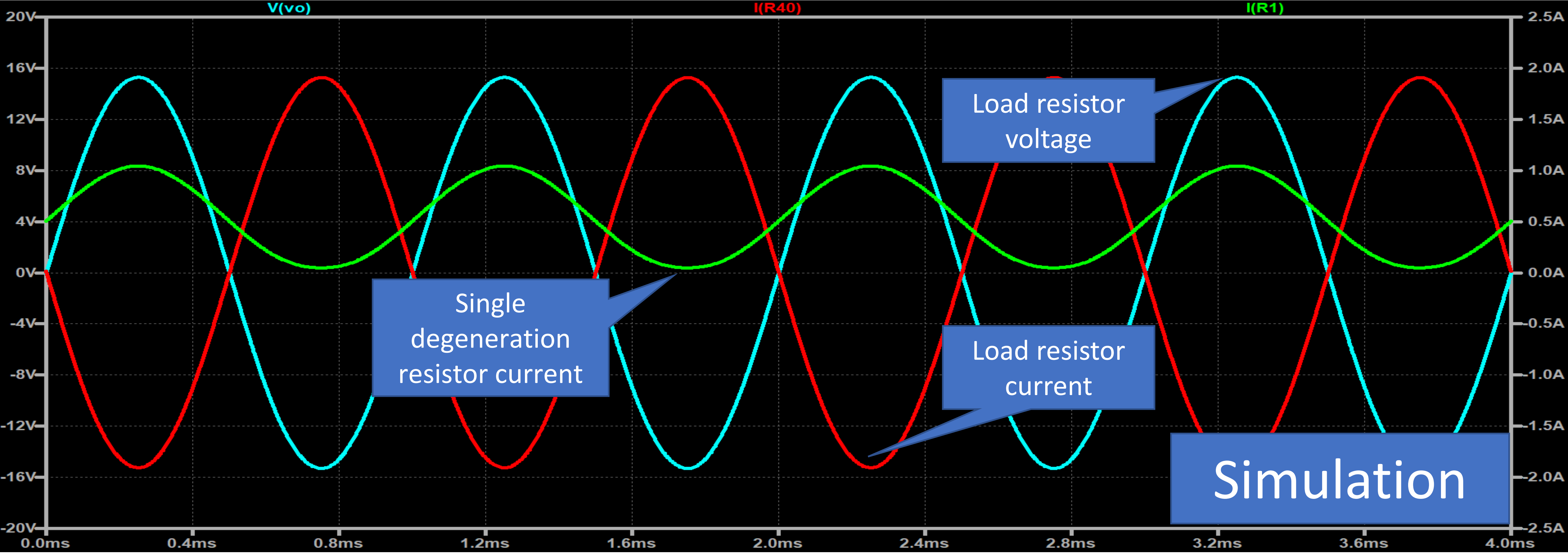

**The kx2-Amplifier features a wide 12 kHz loop gain bandwidth. The Unity Loop Gain Frequency is 1.4 MHz, the phase margin 85 degrees and the gain margin 18 dB. The kx2-Amplifier is unconditionally stable into any load from 2 Ω upwards in parallel with any capacitance up to 2uF.**

# kx2-Amplifier 20k THD at 14W RMS/26 W pk into 8 Ω Output – class A



# kx2-Amplifier 20k THD at 90W RMS Output into 2 Ω – class AB






Here is a simulation of the kx2 Amp driving an 8 Ω load in class A. The OPS standing current is set to ~500mA per pair, 1A total. The current delivered into the 8 Ω load is 1.9A at a peak voltage of 15V, yielding 28 W peak class A, or 14.5W RMS class A.

# kx2-Amplifier Transistor Notes - Important

- Use BC546B and BC556B or BC547C and BC557C types.  You can also use BC550B and BC560B but make sure you use the complementary devices – i.e. don't mix up 546 and say 560 in complementary positions in the amplifier. For the diamond buffer (Q12, 13, 14, 15) I recommend you use the exact complements. I used  a cheap $24 transistor tester to match the PNP <> NPN $h_{FE}$ pairs of all the small signal transistors to within 5% per amplifier. The advantage of this is that the distortion and DC offset are minimized.
- Please note, if you do NOT match the transistors, your amplifier will still work perfectly, albeit with slightly higher output offsets (which you can dial out via R2 potentiometer) and about 5-10 ppm higher distortion.
- For Q7 you must use BC546C, BC547C or BC550C (same data sheets as above) and ensure the $h_{FE}$ is >450 and match the $h_{FE}$ on the devices used on each channel of a stereo amp to within 5%. If you do not do this, the OPS standing current in the amplifiers will not match. Note the mismatch will be worst in class AB where the Q7 Ib forms a significant error term in the bias controller regulation equation as detailed on slide 18.
- Q3 and Q4: For the VAS transistor, use  KSA1381 and KSC3503 or 2SA1381 and 2SC3503.  You do *NOT* need to have the PNP vs NPN gain grades matched to meet the specified performance, however, see the important points below. The reason for this is that the TIS helper transistor + the main TIS transistor composite gain is high and it swamps any gain differences in the KSA1381 and KSC3503, provided you do not use any $h_{FE}$ outliers in the same amplifier
- *All the kx2-Amplifier prototypes were built with gain grade E and F mixed*.
- It is recommended that $h_{FE}$ of all the transistors are grouped together reasonably. For example, I measured about 20 devices out of each tube I have of the 1381 and 3503 and had quite tightly centred $h_{FE}$ values per the data sheets.  However, one of the devices had low gain which was completely to the very low end of the specified gain range and therefore did not use it. So, group the gains so that the devices with the two highest gains are used in one channel, and the remaining two lowest are used in the second channel.  This will minimize distortion.
- Q10 and Q11: Driver transistors – use KSA1220A and KSC2690A. Apply the same grouping technique as mentioned above.
- Q5, Q6, Q8, Q9: Output transistors – NJW3281/NJW1302. Use the recommended devices since the $h_{FE}$ linearity and SOA are superb and go a long way to underpinning the overall kx2-Amplifier performance.

# About the kx2-Amplifier Bias Mode Selection and Heatsink requirements

J8 in the circuit is a 3 pin link that can be used to select between the different operating modes. Use a 2 way toggle switch with a centre OFF position.  A suitable part from Mouser is Pt # 612-100-DP1T8. See the next slide on how to wire up the switch.

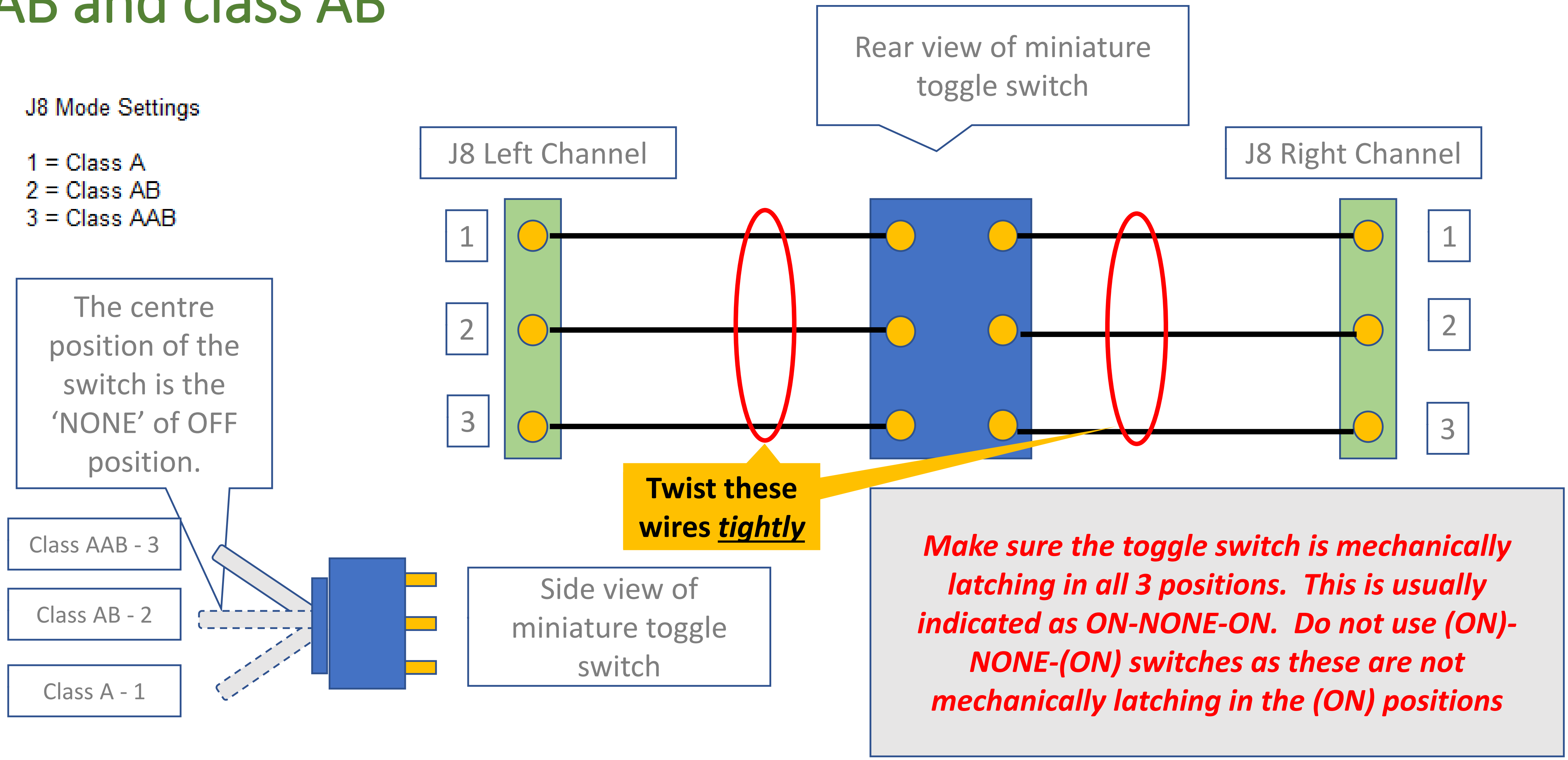
Further, if you elect to run the kx2 permanently in class AAB mode, you can use +-35V rails which will provide  50W RMS into 8 Ω, and close to 100W into 4 Ω. You will still need substantial heatsinks even in class AAB mode, where the standing dissipation will be around 50 Watts

**IMPORTANT: running the kx2-Amplifier on +-35V rails in class A mode will result in a standing dissipation of 85 Watts per channel which is not recommended. Above +-31 Volts up to +-35V supply rails only run in class AAB or class AB mode.**

**The kx2-Amplifier requires  a heatsink of at least 0.3˚C/Watt or lower per channel in class A mode. Each channel heatsink will therefore weigh a minimum of 1.5 kG**

So, either run on the +-22-31V and have the option to switch between the three modes, or  leave J8 ***permanently OPEN*** and run the amplifier on +-35V rails in class AB mode.

# How to wire up J8 to a switch to select between class A, class AAB and class AB



# Notes About the kx2 Bias Circuit 1/4

- There is no bias adjustment on the kx2-Amplifier, but instead, a facility to switch between class A, AAB and AB
- The bias current value relies on the Vbe junction voltages of Q7, Q11 and Q6 and the $h_{FE}$ of Q7 lying in a predictable range
- For $h_{FE}$ of Q7 = 520 (the typical value for the BC547***C*** through BC550***C*** series), the spread in class A standing current of 600 mA per pair is around 10% *after* the amplifier is fully warmed up. If $h_{FE}$ is matched, the inter-channel spread is very tight (<3% on the 4 amplifiers modules I did for builds 1 and 2).
- However, if the Vbe voltages mentioned above happen to all skew to either the low side or the high side, the standing current may fall outside this range.
- In severe cases, you should temporarily replace R8 (4.7k) with a 10k potentiometer initially set to 5k and then adjust it for 396mV across R12 and R13 *after the amplifier is fully warmed up*. Power the amp down, measure the potentiometer resistance, and replace it with the nearest fixed value resistor. R50 is a spare unused location (marked 'DNF' on the PCB) that can be used to make up the required value more accurately by paralleling it with R8

# Notes About the kx2 Bias Circuit 2/4

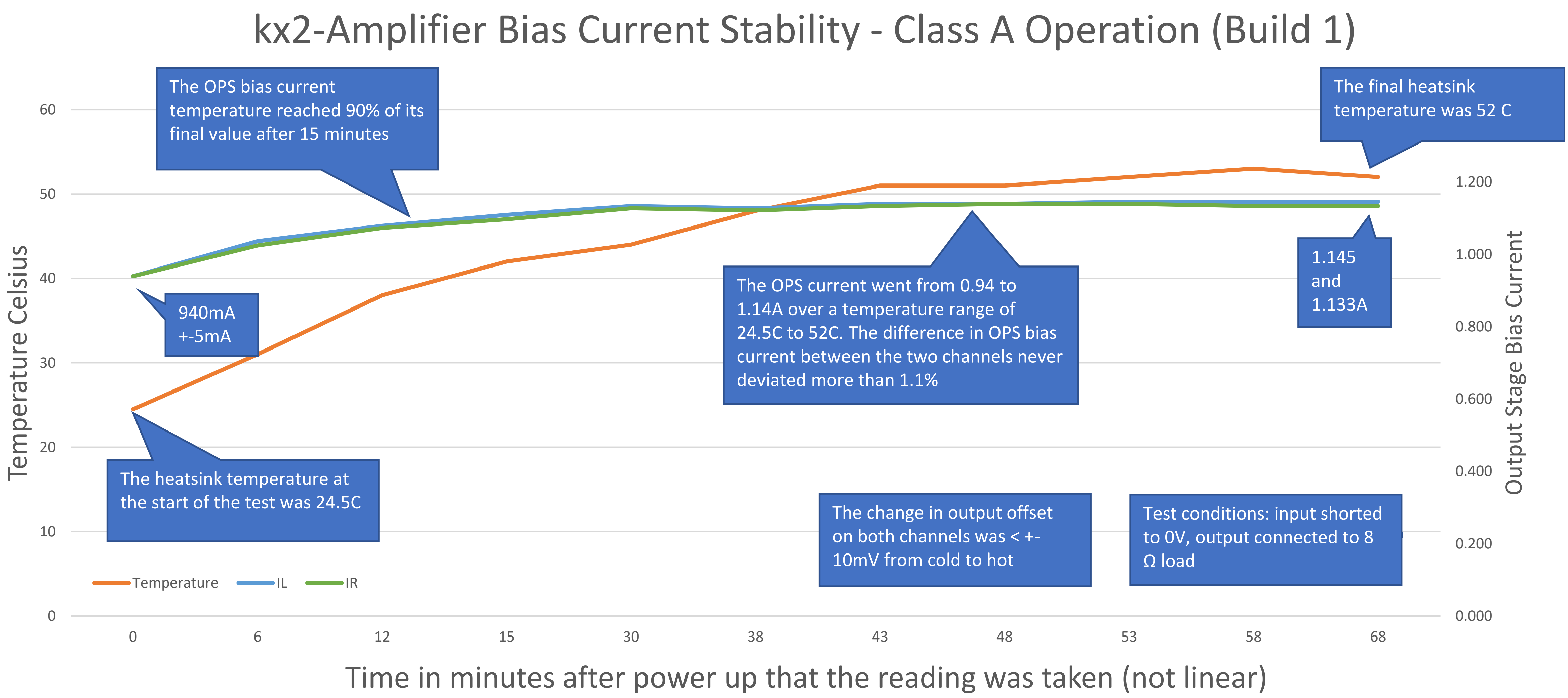
- Some builders on the earlier kx-Amplifier noted differences of up to +-10% in the OPS standing current between channels. This is due to the base current in Q7 which adds as an error term to the bias controller equation :

$$Iq_{OPS} = \frac{\left[ (V_{d_1} + Vbe_{Q_7}) \cdot \frac{R_1 + R_8}{R_1} + \frac{R_8 \cdot I_{cQ7}}{hFE_{Q_7}} \right] - (V_{beQ_{11}} + V_{beQ_6})}{R_{12} + R_{13}}$$

*Note: R1 is the parallel combination of R1//R18 or R48//R18); $I_{cQ7}$ is 12mA*

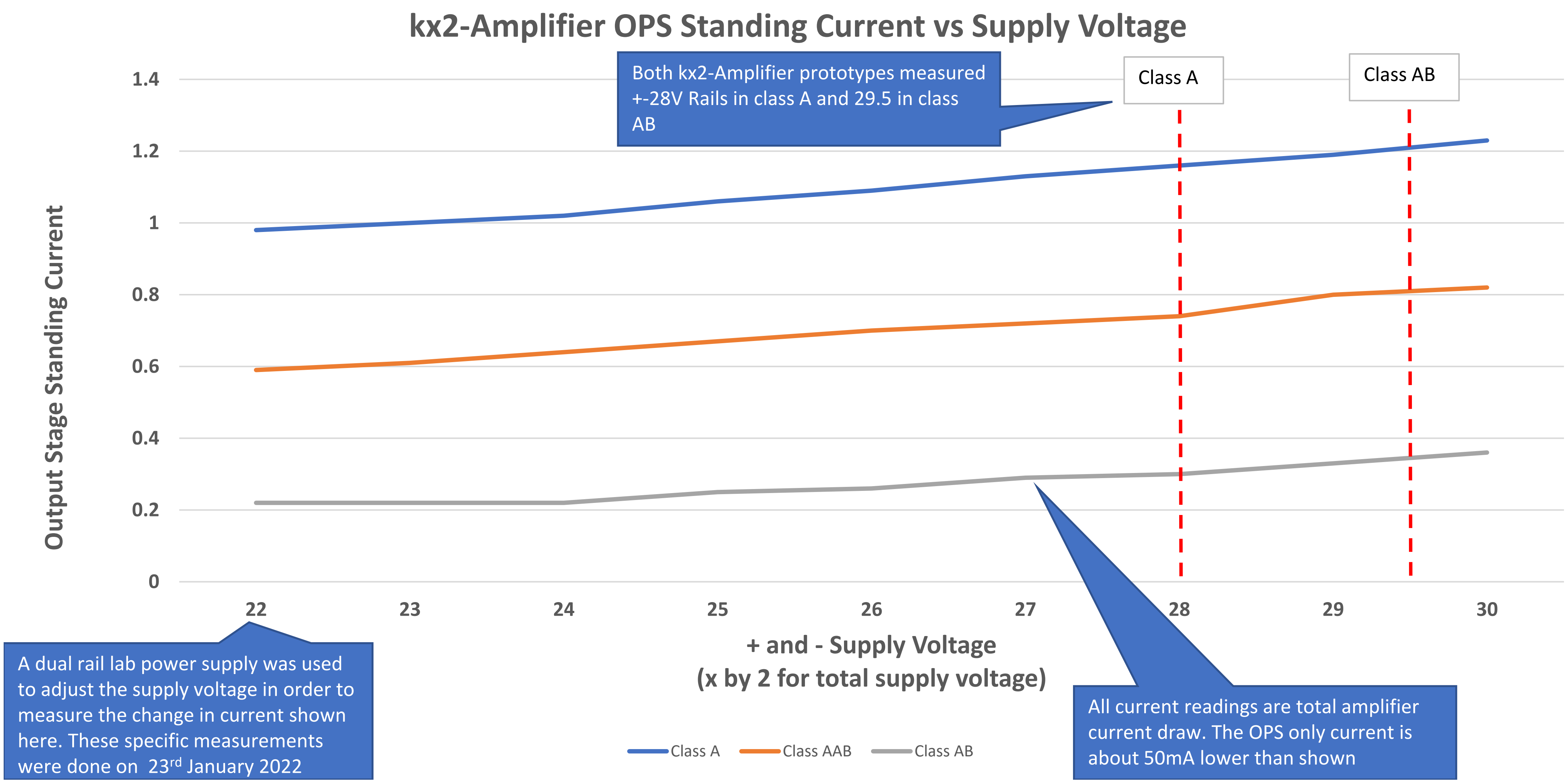
- To mitigate this, Q7 must be a high $h_{FE}$ ‘C’ suffice BC546, BC547 or BC550 device and the $h_{FE}$ on the devices > 450 and matched to within 5% to ensure inter-channel class A current balance is matched. Note that in class AB the mismatch will be worst, so the closer the match the better.
- The spread in OPS bias current with $h_{FE}$ 450 ~ 800 is 600mA down to 530 mA per pair – so 1.2 A down to 1.06 A for both output pairs (figures for fully warmed up amplifier). The higher the gain of Q7, the lower the OPS current.
- With a 10% $h_{FE}$ mismatch, the difference will be ~18mA between the channels across the spread given above and about half that with a 5% transistor gain match
- Note, to use the above equation, you have to use the *exact measured voltages for the different semiconductor base-emitter junctions* – you will not get the correct answers by simply plugging in 0.6V

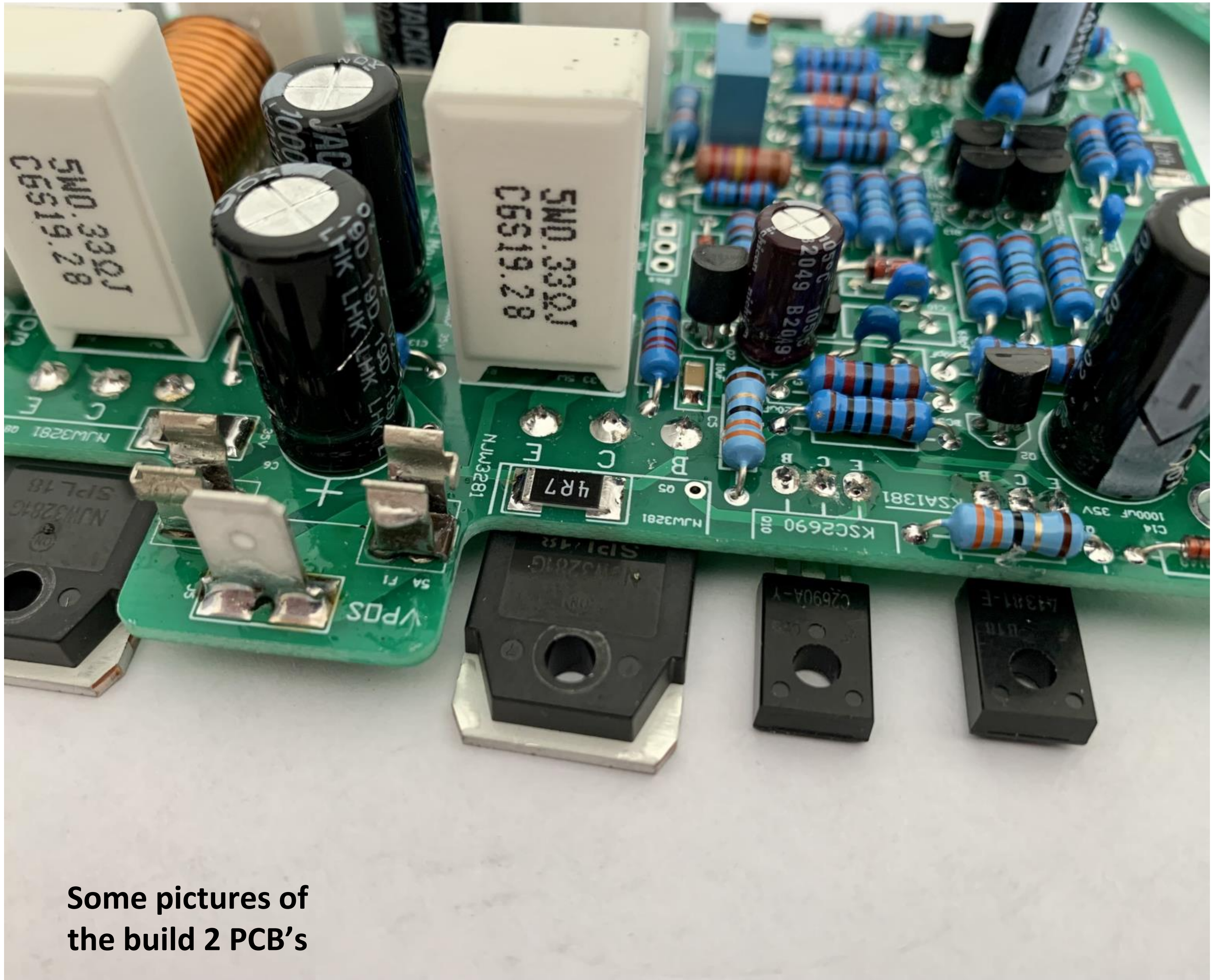
# Notes About the kx2 Bias Circuit 3/4 - Measurements



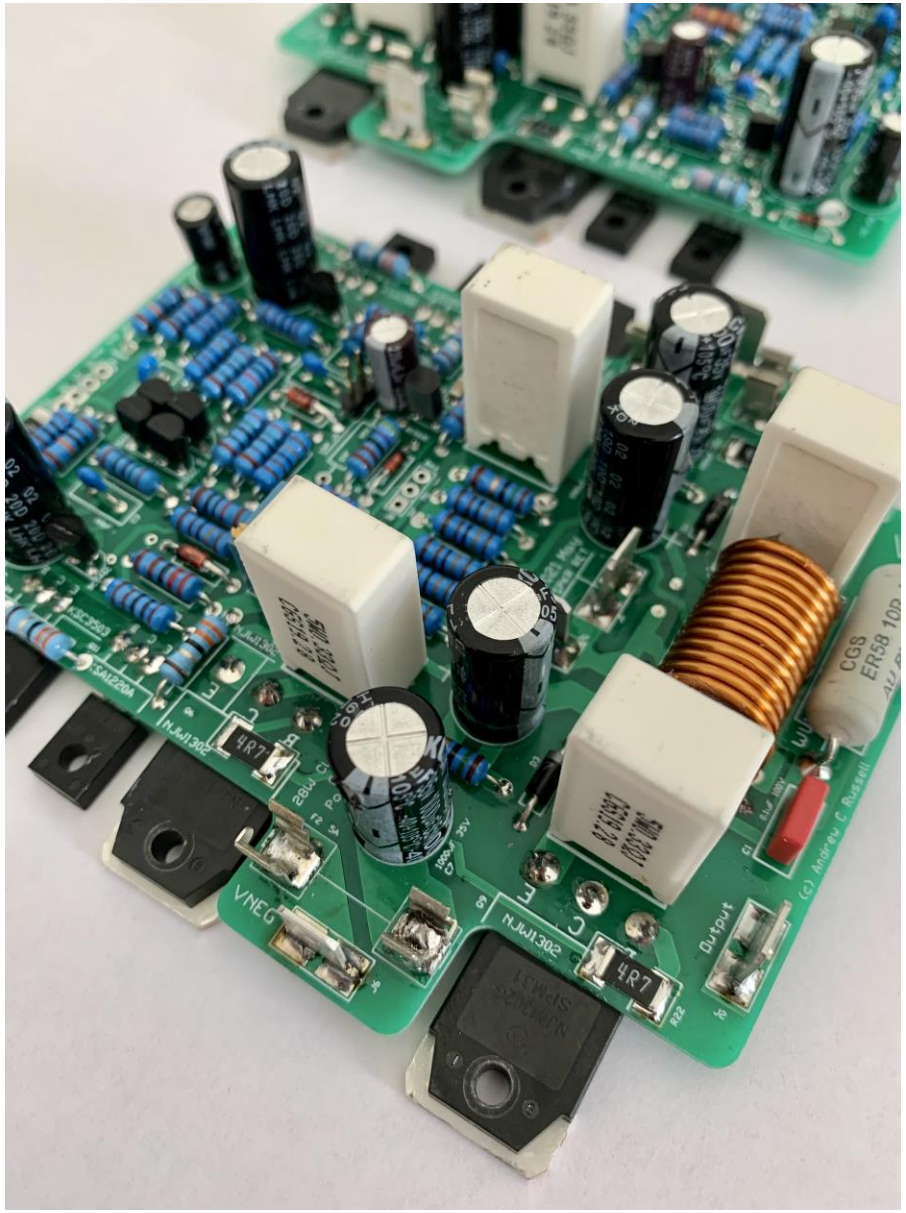

Note: The standing current in build 2 was adjusted upwards slightly compared to build 1. However, the thermal stability and settling performance between the two builds is essentially identical.

# Notes About the kx2 Bias Circuit 4/4 - Measurements






Some pictures of the build 2 PCB's



# Construction and BOM Details

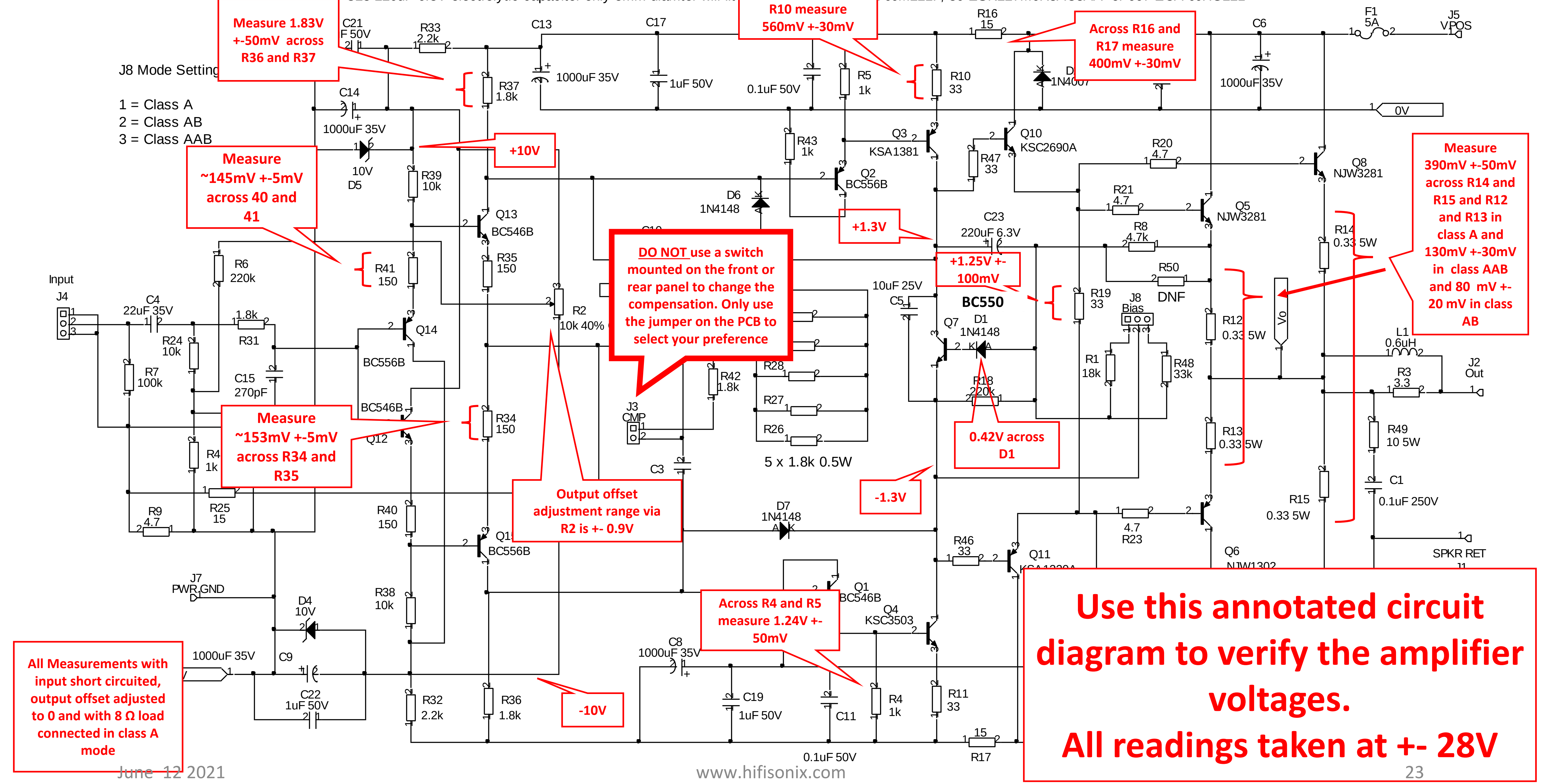
Click to download the kx2-Amplifier BOM (Excel)

Or alternatively go to the

kx2-Amplifier page at hifisonix.com

Attention: The 35V 1000uF capacitors have a diameter of 10mm. 13mm diameter capacitors do not fit on the PCB!

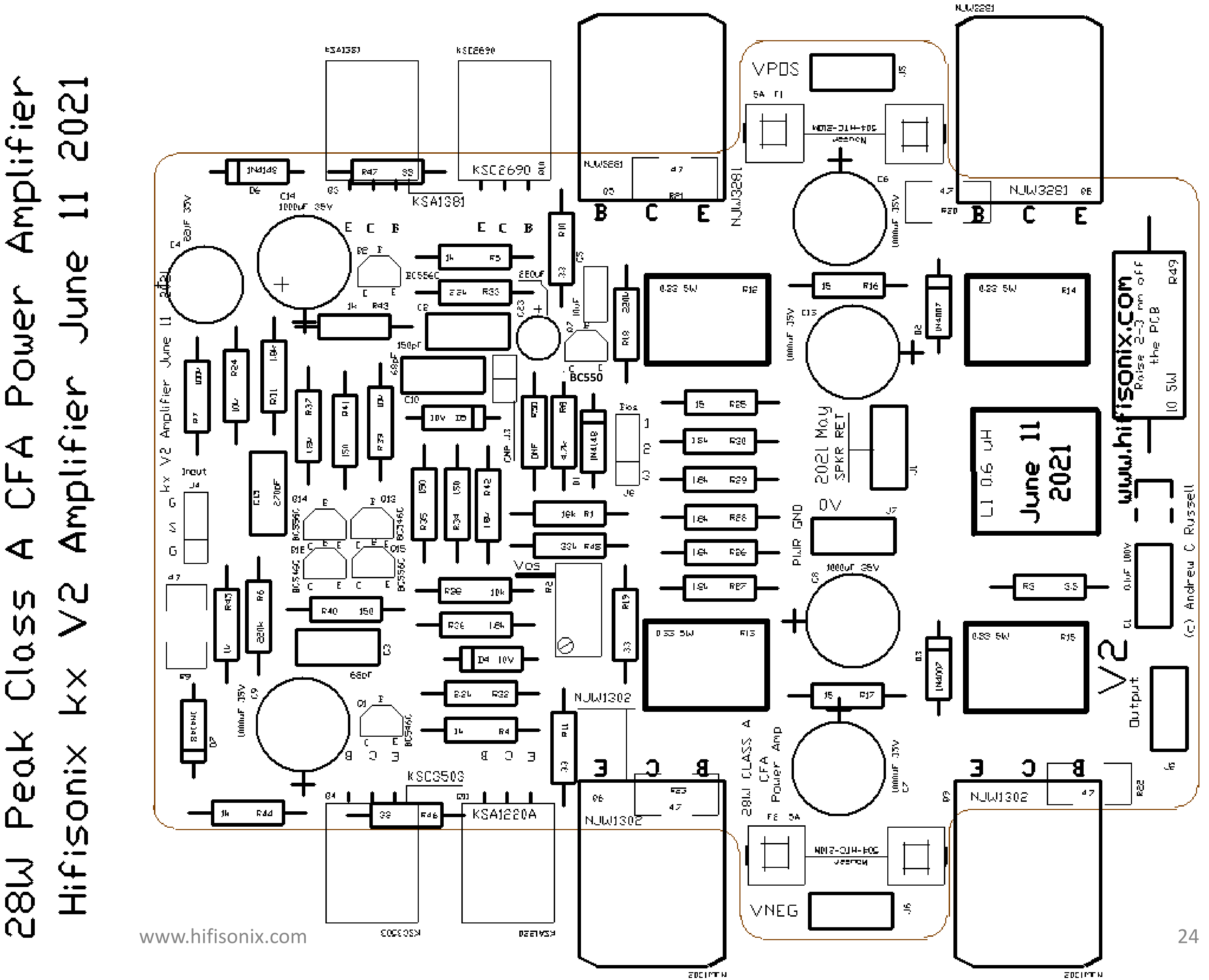
For C23 220uF 6.3V electrolytic capacitor only 5mm diamter will fit -0JM221I , 80-ESK227M6R3AC3AA or 667-ECA-0JHG221



# kx2-Amplifier Overlay April 2021

## Top Layer

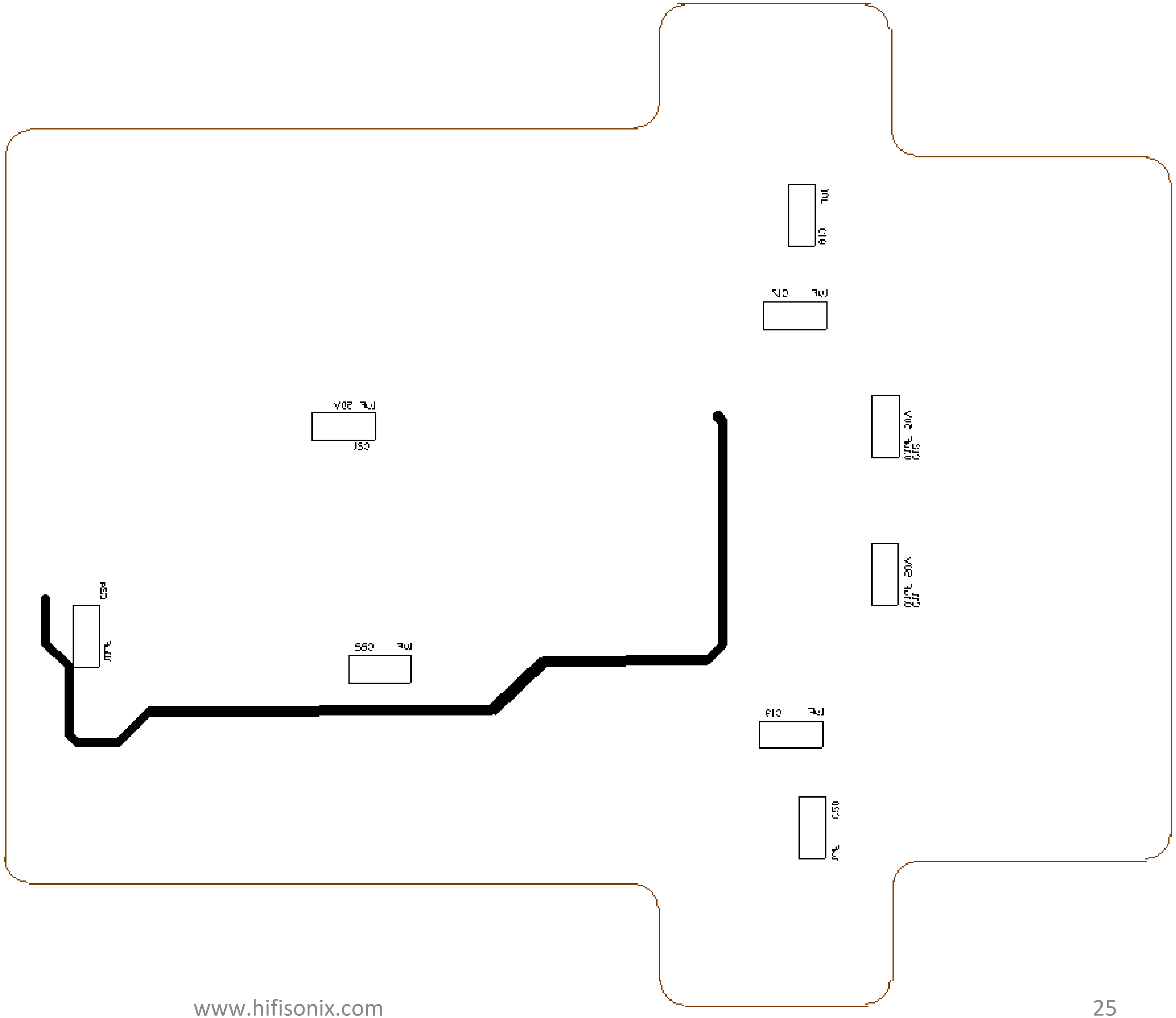
**Note: All values and component designations are silk screened onto the PCB – both top and underside layers**



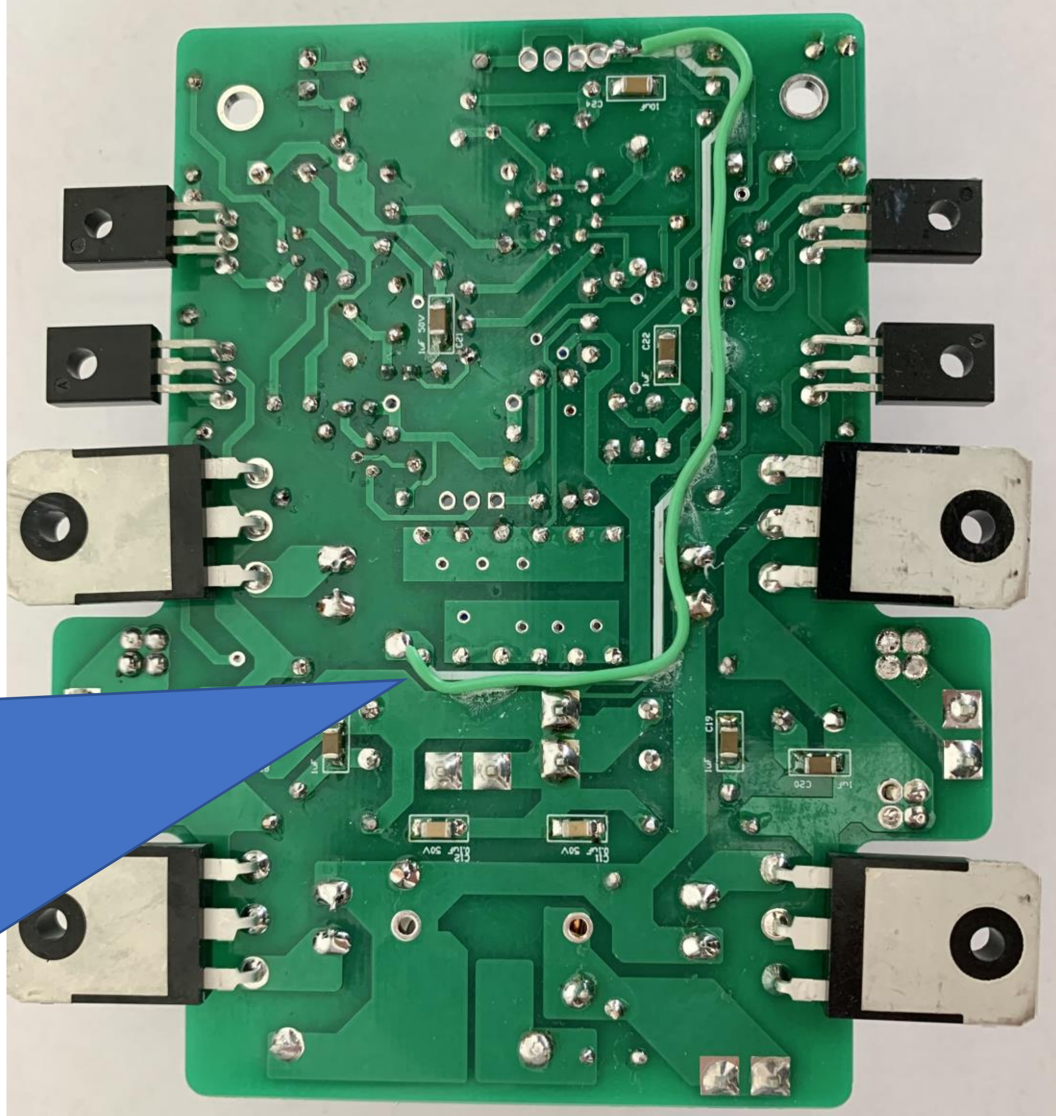
# kx2-Amplifier Overlay April 2021

## Bottom Layer

**Note: All values and component designations are silk screened onto the PCB – both top and underside layers**

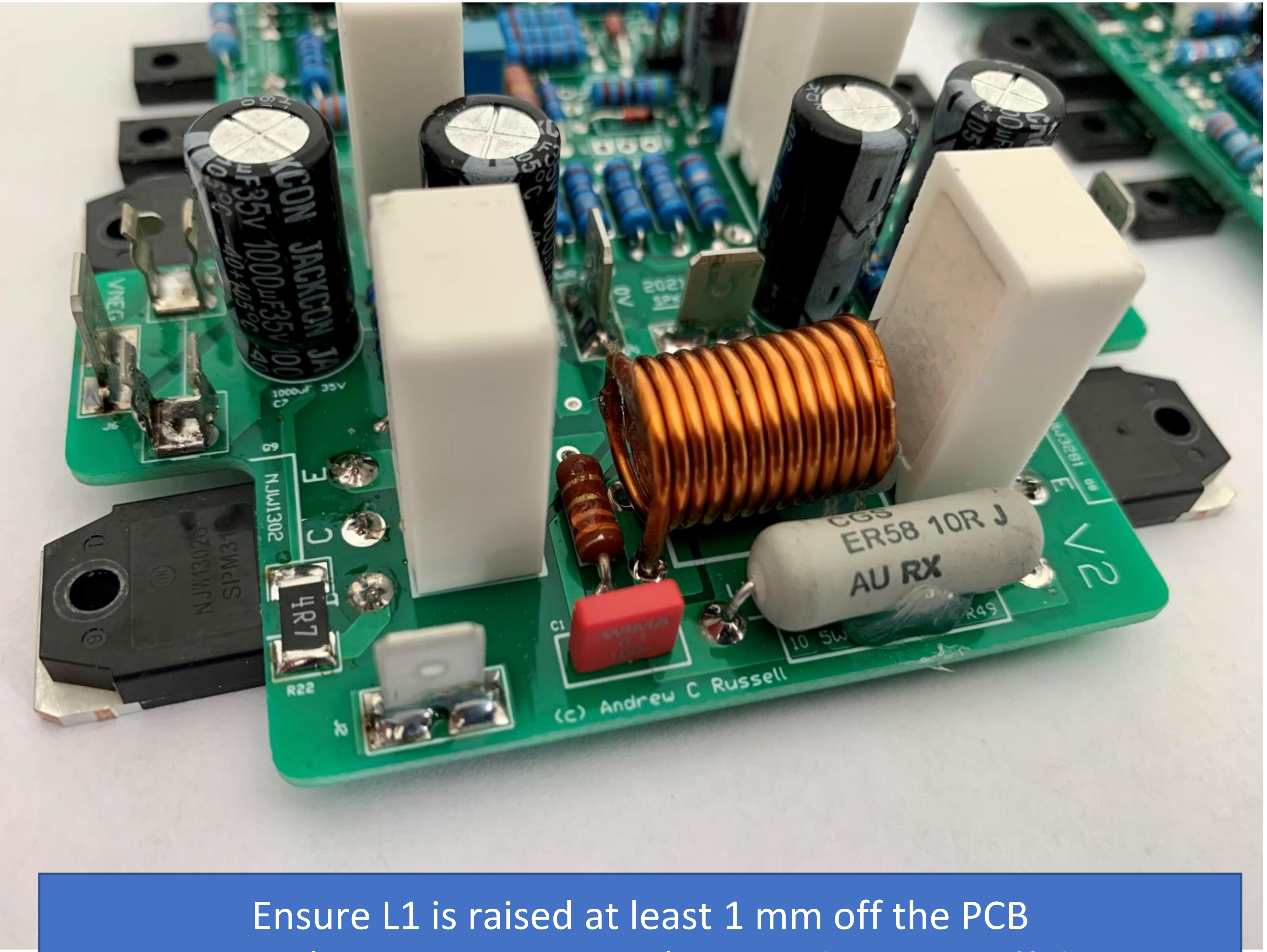


- The feedback ground wire is routed back to the input side of the front end hum breaking resistor via a thin wire (green in this picture) on the bottom side of the PCB.
- Make sure the wire follows the silk screen line under the PCB as shown
- Tack the wire in place with a small amount of super glue. It must stay close to the PCB to minimize loop area
- Using this technique, the amplifier noise floor is at or below -120 dBr 15 W RMS into 8 Ωs. This is a 15 dB improvement on the kx-Amplifier



# L1 Winding Details

- Use a cylindrical former of 10mm diameter
- Use 1.2~1.25 mm diameter insulated copper wire
- Wind 13 turns on the former
- The finished coil should measure between 0.7 uH and 0.9 uH. Anything up to 1 uH is ok

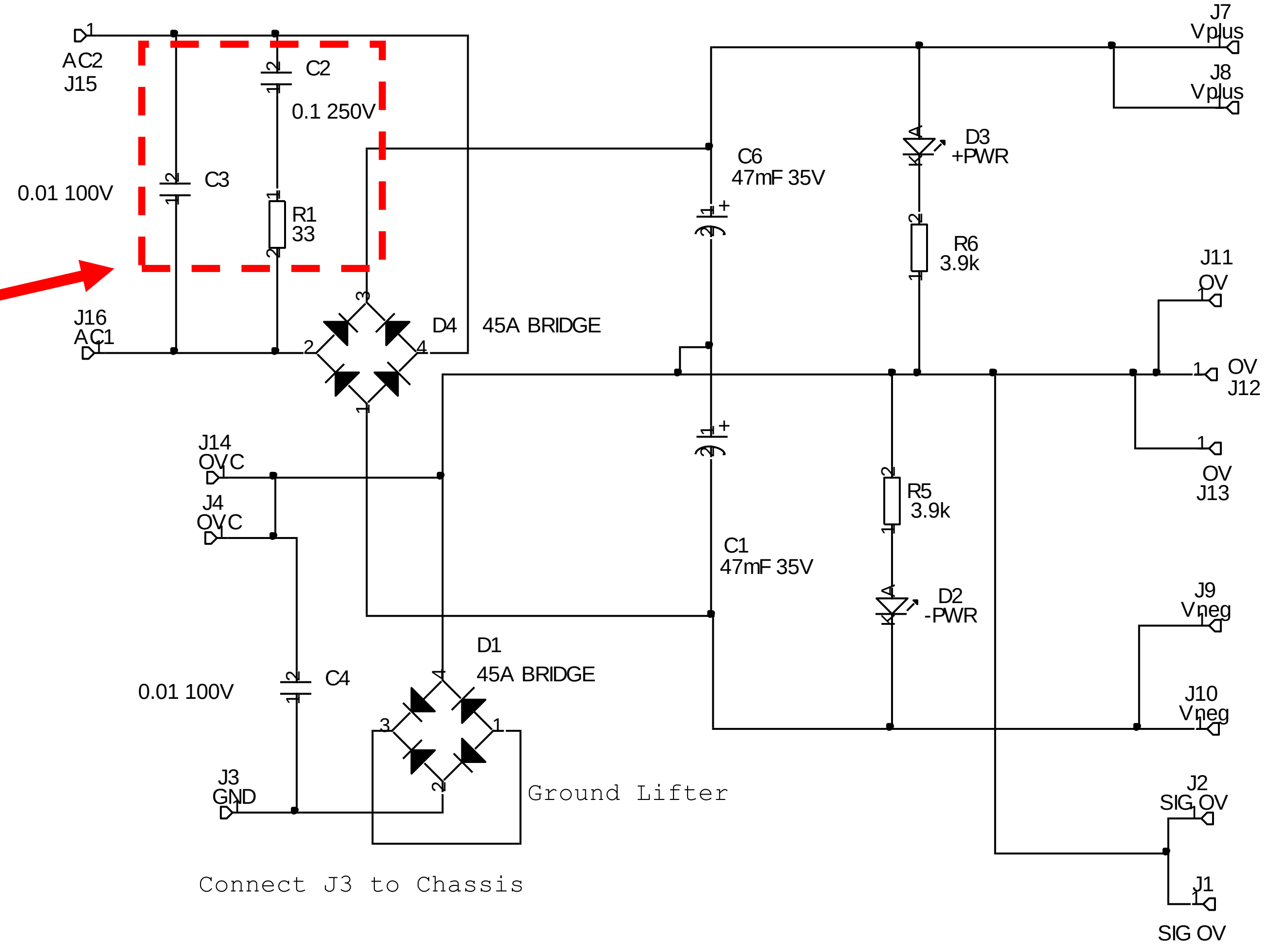



Ensure L1 is raised at least 1 mm off the PCB
Ensure R49 (10 Ω power resistor) is raised 2-3 mm off the PCB
USE RTV to secure both L1 and R49 to the PCB as shown above

# kx2-Amplifier Basic Power Supply Circuit

**On the kx2 basic PSU, the Zobel has been removed as is now on the amplifier board and the main bridge rectifier D2 has a snubber (C2, C3 and R1) added.**

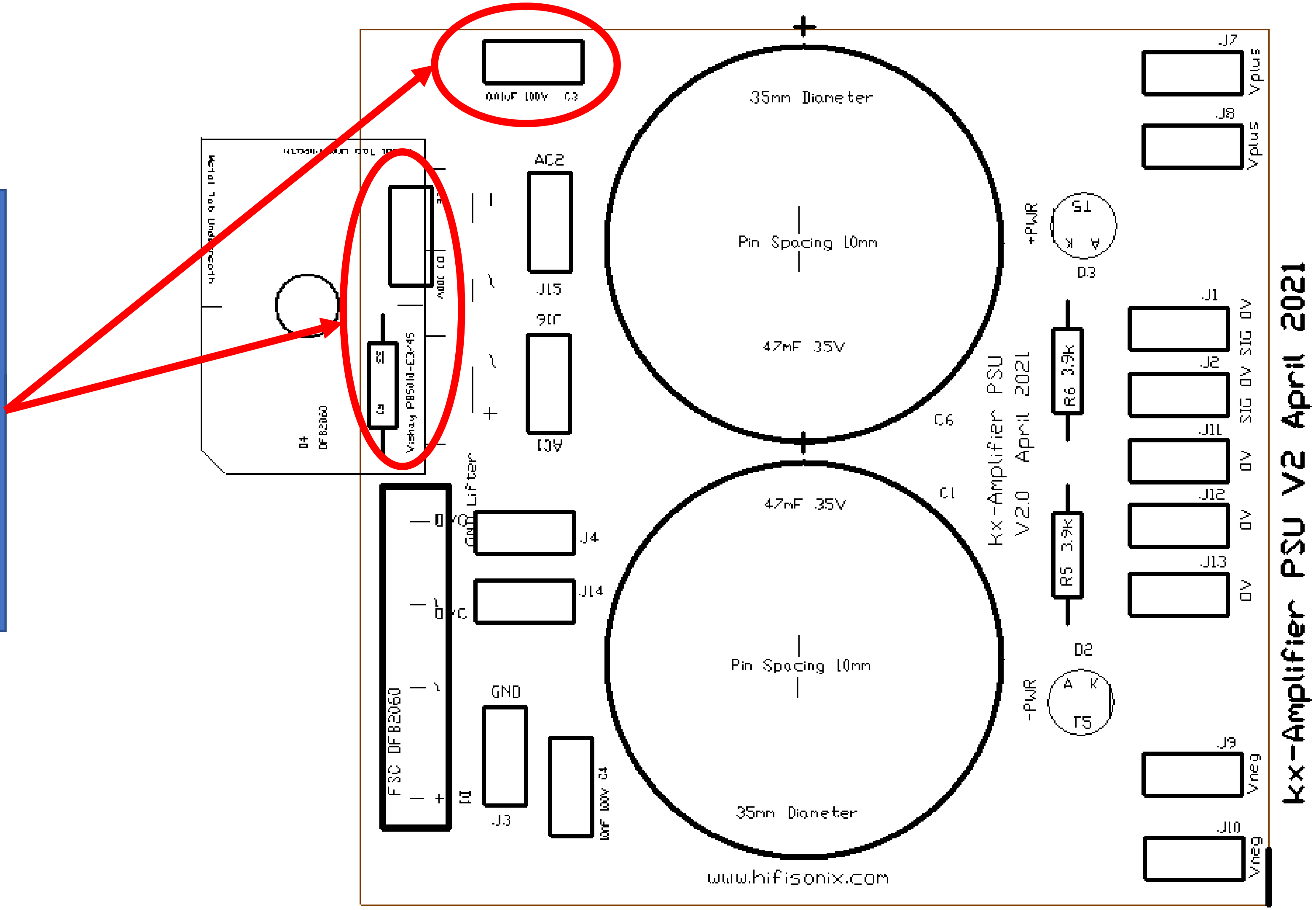
**The values shown for R1 and C2 are general values that you can use as is. However, see Mark Johnson's excellent thread on why snubbering power supply rectifiers is important and how to optimize these values specifically for your transformer.**



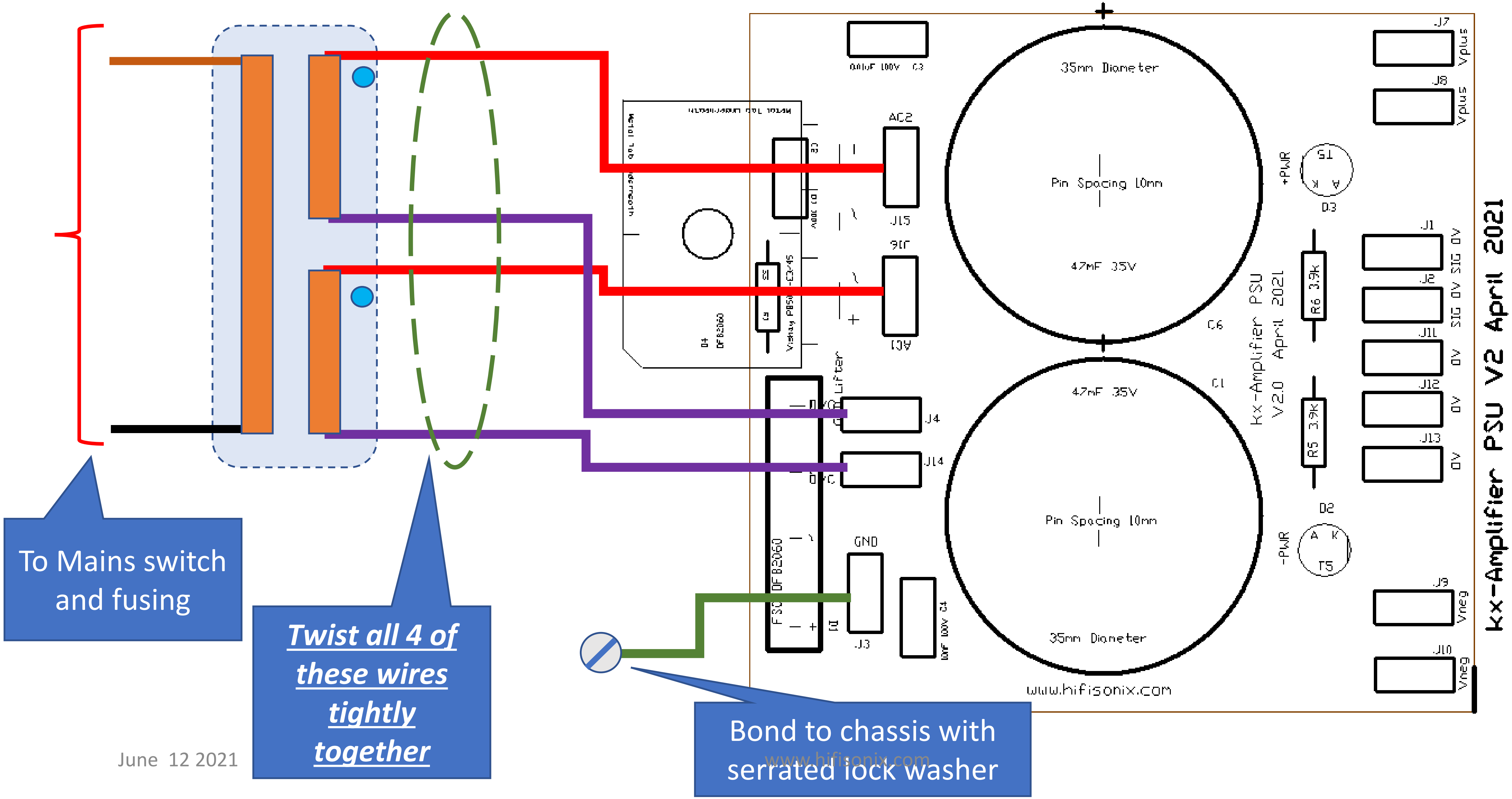

**kx2 Amplifier Basic PSU June 13 2021 www.hifisonix.com**

# kx2-Amplifier PSU Overlay – April 2021

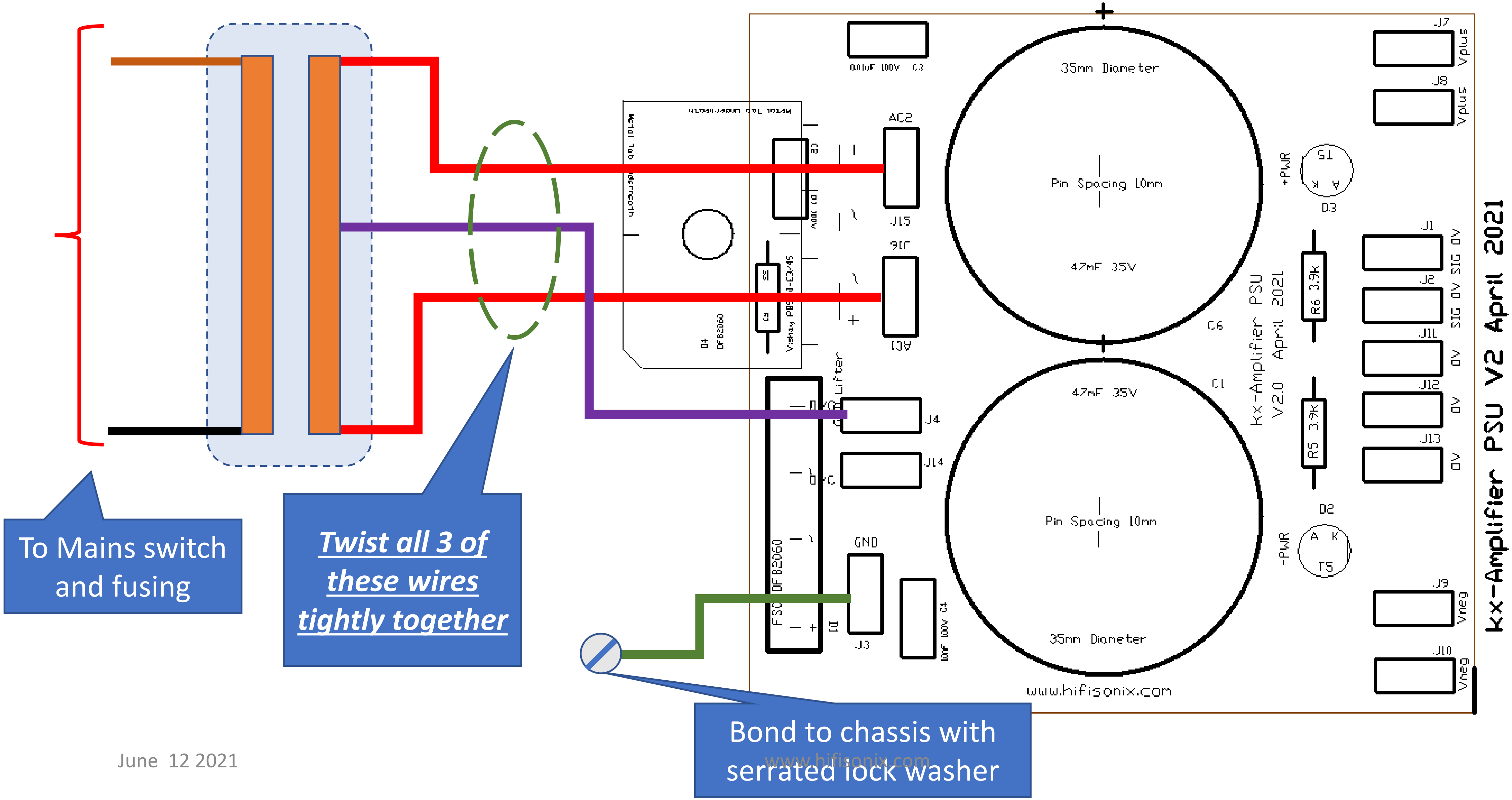
The kx2 Basic PSU incorporates a rectifier snubber in order to reduce switching noise



# kx2-Amplifier PSU Board Wiring – Split Secondary Transformer



# kx2-Amplifier PSU Board Wiring – Centre-tapped Secondary Transformer



# How to mount the main bridge rectifier

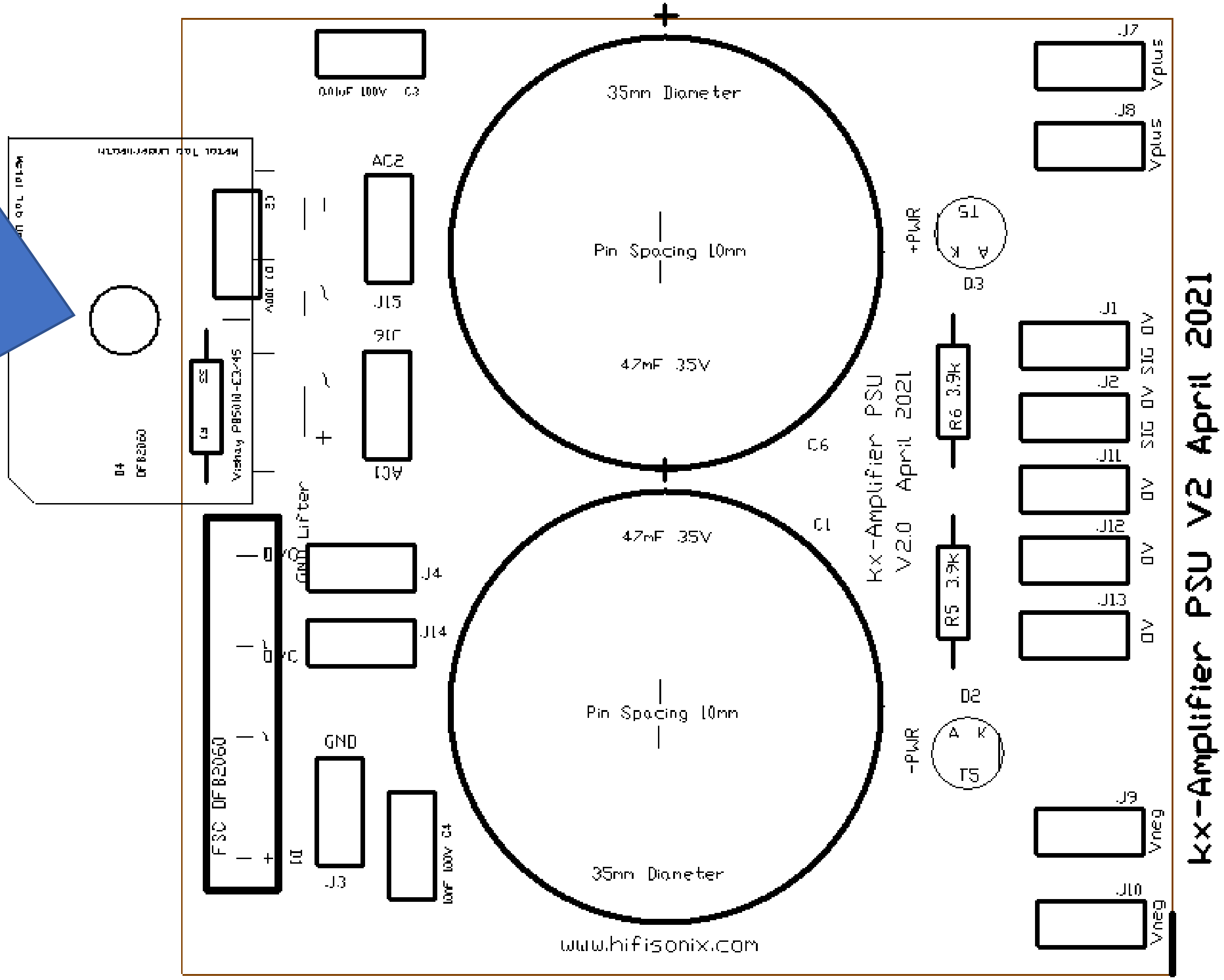
D4 is the main bridge rectifier.  It must be bolted directly onto the base of the chassis with thermal grease between the chassis and the exposed heatsink tab on the bottom of the rectifier (the tab is isolated electrically from the internal rectifier diodes).

The legs are bent up at 90 degrees and enter the PSU board from the bottom.

Use 4 off 10mm M3 standoffs to mount the PSU board to the chassis.

Do not operate the amplifier in class A mode without heatsinking D4

Do not mount D4 remotely and run cables to the PCB – there are very large charging currents flowing in the rectifier legs and it will radiate noise inside the amplifier



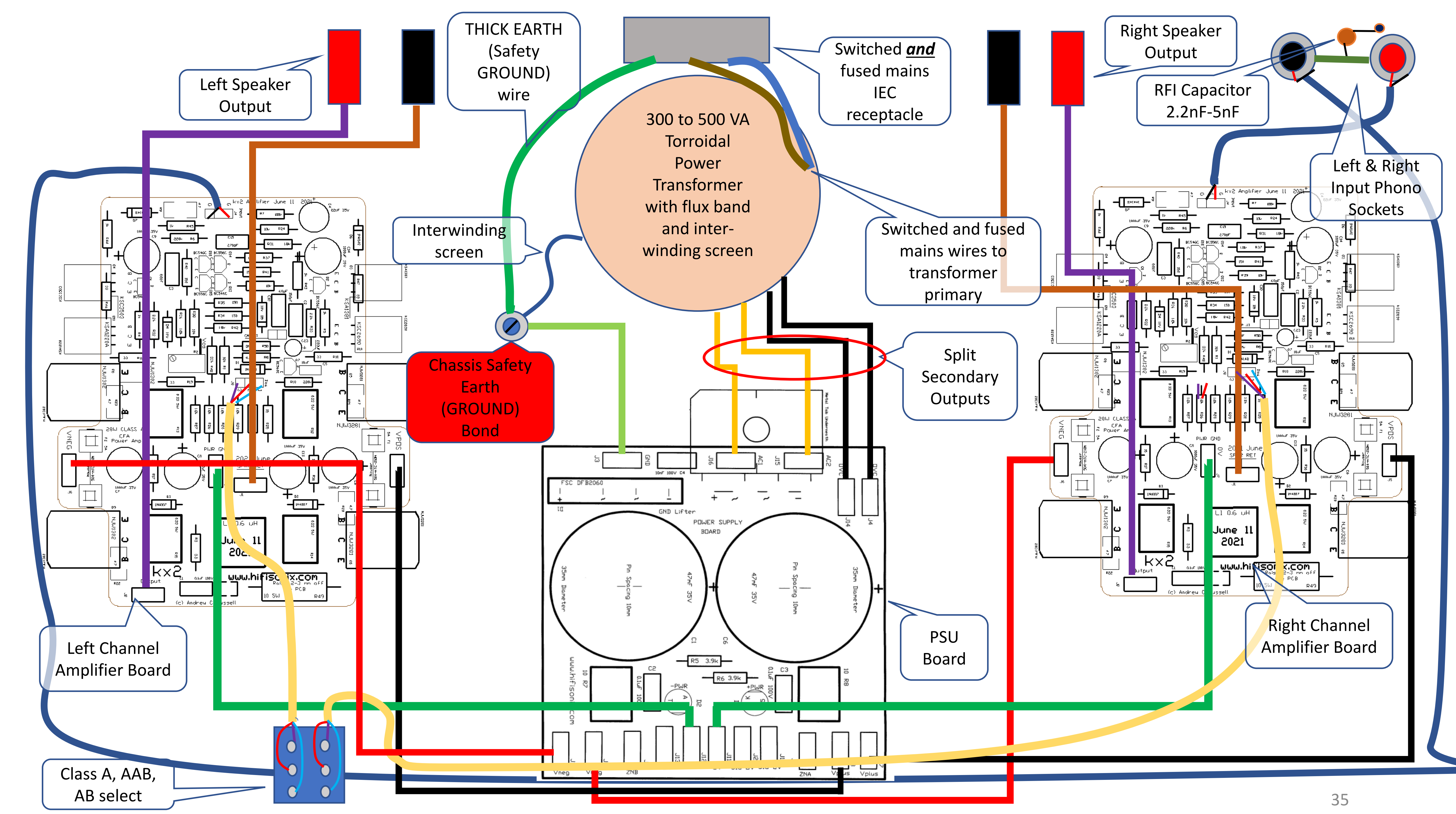
# Construction Details – 1 of 2

1. Stick to the interconnect wiring shown on slide 34.  Do not be tempted to try any other wiring schemes.
2. In the hook-up drawing, I have not shown the cables twisted together in order to make wiring clearer.  However, note carefully the points below:-
    - Keep input wiring well away from the power cables
    - Make sure the power supply cables (-, + and 0V) from the PSU to the amplifier modules are ***tightly coupled (twisted) together***. Cable tie the twisted wires every 3-4 cm (1.5 inches)
    - Make sure the speaker output cable and the return to and from the amplifier module to the speaker connectors ***are tightly twisted together.*** Cable tie the wires every  3-4 cm (1.5 inches). Alternatively, use thick bonded speaker cable.
    - Make sure the secondary wires from the transformer to the PSU PCB are tightly twisted together.
3. When operated in class A mode, the kx2-Amplifier requires a heatsink of 0.3 deg C/watt per amplifier module.  This is a LARGE heatsink and will weigh ***at least*** 1.5 kg per channel.  Do not skimp on the heatsink – if you do it will lead to reliability issues, overheating and the early demise of your amplifier.
4. A 300 to 500 VA transformer is recommended for this project.  For class A operation, the AC *loaded voltage* should be 19 to 23 volts.  After rectification and wiring voltage drops, this should provide 25 - 30 VDC max under load.
    - It is highly recommended that you specify a transformer with a flux band. This will help trap any radiated leakage flux from the transformer, and therefore reduce hum and noise from the speaker output. ***Remember, the load current on a class A amplifier is high (~2.5A for 2 channels on this design) so the radiated magnetic fields are large.***
    - If you are having your transformer custom would, get an inter-winding screen included as well.  This will help reduce mains borne noise coupling through into the secondary circuit. Connect the interwinding screen to the common ground bond point on the chassis.

- You can buy the same very high quality 400 VA transformer I used from 'Tiger Toroids'. The contact is Stephen Foster.  The part number is TT2276  ***You must specify your mains supply voltage***.  The transformer has an interwinding screen and a GOSS band and is acoustically very quiet. It is cloth wrapped, double vacuum impregnated and the centre is potted.

# Construction Details – 2 of 2

5. The input phono sockets must be insulated from the metal chassis and located next to each other and the signal grounds bonded together. Wire a 2.2nF – 5nF 100V or higher voltage ceramic capacitor from the common bond directly to the chassis. Keep the capacitor leads SHORT ie 2-3 cm maximum. This will help prevent common mode RFI ingress via the input cable screens.
6. DO NOT omit to earth (in USA called 'SAFETY GROUND') the amplifier chassis. Use a good quality 3 pin IEC mains receptacle and run a thick wire from the receptacle earth pin to the amplifier metal chassis. Run a thick wire from J3 GND on the PSU board to the chassis bonding point. Screw both wires to the chassis using closed lugs and a serrated washer and associated screw and nut. Use an Ωmeter and check that every part of the metal chassis is connected to the IEC earth pin.
7. Always have only *one earth bonding point* to the chassis.

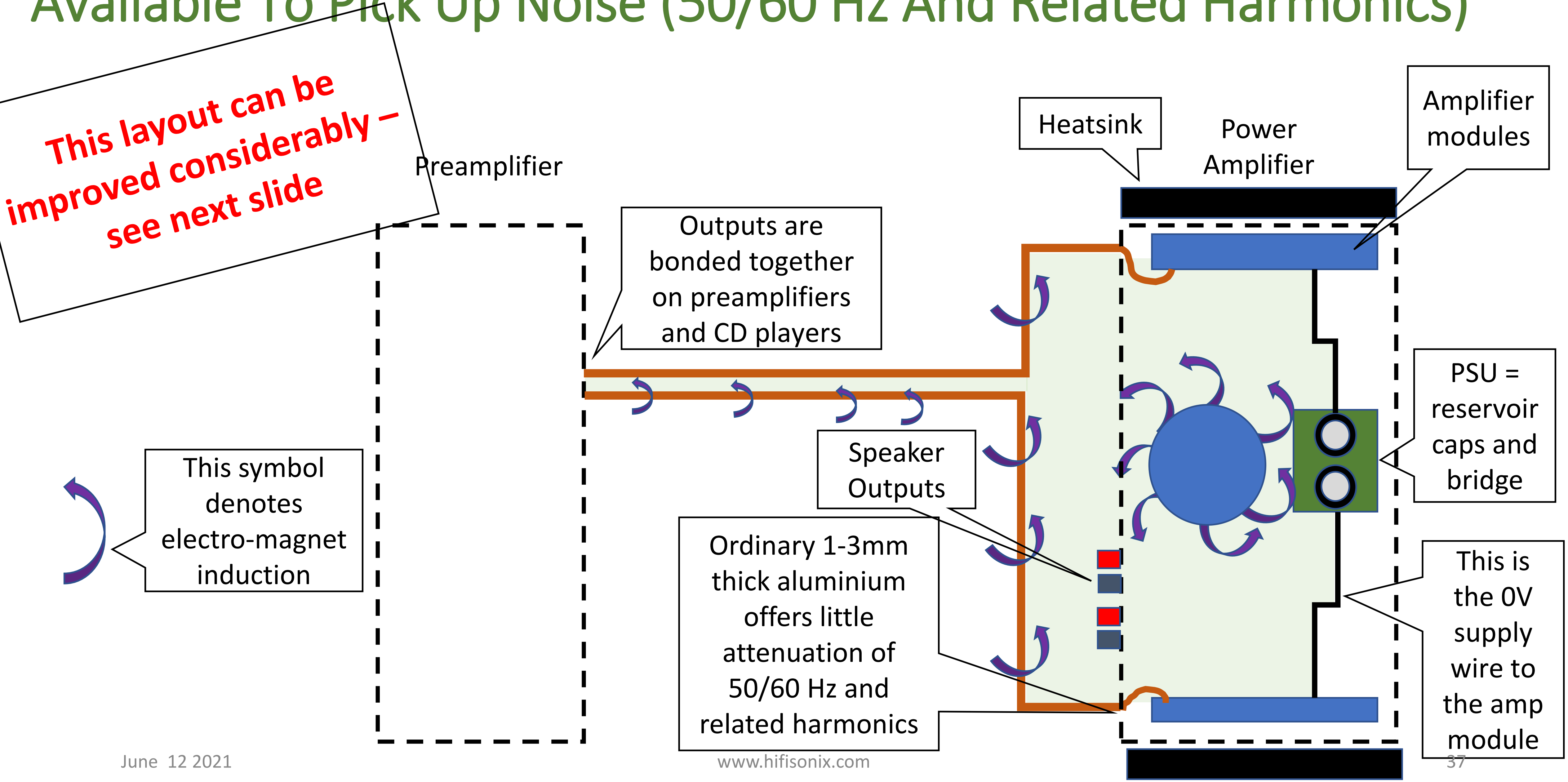

Left Speaker Output
THICK EARTH (Safety GROUND) wire
Switched and fused mains IEC receptacle
Right Speaker Output
RFI Capacitor 2.2nF-5nF
Left & Right Input Phono Sockets
300 to 500 VA Torroidal Power Transformer with flux band and inter-winding screen
Interwinding screen
Switched and fused mains wires to transformer primary
Chassis Safety Earth (GROUND) Bond
Split Secondary Outputs
PSU Board
Left Channel Amplifier Board
Right Channel Amplifier Board
Class A, AAB, AB select

# The Next Two Slides Show How To Route The Input Wiring

- Do not place the input connectors on opposite sides of the rear panel. Place them right next to each other in order to minimize the cross channel loop area. Make sure the signal grounds are insulated from the chassis – check with a meter
- Bond the signal grounds together at the input sockets. This traps internally generated cross channel ground loops inside the amplifier and prevents them from flowing in the interconnect shield where they generate additional noise voltages in series with the signal source, degrading signal to noise ratio.
- Connect a 2.2 to 5nF NPO/COG ceramic capacitor from the bonded grounds to the rear panel – keep the leads very short – not more than 2-3cm.
- Note carefully how the left hand screened input cable is routed in order to minimize cross channel ground loops – *around the top edge of the amplifier the long way around*
- Use the 'headphone scope' trick to optimize the wiring positioning for lowest noise.
- Do not forget to rotate your transformer approx. +-60 degrees to find the null noise point!

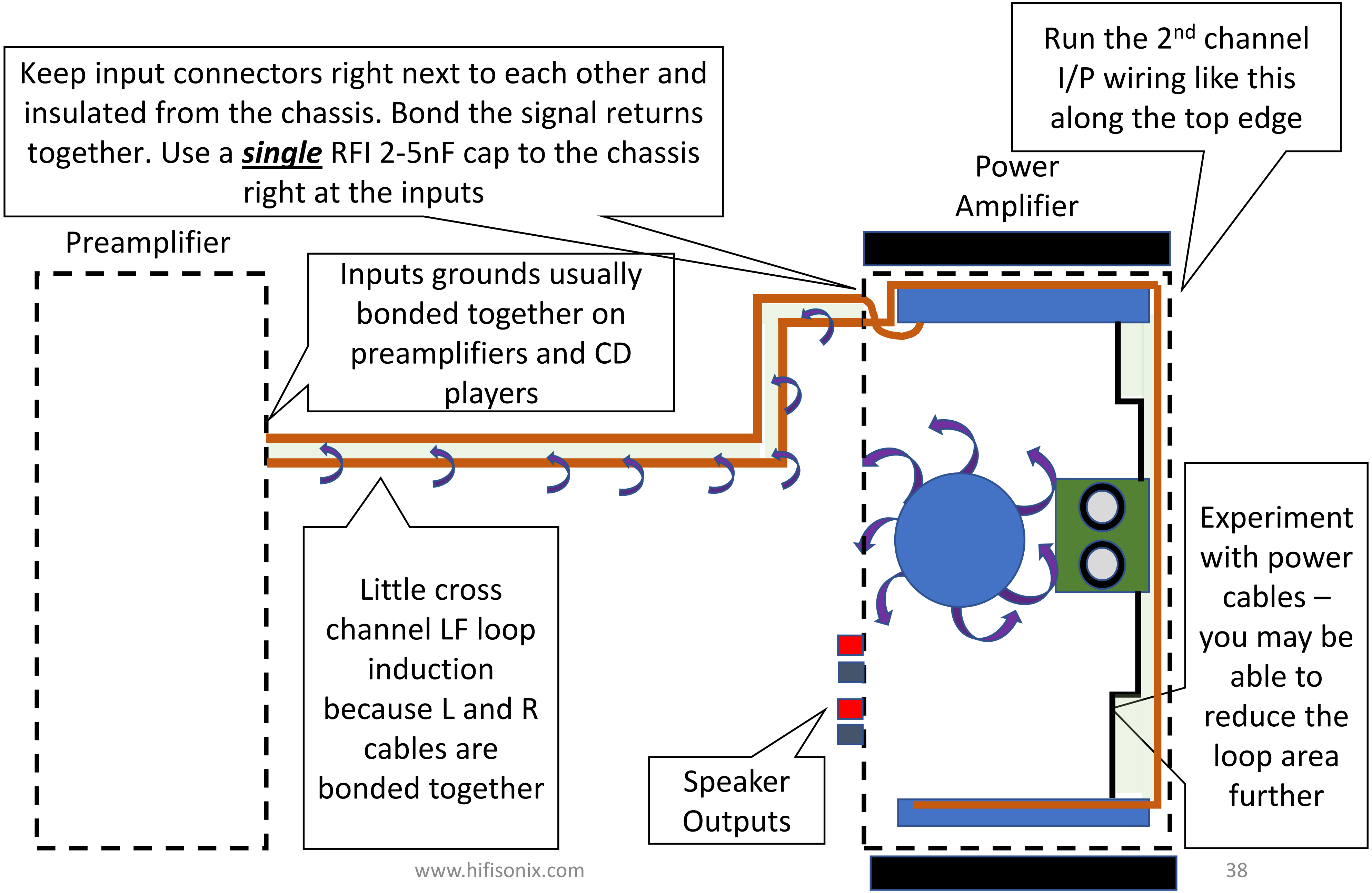
- See 'Ground Loops' for more detailed information and a general guide to minimizing noise in electronic systems.

# The Green Shaded Area Shows The Very Large Loop Area Available To Pick Up Noise (50/60 Hz And Related Harmonics)



# This Layout Is Much Quieter Than The One On The Previous Slide

**Do not forget to rotate the transformer through +-60 degrees to find the noise null point. Once done, secure the transformer in place**



# ‘Headphone Scope’ Trick – Quick and Easy Hum/Noise Debugging (1)

A pair of 90 dB at 1mW headphones is about 1000 times more sensitive than a loudspeaker – a typical speaker spec being 1 Watt for 90 dB SPL at 1 meter. Relatively speaking, that’s of the same order as a good high gain, low noise measurement preamplifier.

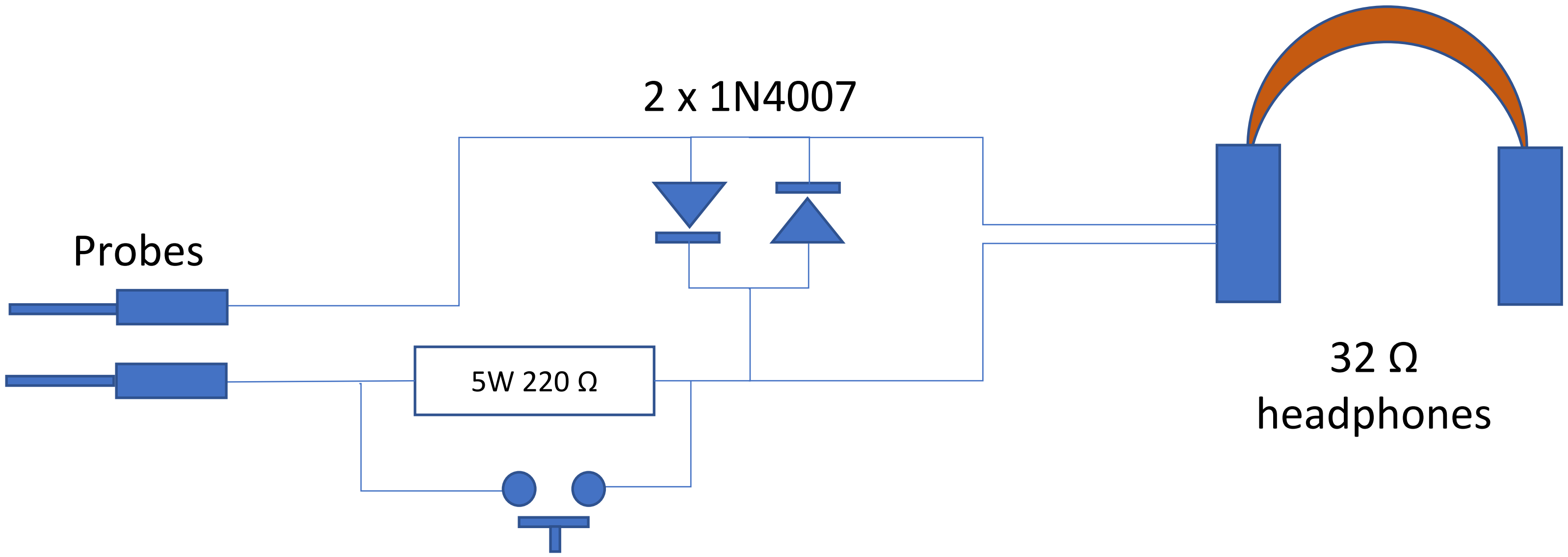
Connect a pair of headphones directly to the output of your amplifier **(do this AFTER it has been switched on and the outputs have settled)** and without any input source connected.  Make sure your amp does not have any DC offsets.

You can then experiment with cable dressing, transformer orientation etc to get the lowest noise on the ‘phones.

On a *really good* layout and execution, you should struggle to hear any hum/buzz on the headphones. **Disconnect the headphones before powering down your amp.**

Once you are at this level, you can then use a sound card to do further debugging.  A good, practical result will be -90 to -100 dBV as measured on a sound card. On a really excellent built, better than -110 dBV is achievable

# Headphone Trick – Protecting your headphone from overload (2)




Connect the headphone probe across the amplifier output terminals.

Here is a simple way to protect your headphones when using the headphone to probe cable dressing and layout in your amplifier and it will also protect your ears of you happen to probe in the wrong place. You can fit a pushbutton switch across the 220 Ω resistor – if you hear nothing or little noise, depress the switch to momentarily improve the sensitivity.

**Do not connect the headphone probe across DC!**

# kx2-Amplifier Listening Evaluation

A subjective View on the kx2-Amplifier sonic performance carried out in May and June 2021

Equipment: Ovation High Fidelity Model 1501 Preamplifier, OPPO BD103 CD player, Michel Gyrodec + Dennon DL103 cart using the X-Altra MC/MM Phono Amp. You can read about the speakers used for the evaluation here

Music

Vinyl: Firebird Suite (Stravinsky) – Claudio Abbado with the LSO, Sibelius Symphony 5 and 7 - Von Karajan and the Berlin Philharmonic, Ella Fitzgerald Sings the 'Irving Berlin Songbook'

CD: Leonard Bernstein and George Gershwin conducted by Leonard Bernstein - New York Philharmonic, Diana Krall 'Live in Paris', Silk Road Journeys – When Strangers Meet' Yo-Yo Ma and the Silk Road Ensemble, Itzhak Perlman 'Greatest Hits', Lua Amarela - Rita Payes and Joan Chamorro

The original hifisonix sx-Amplifier (2012) came about because I offered to repair an ancient Musical Fidelity A1 class A amplifier for a friend while I was resident in Taiwan. The repair job was simple, and afterwards I decided to give the A1 a spin on my B&W 703's, not expecting much.  Despite the low output power, I was struck by the smoothness and sheer 'musicality' of the A1 and decided to investigate further. None of the designs  on the internet featured ultra low distortion, but everyone raved about the sound (Hiraga, JLH, Pass et al). Some months later in 2012, the sx-Amplifier emerged and I was not disappointed with the result. I was struck by the sound and the imaging and ended up using it for close on 6 years, finally retiring it to use part of the housing and power supply for the kx –Amplifier (I replaced the top plate and had a 'kx-Amplifier' badge machined at Front Panel Express), and now kx2-Amplifier. So, indeed, I discovered that there was something in the 'class A magic' claim.

The kx2-Amplifier retains the warmth and 'liquidity' of the kx-Amplifier and the sx-Amplifier.  The top end is very clean (cymbals, strings) and the bass performance is excellent – its almost as if it was slightly more boosted than the sx-Amp and the notes better articulated.  The mid range remains clean – and I think this has to do with the dramatically lower (measured) distortion.

I use a B&W sub-bass (ASW610) to augment the LS50's low end (down by 3 dB at 79 Hz), which in a small listening environment, makes for a wonderfully immersive experience. The kx2-Amplifier, like the kx and sx amplifiers  is very smooth and euphonic, but above all, its also accurate. On B&W 703's (nice easy load to drive), it has a wonderfully relaxed sound with plenty of beautifully articulated bass.

Imaging remains outstanding, and particularly enjoyable on the KEF's which really excel in this department. The left to right and sound stage depth are the best out of all the amplifiers I use.  This characteristic seems to be a particular feature of class A amps – I have no explanation as to why – it's a matter that needs some investigation in my view, although Nelson Pass believes it is to do with the phase of the distortion harmonics (inverted wrt the fundamental gives better imaging IIRC). On the 703's the bass is superb and extends very low with fantastic articulation, and the 3-4 dB higher efficiency than the LS50's mean very realistic sound levels are on tap should that be required.

Used with the appropriate speakers (either 90 dB+ efficiency, or if lower, in a small listening space, the kx2-Amplifier delivers an outstanding listening experience.  It retains the classic class A smoothness that I wrote about in the sx and kx-amplifiers, lack of any glare and the effortless mid-range are available in bucketloads. The bass performance, like that of the kx-Amplifier, is a significant improvement as well and I put that down to the more capable EF2 output stage.


kx-Amplifier
hifisonix

# ADDENDUMS

# kx2-Amplifier Measurements

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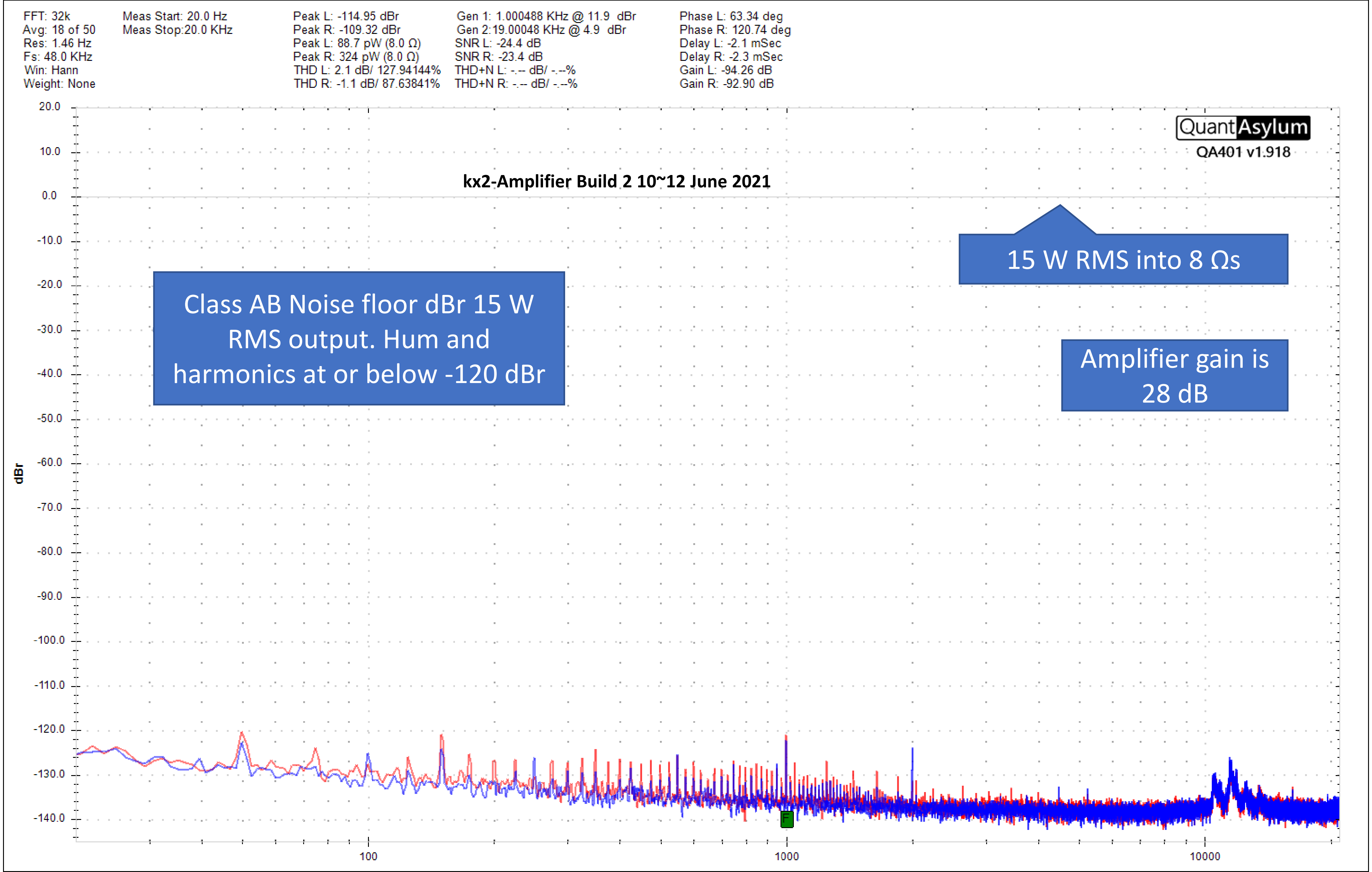
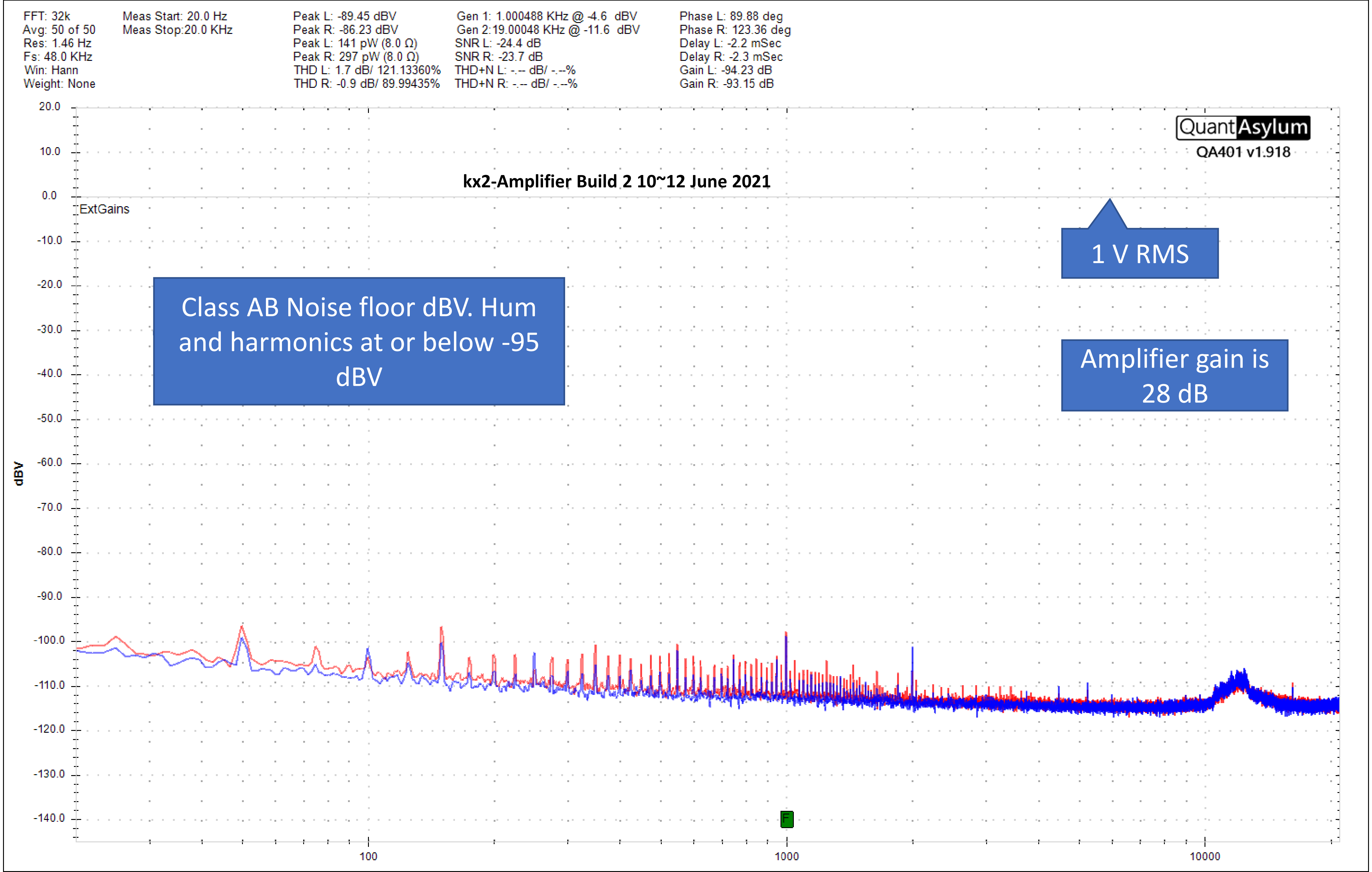
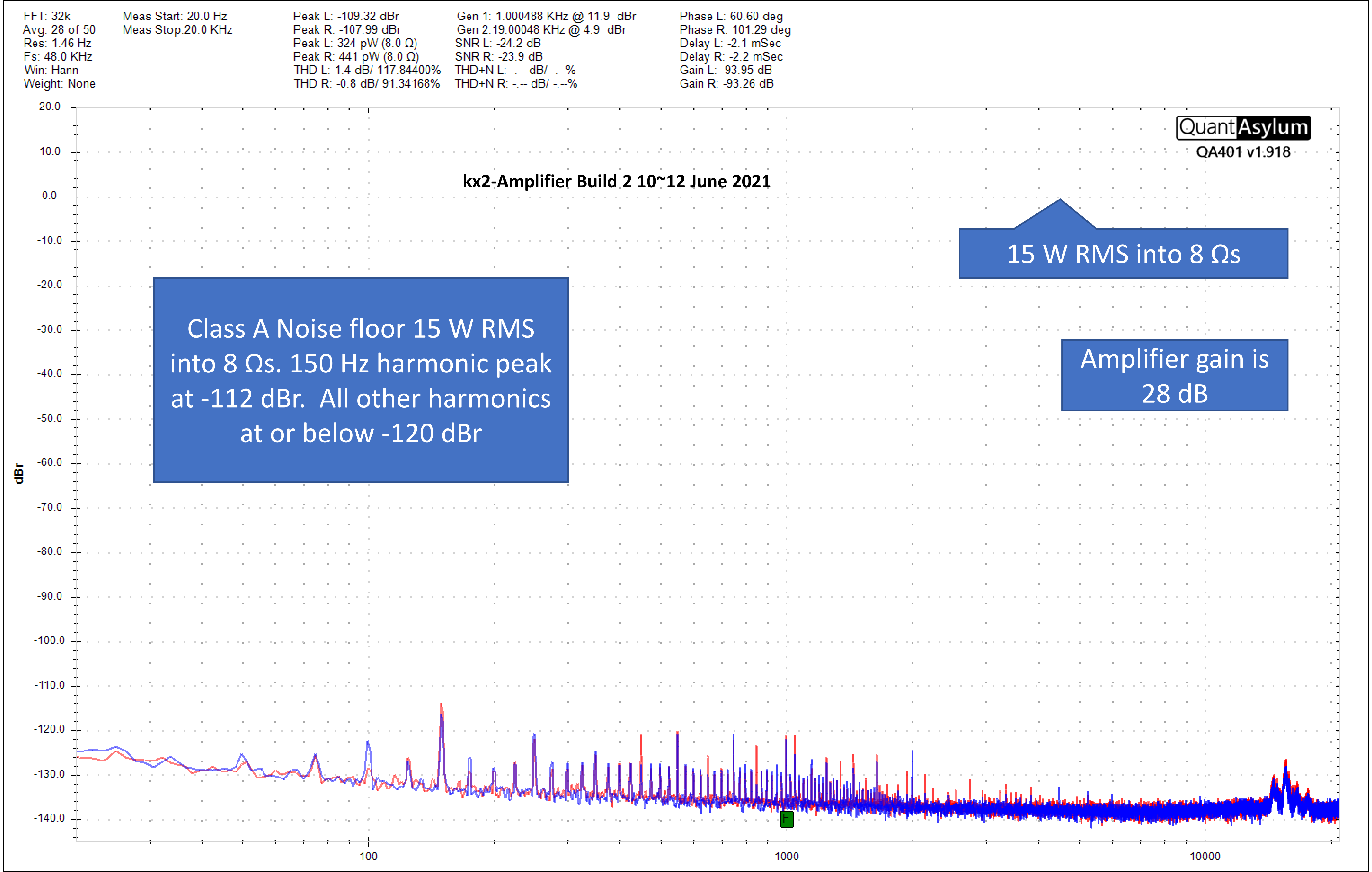
# kx2-Amplifier Measurement - Notes

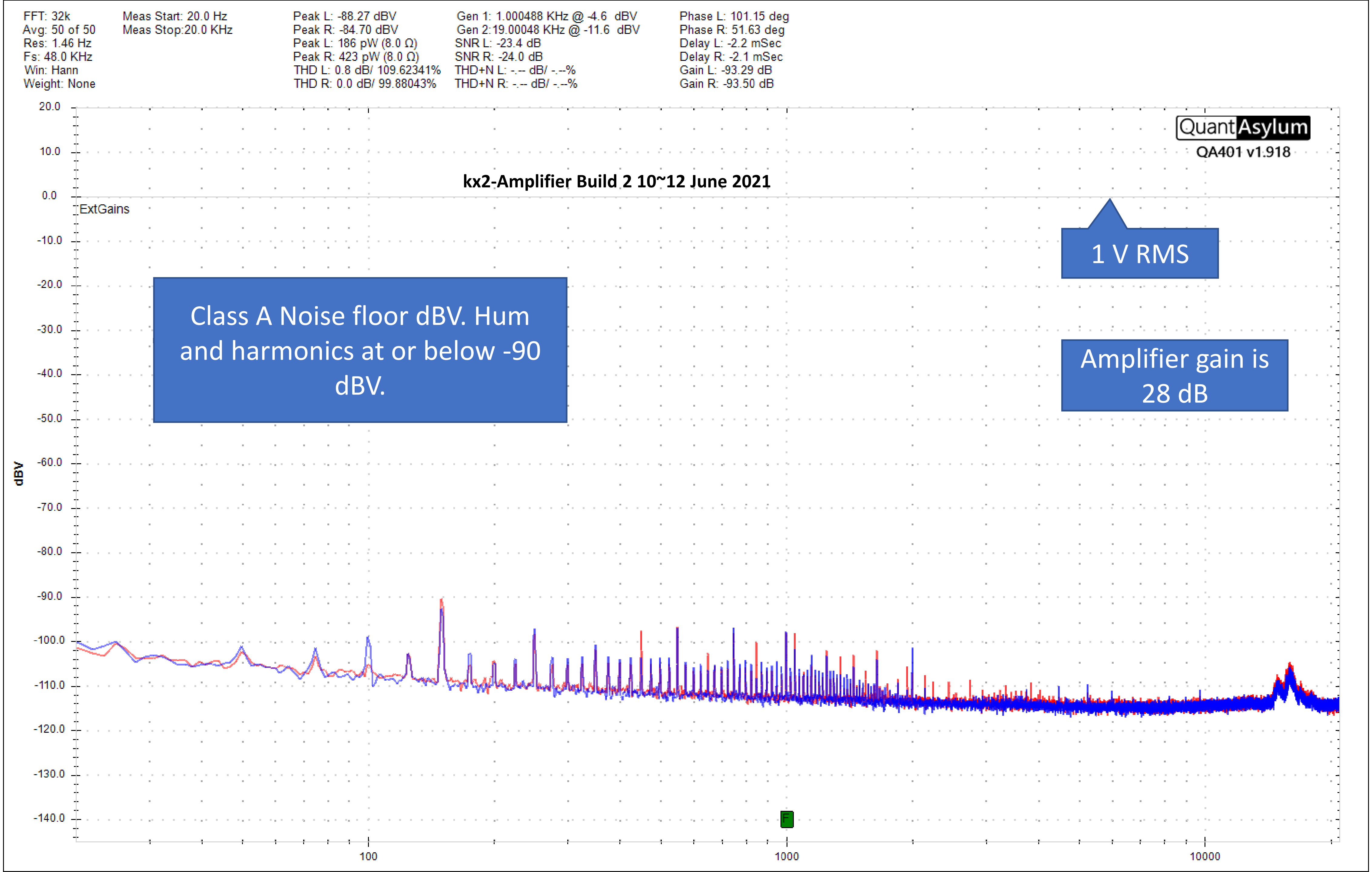
- A 40 dB attenuator was used between the load and the QA401 for all of the measurements that follow (the attenuator is incorporated in my load)
- Two development builds of the kx2-Amplifier were undertaken. Build 1 was with the first PCB iteration and build 2 was with the 2nd and final production version
- The first four slides show the kx2-Amplifier noise floor (build 2) with the inputs shorted. Some of this noise is attributable to the measurement set-up, but in general, the new amplifier total mains hum and related harmonic peaks are very low at < -115 dBr 15W RMS in class A. The amplifier was loaded with 8 Ωs for these measurements
- Distortion measurements for both build 1 and build 2 follow after that.
- Note: A hifisonix Ripple Eater PSU was used in both build 1 and build 2. All measurements in this document are with the ripple eater PSU fitted. The MJE15032/15033 pass transistors were replaced with NJW1302 and NJW3281 15A 200 W transistors to allow full power testing into 2 Ohms.


FFT: 32k
Avg: 18 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -114.95 dBr
Peak R: -109.32 dBr
Peak L: 88.7 pW (8.0 Ω)
Peak R: 324 pW (8.0 Ω)
THD L: 2.1 dB/ 127.94144%
THD R: -1.1 dB/ 87.63841%
Gen 1: 1.000488 KHz @ 11.9 dBr
Gen 2:19.00048 KHz @ 4.9 dBr
SNR L: -24.4 dB
SNR R: -23.4 dB
THD+N L: -.-- dB/ -.--%
THD+N R: -.-- dB/ -.--%
Phase L: 63.34 deg
Phase R: 120.74 deg
Delay L: -2.1 mSec
Delay R: -2.3 mSec
Gain L: -94.26 dB
Gain R: -92.90 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
15 W RMS into 8 Ωs
Class AB Noise floor dBr 15 W RMS output. Hum and harmonics at or below -120 dBr
Amplifier gain is 28 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

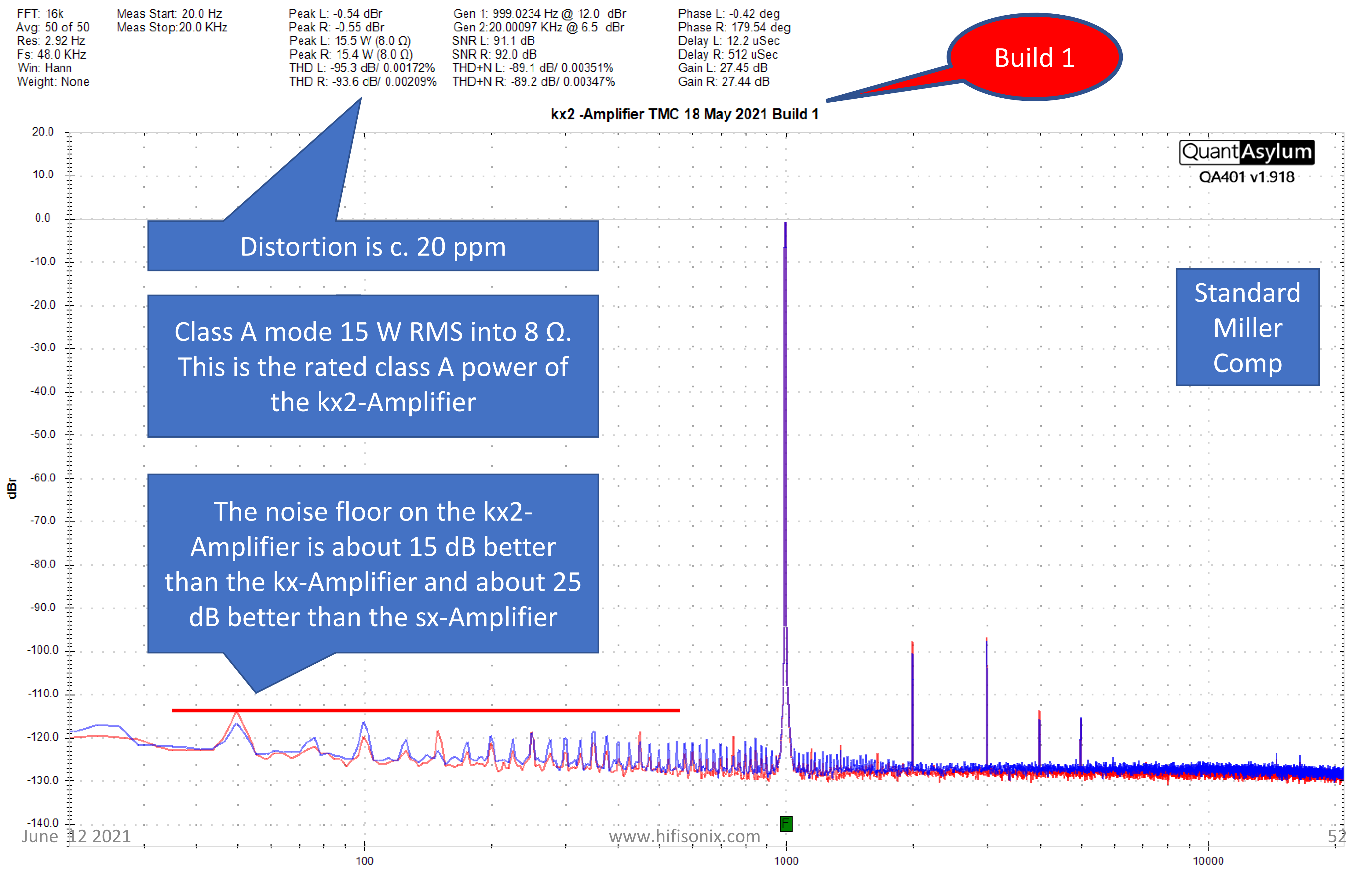


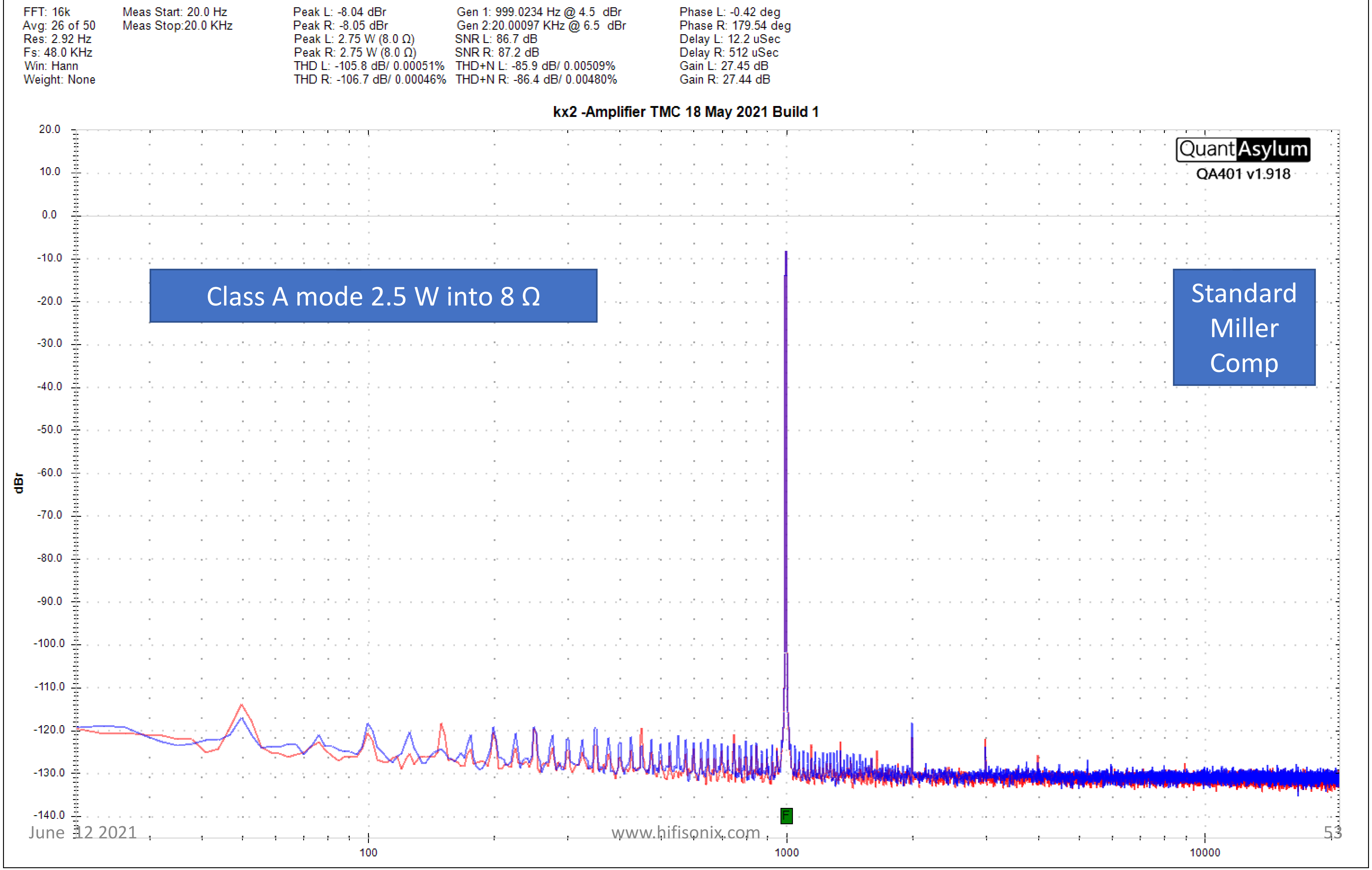
FFT: 32k
Avg: 50 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -89.45 dBV
Peak R: -86.23 dBV
Peak L: 141 pW (8.0 Ω)
Peak R: 297 pW (8.0 Ω)
THD L: 1.7 dB/ 121.13360%
THD R: -0.9 dB/ 89.99435%
Gen 1: 1.000488 KHz @ -4.6 dBV
Gen 2:19.00048 KHz @ -11.6 dBV
SNR L: -24.4 dB
SNR R: -23.7 dB
THD+N L: -.-- dB/ -.--%
THD+N R: -.-- dB/ -.--%
Phase L: 89.88 deg
Phase R: 123.36 deg
Delay L: -2.2 mSec
Delay R: -2.3 mSec
Gain L: -94.23 dB
Gain R: -93.15 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
ExtGains
1 V RMS
Class AB Noise floor dBV. Hum and harmonics at or below -95 dBV
Amplifier gain is 28 dB
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

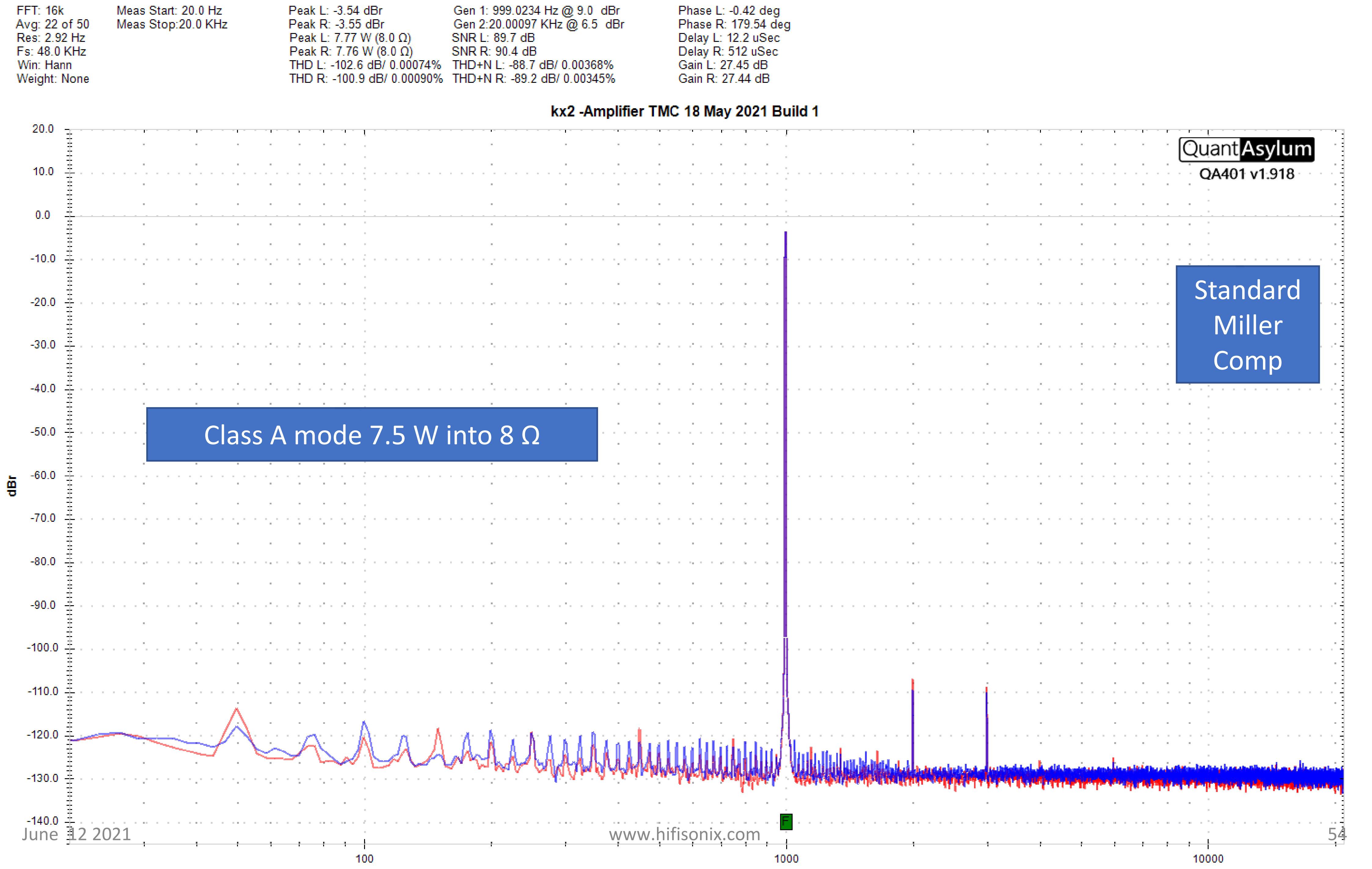

FFT: 32k
Avg: 28 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -109.32 dBr
Peak R: -107.99 dBr
Peak L: 324 pW (8.0 Ω)
Peak R: 441 pW (8.0 Ω)
THD L: 1.4 dB/ 117.84400%
THD R: -0.8 dB/ 91.34168%
Gen 1: 1.000488 KHz @ 11.9 dBr
Gen 2:19.00048 KHz @ 4.9 dBr
SNR L: -24.2 dB
SNR R: -23.9 dB
THD+N L: -.-- dB/ -.--%
THD+N R: -.-- dB/ -.--%
Phase L: 60.60 deg
Phase R: 101.29 deg
Delay L: -2.1 mSec
Delay R: -2.2 mSec
Gain L: -93.95 dB
Gain R: -93.26 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
15 W RMS into 8 Ωs
Class A Noise floor 15 W RMS into 8 Ωs. 150 Hz harmonic peak at -112 dBr. All other harmonics at or below -120 dBr
Amplifier gain is 28 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


FFT: 32k
Avg: 50 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz
Peak L: -88.27 dBV
Peak R: -84.70 dBV
Peak L: 186 pW (8.0 Ω)
Peak R: 423 pW (8.0 Ω)
THD L: 0.8 dB/ 109.62341%
THD R: 0.0 dB/ 99.88043%
Gen 1: 1.000488 KHz @ -4.6 dBV
Gen 2: 19.00048 KHz @ -11.6 dBV
SNR L: -23.4 dB
SNR R: -24.0 dB
THD+N L: -.-- dB/ -.--%
THD+N R: -.-- dB/ -.--%
Phase L: 101.15 deg
Phase R: 51.63 deg
Delay L: -2.2 mSec
Delay R: -2.1 mSec
Gain L: -93.29 dB
Gain R: -93.50 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
ExtGains
Class A Noise floor dBV. Hum and harmonics at or below -90 dBV.
1 V RMS
Amplifier gain is 28 dB
dBV
F
100
1000
10000

# kx2-Amplifier Distortion Measurements
# for
# Build 1 and Build 2


FFT: 16k
Avg: 50 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.54 dBr
Peak R: -0.55 dBr
Peak L: 15.5 W (8.0 Ω)
Peak R: 15.4 W (8.0 Ω)
THD L: -95.3 dB/ 0.00172%
THD R: -93.6 dB/ 0.00209%
Gen 1: 999.0234 Hz @ 12.0 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 91.1 dB
SNR R: 92.0 dB
THD+N L: -89.1 dB/ 0.00351%
THD+N R: -89.2 dB/ 0.00347%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.45 dB
Gain R: 27.44 dB
Build 1
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Distortion is c. 20 ppm
Class A mode 15 W RMS into 8 Ω. This is the rated class A power of the kx2-Amplifier
The noise floor on the kx2-Amplifier is about 15 dB better than the kx-Amplifier and about 25 dB better than the sx-Amplifier
Standard Miller Comp
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: 16k
Avg: 26 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -8.04 dBr
Peak R: -8.05 dBr
Peak L: 2.75 W (8.0 Ω)
Peak R: 2.75 W (8.0 Ω)
THD L: -105.8 dB/ 0.00051%
THD R: -106.7 dB/ 0.00046%
Gen 1: 999.0234 Hz @ 4.5 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 86.7 dB
SNR R: 87.2 dB
THD+N L: -85.9 dB/ 0.00509%
THD+N R: -86.4 dB/ 0.00480%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.45 dB
Gain R: 27.44 dB
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Class A mode 2.5 W into 8 Ω
Standard Miller Comp
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

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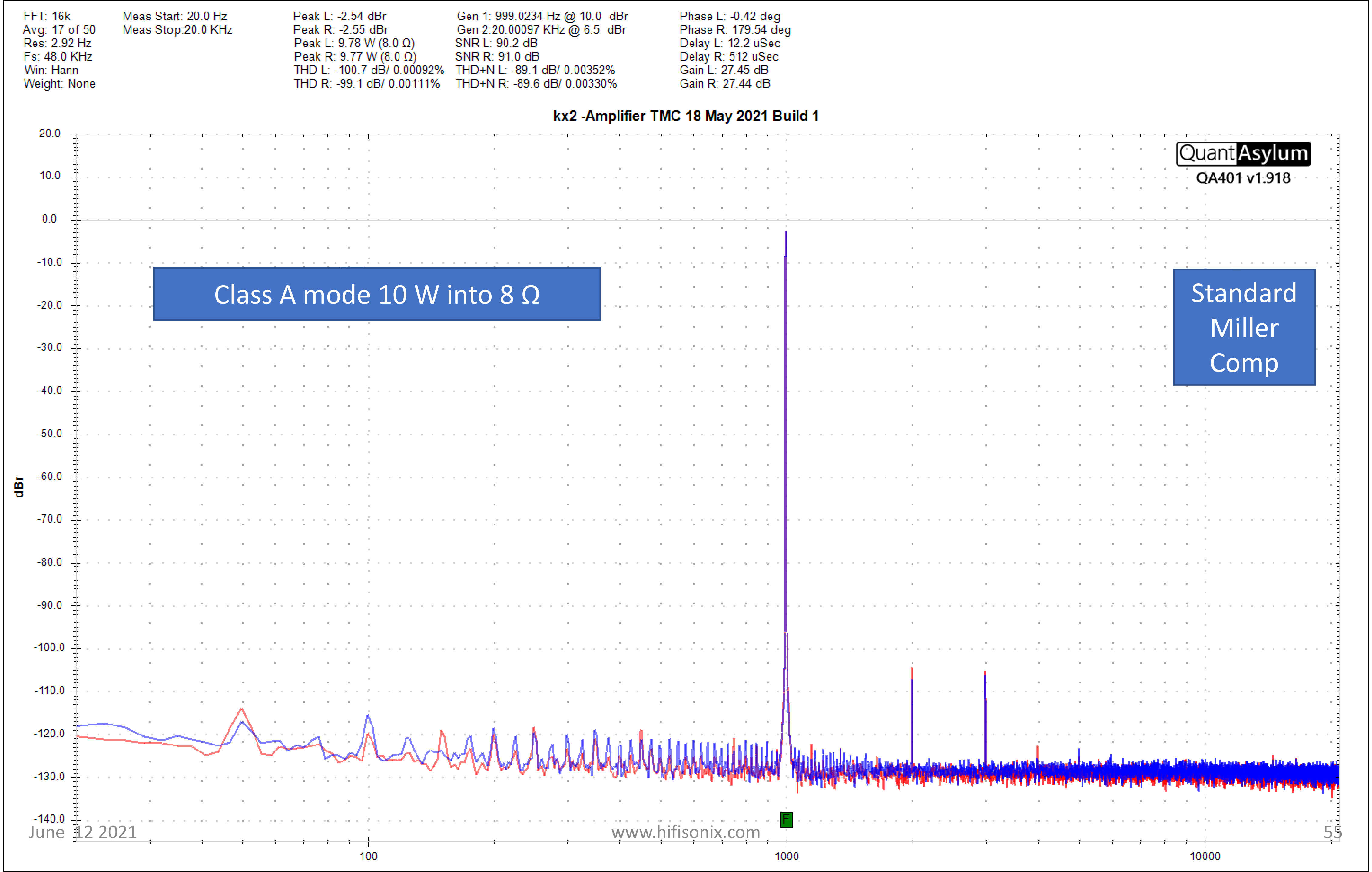
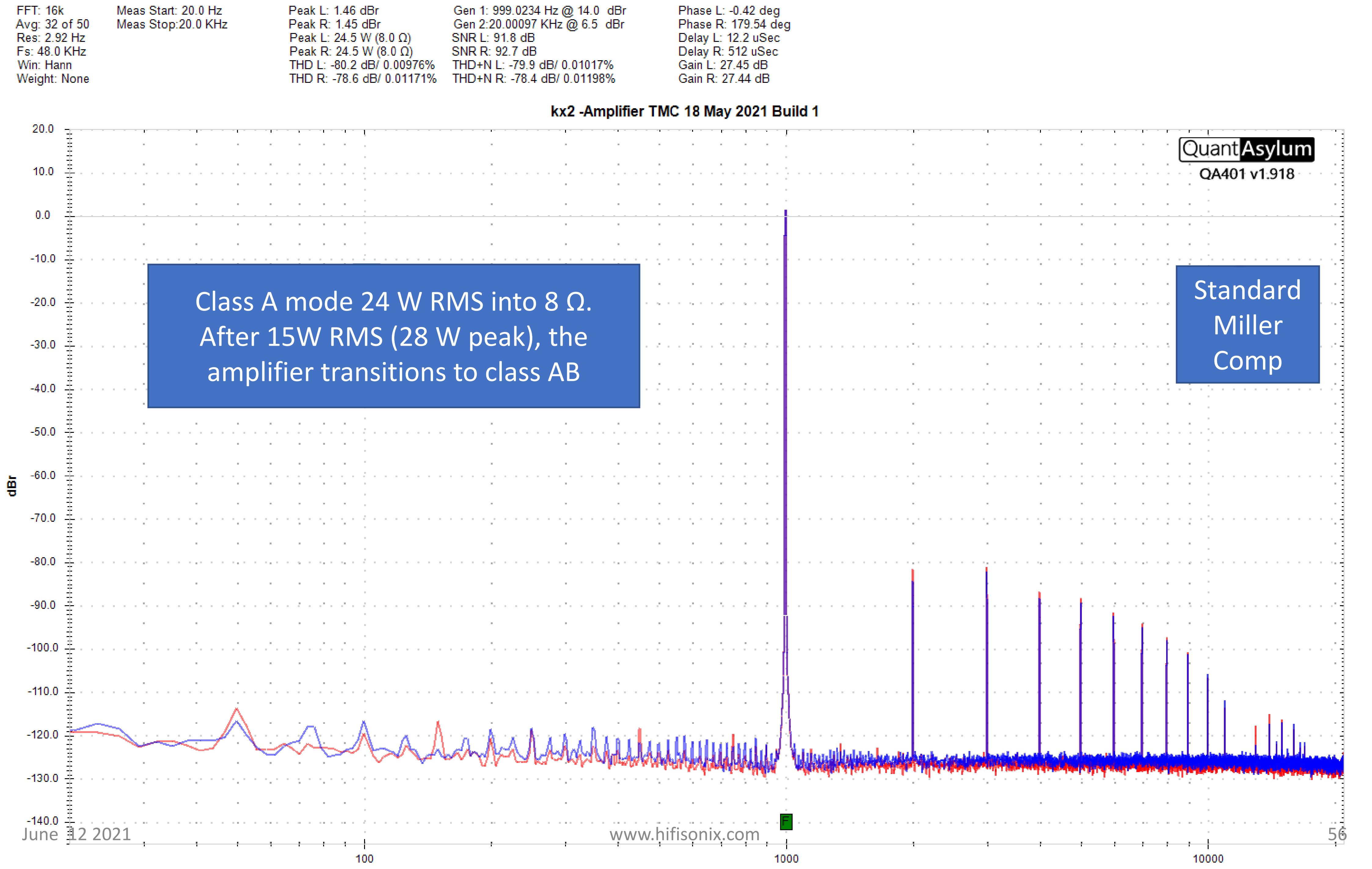
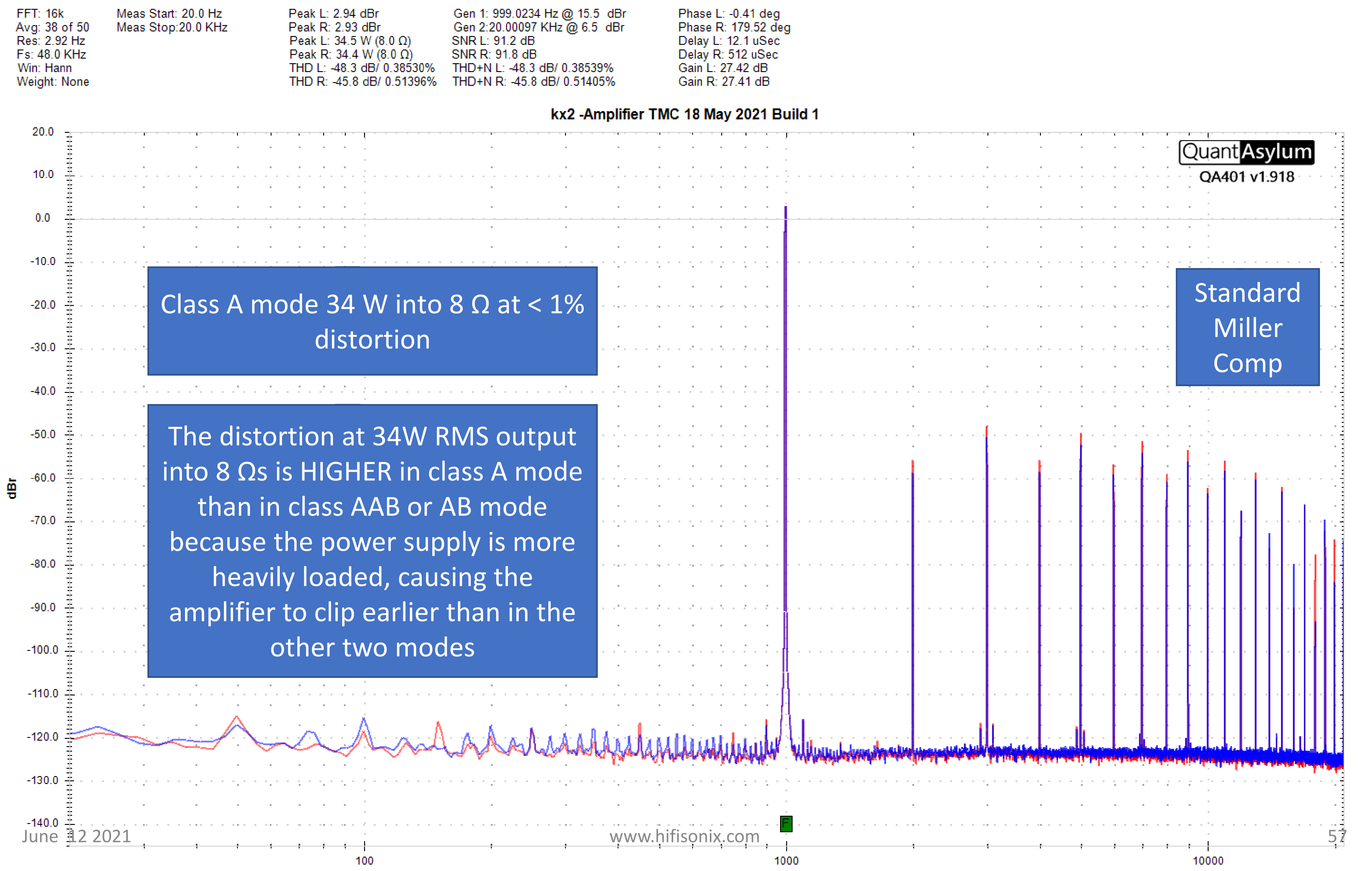

FFT: 16k
Avg: 17 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -2.54 dBr
Peak R: -2.55 dBr
Peak L: 9.78 W (8.0 Ω)
Peak R: 9.77 W (8.0 Ω)
THD L: -100.7 dB/ 0.00092%
THD R: -99.1 dB/ 0.00111%
Gen 1: 999.0234 Hz @ 10.0 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 90.2 dB
SNR R: 91.0 dB
THD+N L: -89.1 dB/ 0.00352%
THD+N R: -89.6 dB/ 0.00330%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.45 dB
Gain R: 27.44 dB
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Class A mode 10 W into 8 Ω
Standard Miller Comp
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

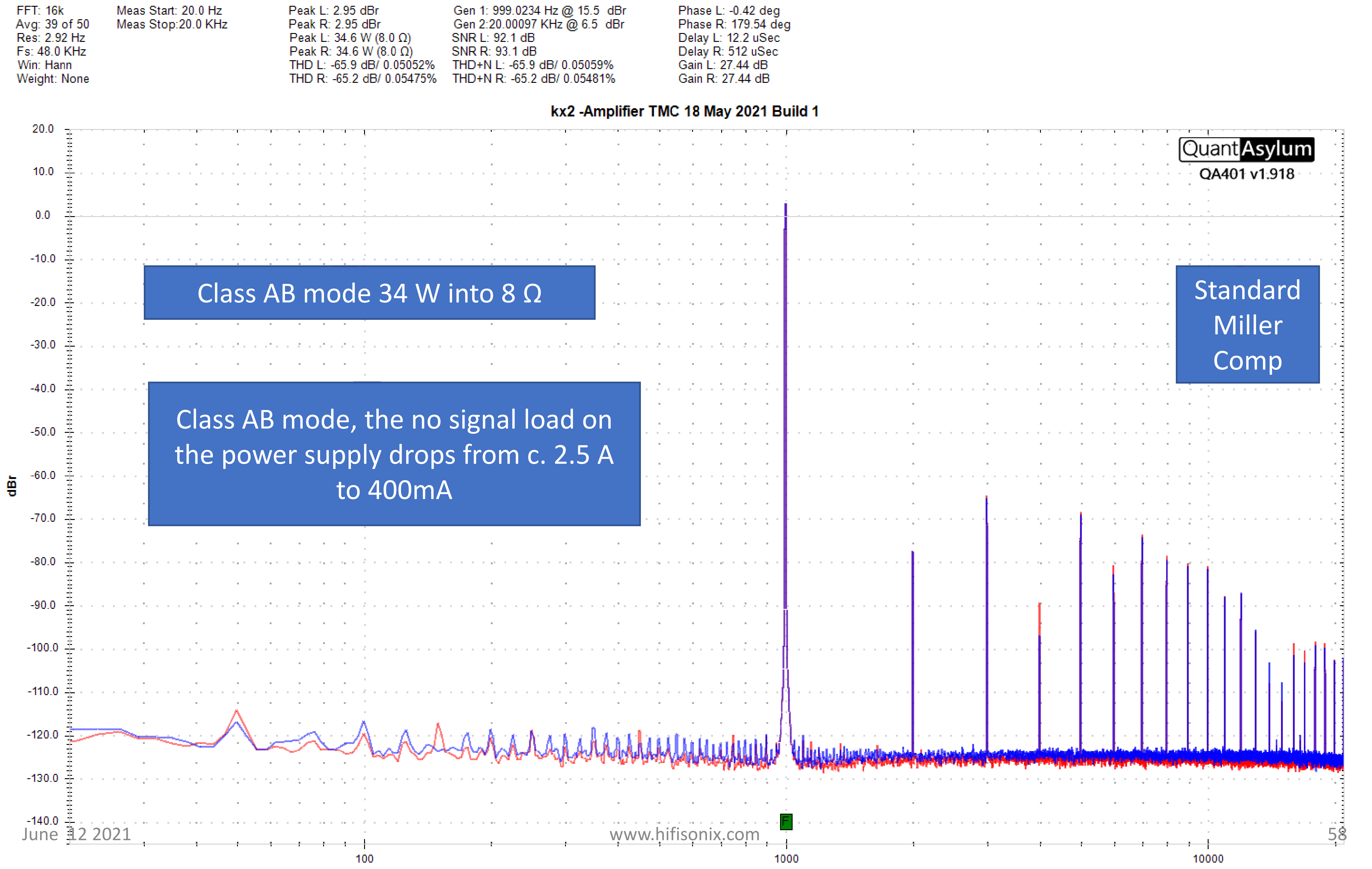

FFT: 16k
Avg: 32 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 1.46 dBr
Peak R: 1.45 dBr
Peak L: 24.5 W (8.0 Ω)
Peak R: 24.5 W (8.0 Ω)
THD L: -80.2 dB/ 0.00976%
THD R: -78.6 dB/ 0.01171%
Gen 1: 999.0234 Hz @ 14.0 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 91.8 dB
SNR R: 92.7 dB
THD+N L: -79.9 dB/ 0.01017%
THD+N R: -78.4 dB/ 0.01198%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.45 dB
Gain R: 27.44 dB
kx2 -Amplifier TMC 18 May 2021 Build 1
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
Class A mode 24 W RMS into 8 Ω. After 15W RMS (28 W peak), the amplifier transitions to class AB
Standard Miller Comp

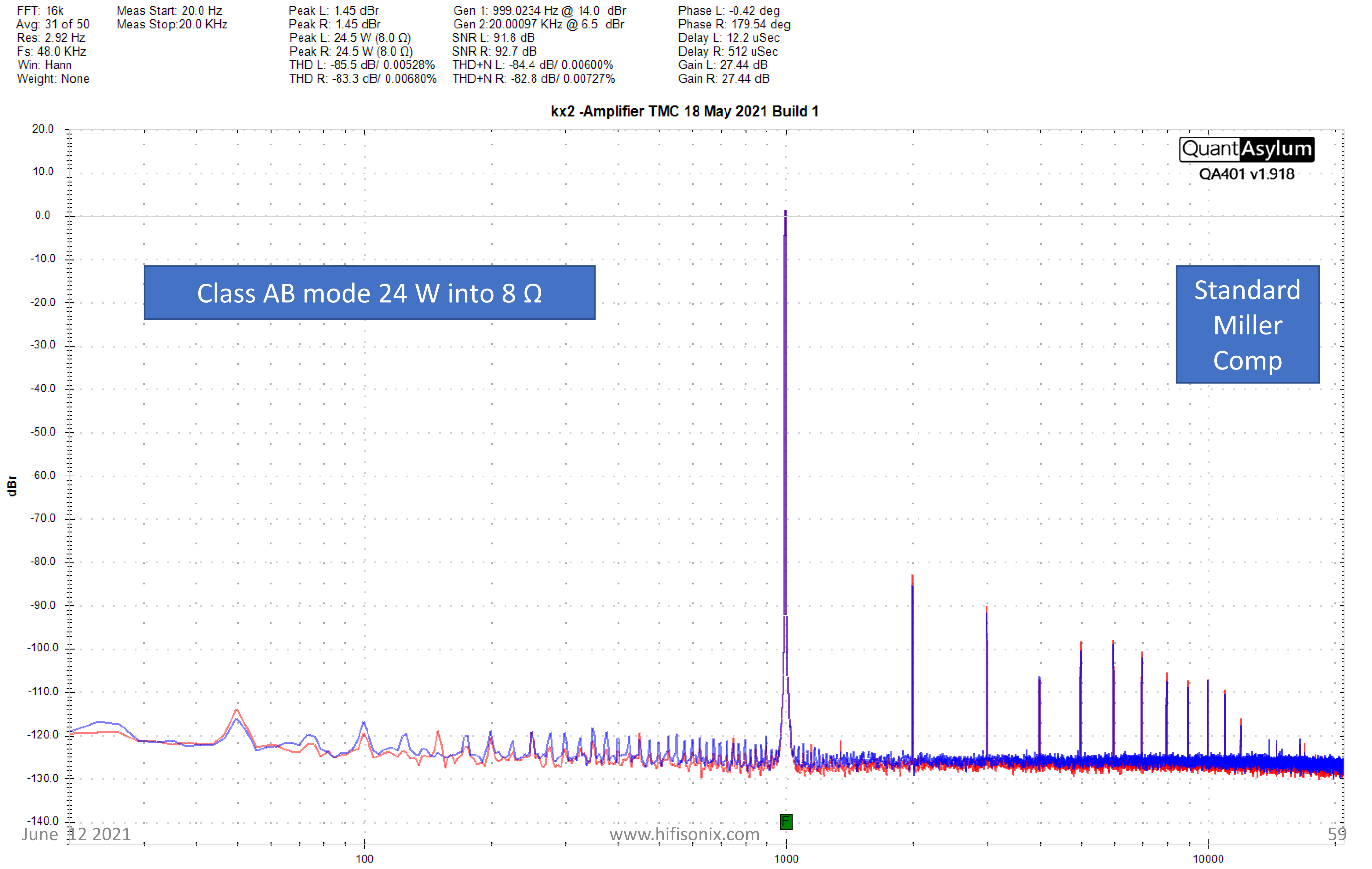



Class A mode 34 W into 8 Ω at < 1% distortion

The distortion at 34W RMS output into 8 Ωs is HIGHER in class A mode than in class AAB or AB mode because the power supply is more heavily loaded, causing the amplifier to clip earlier than in the other two modes

Standard Miller Comp


FFT: 16k
Avg: 39 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 2.95 dBr
Peak R: 2.95 dBr
Peak L: 34.6 W (8.0 Ω)
Peak R: 34.6 W (8.0 Ω)
THD L: -65.9 dB/ 0.05052%
THD R: -65.2 dB/ 0.05475%
Gen 1: 999.0234 Hz @ 15.5 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 92.1 dB
SNR R: 93.1 dB
THD+N L: -65.9 dB/ 0.05059%
THD+N R: -65.2 dB/ 0.05481%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.44 dB
Gain R: 27.44 dB
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Class AB mode 34 W into 8 Ω
Class AB mode, the no signal load on the power supply drops from c. 2.5 A to 400mA
Standard Miller Comp
dBr
100
1000
10000

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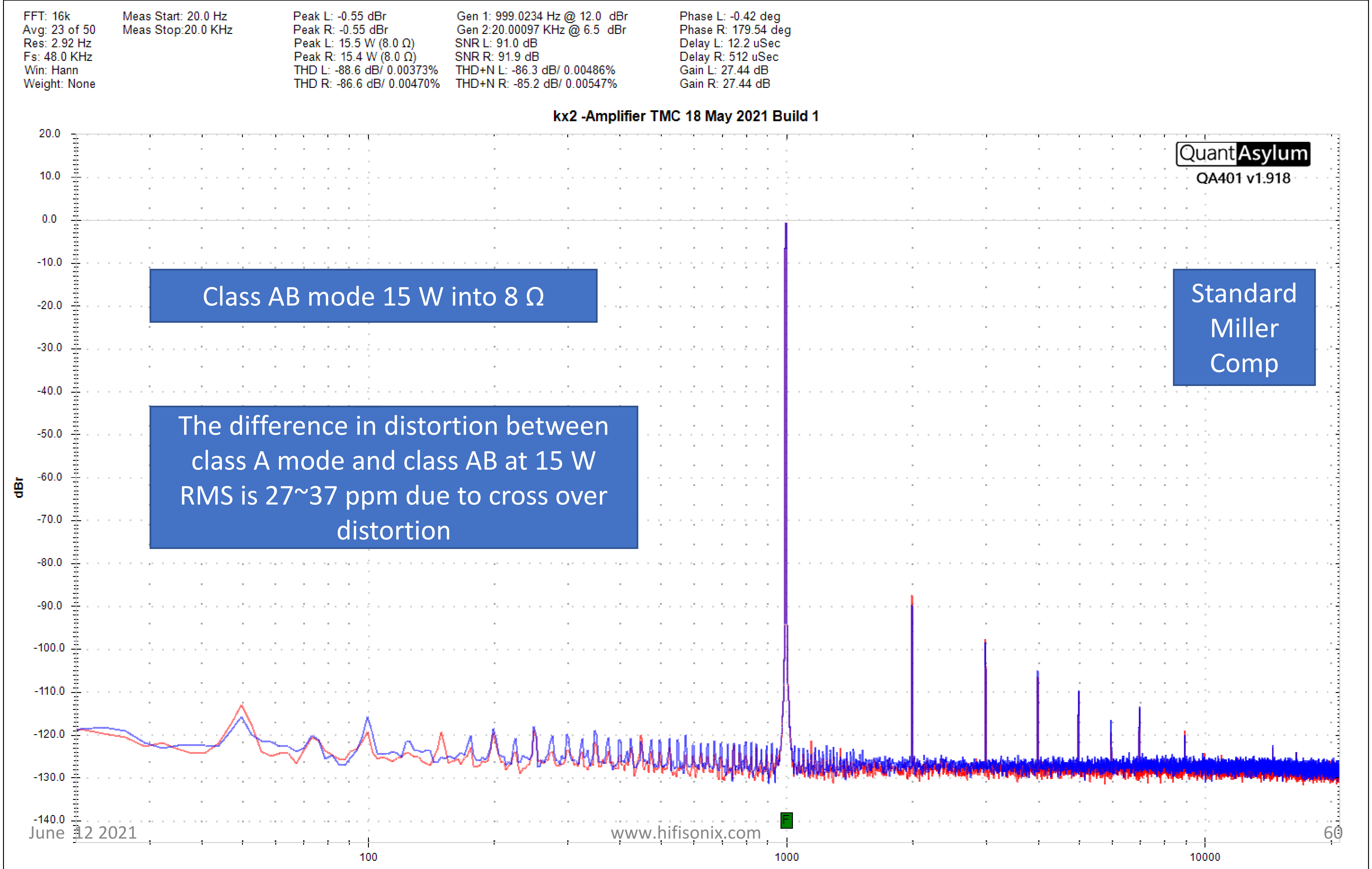
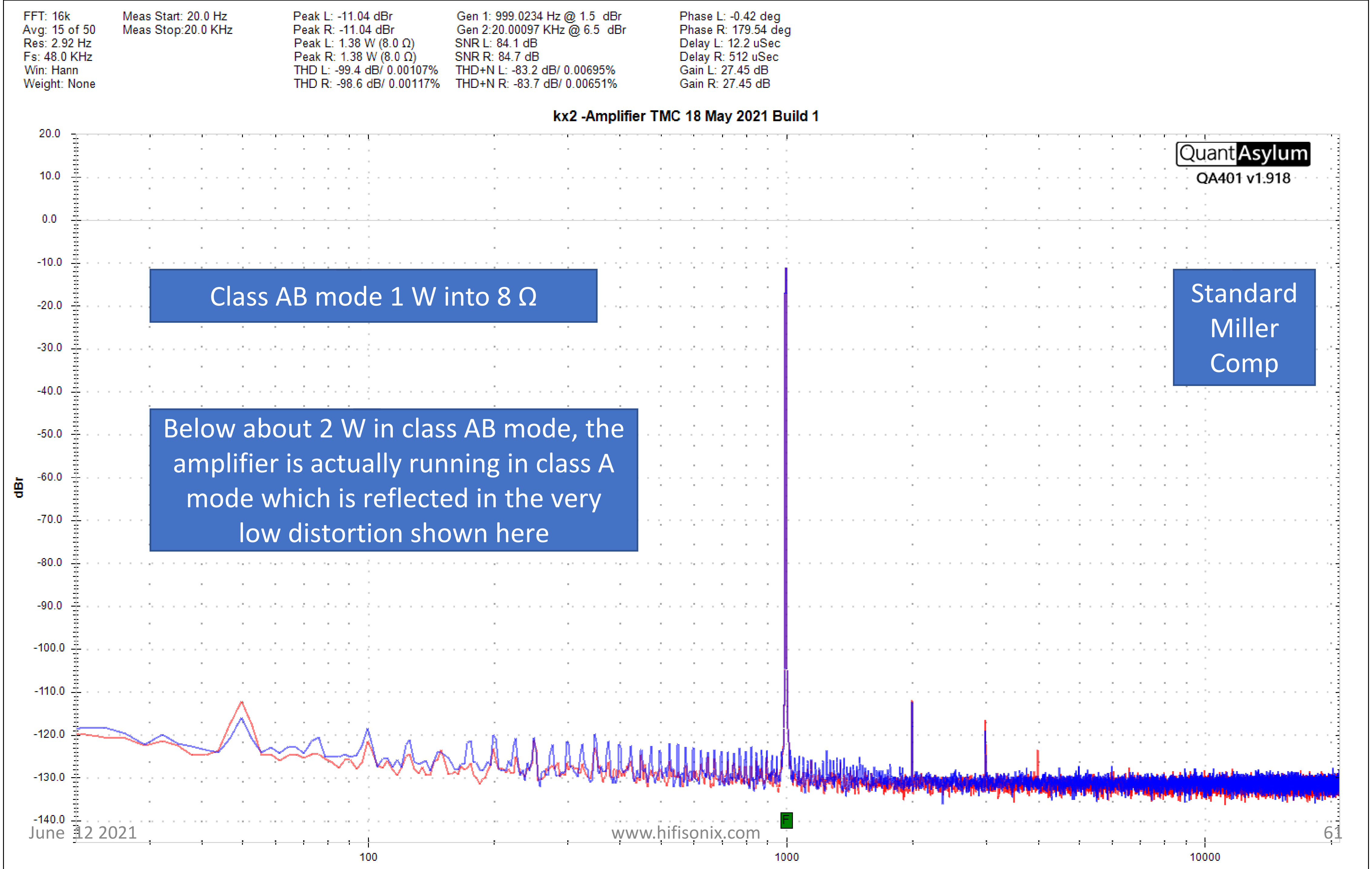


FFT: 16k
Avg: 23 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.55 dBr
Peak R: -0.55 dBr
Peak L: 15.5 W (8.0 Ω)
Peak R: 15.4 W (8.0 Ω)
THD L: -88.6 dB/ 0.00373%
THD R: -86.6 dB/ 0.00470%
Gen 1: 999.0234 Hz @ 12.0 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 91.0 dB
SNR R: 91.9 dB
THD+N L: -86.3 dB/ 0.00486%
THD+N R: -85.2 dB/ 0.00547%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.44 dB
Gain R: 27.44 dB
kx2 -Amplifier TMC 18 May 2021 Build 1
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
Class AB mode 15 W into 8 Ω
Standard Miller Comp
The difference in distortion between class A mode and class AB at 15 W RMS is 27~37 ppm due to cross over distortion

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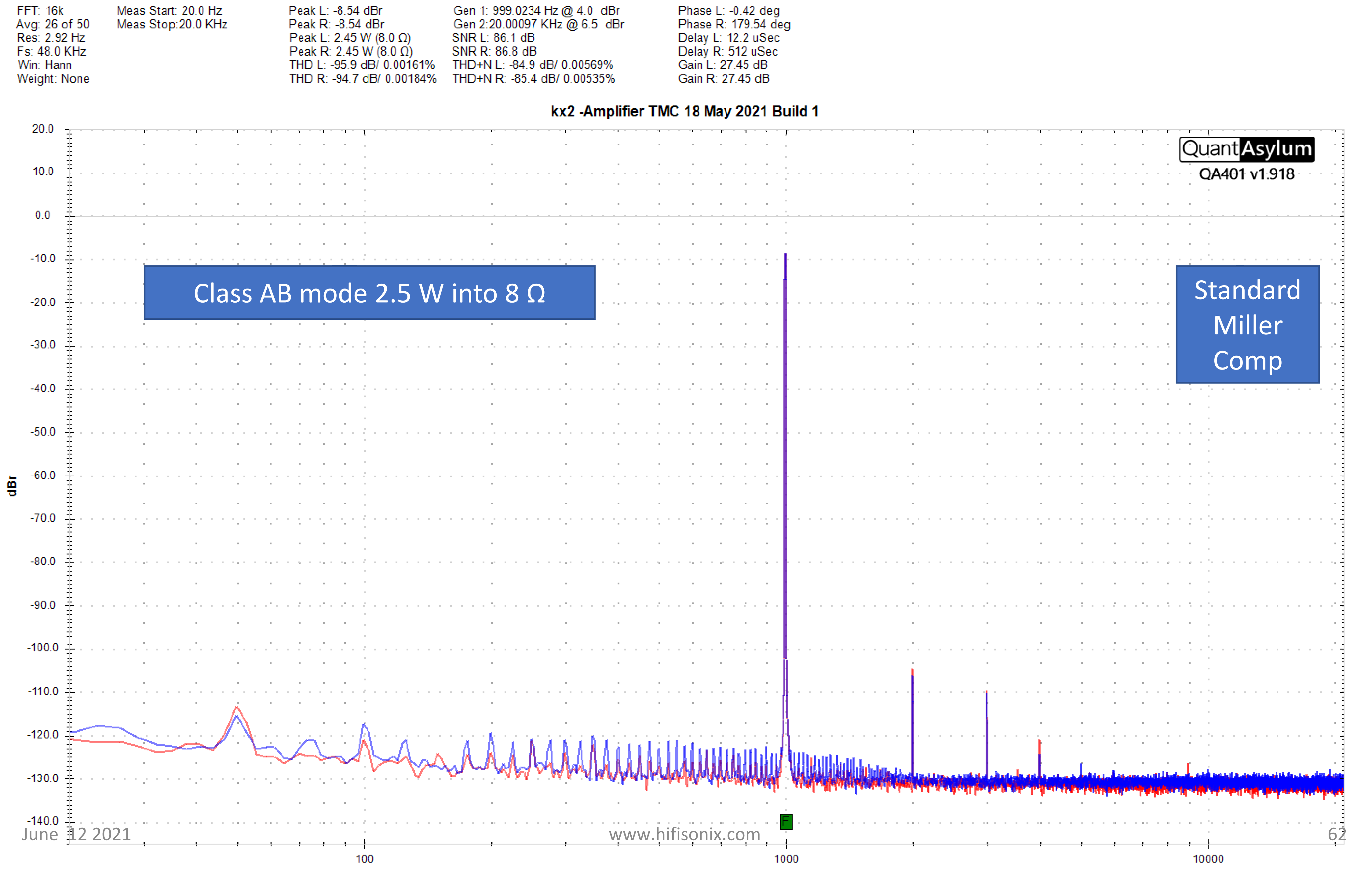


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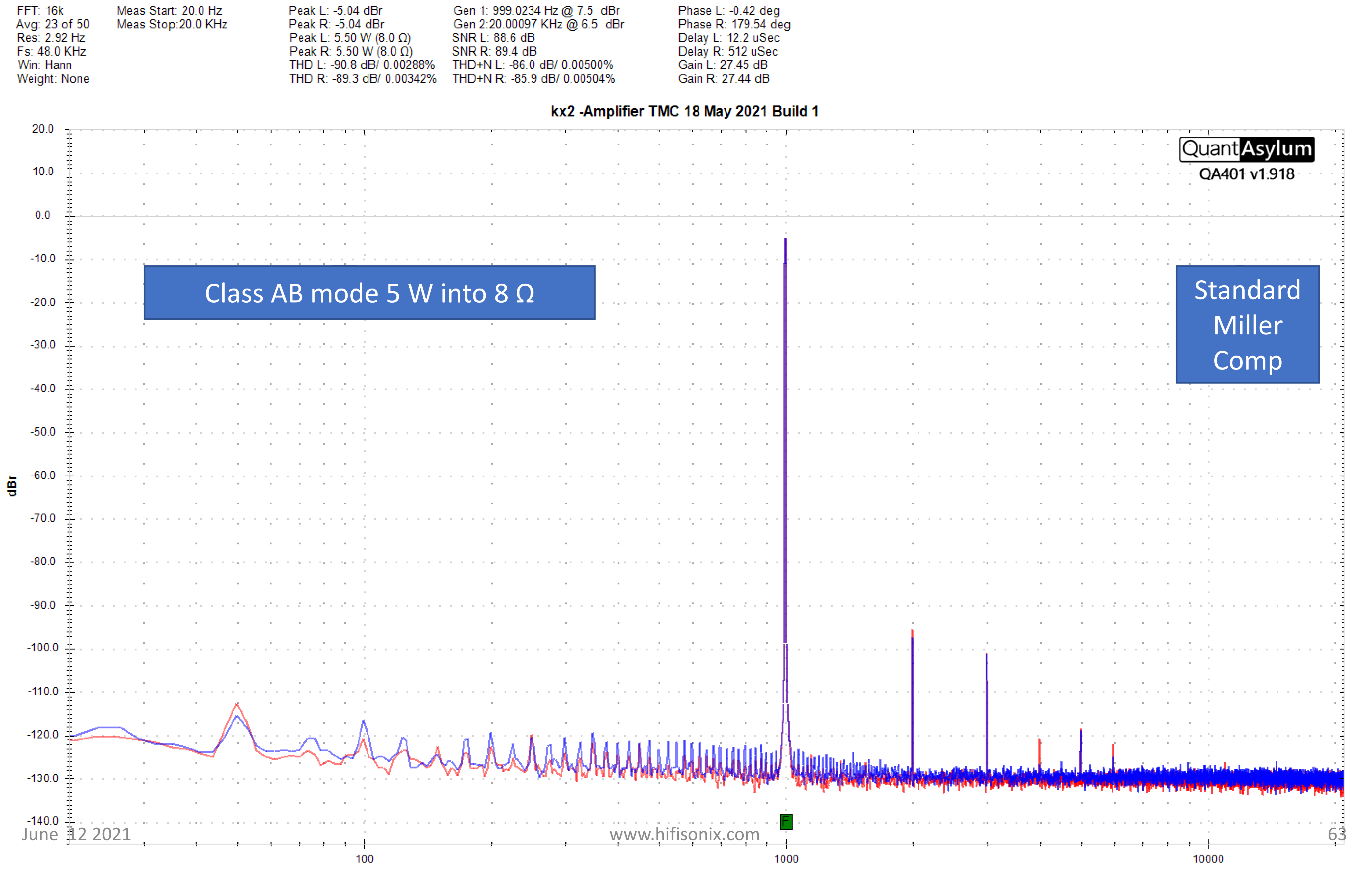
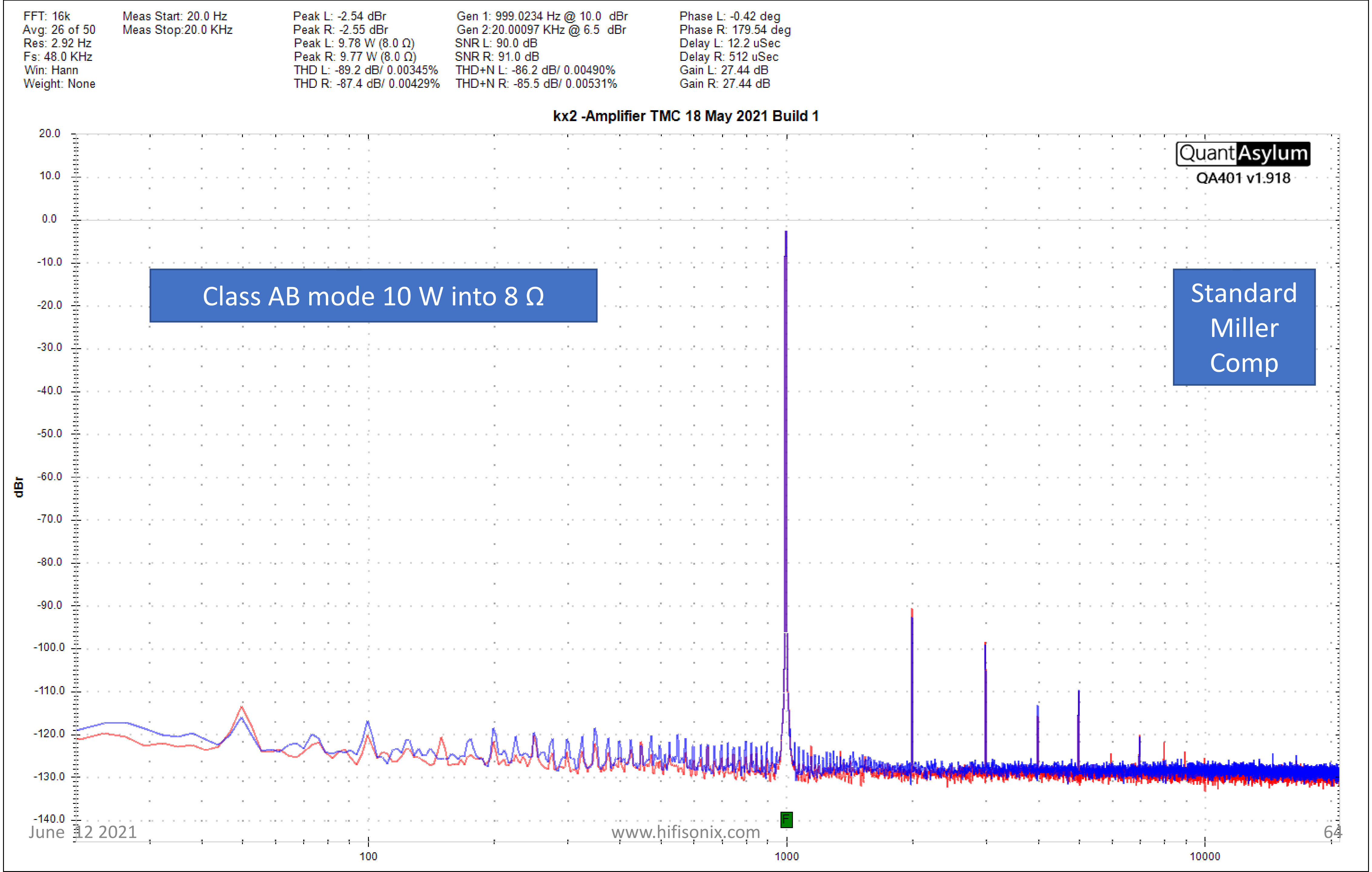
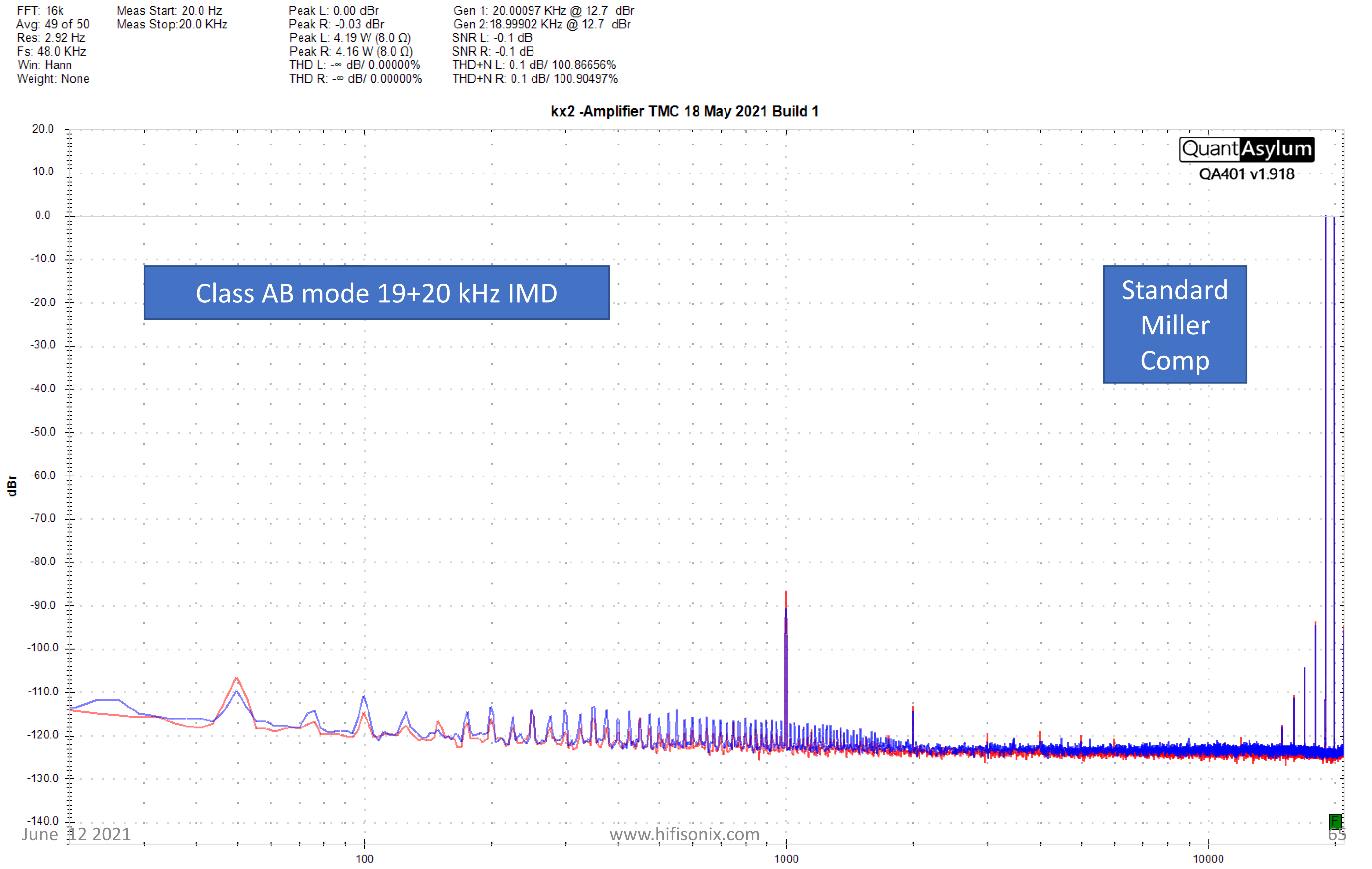
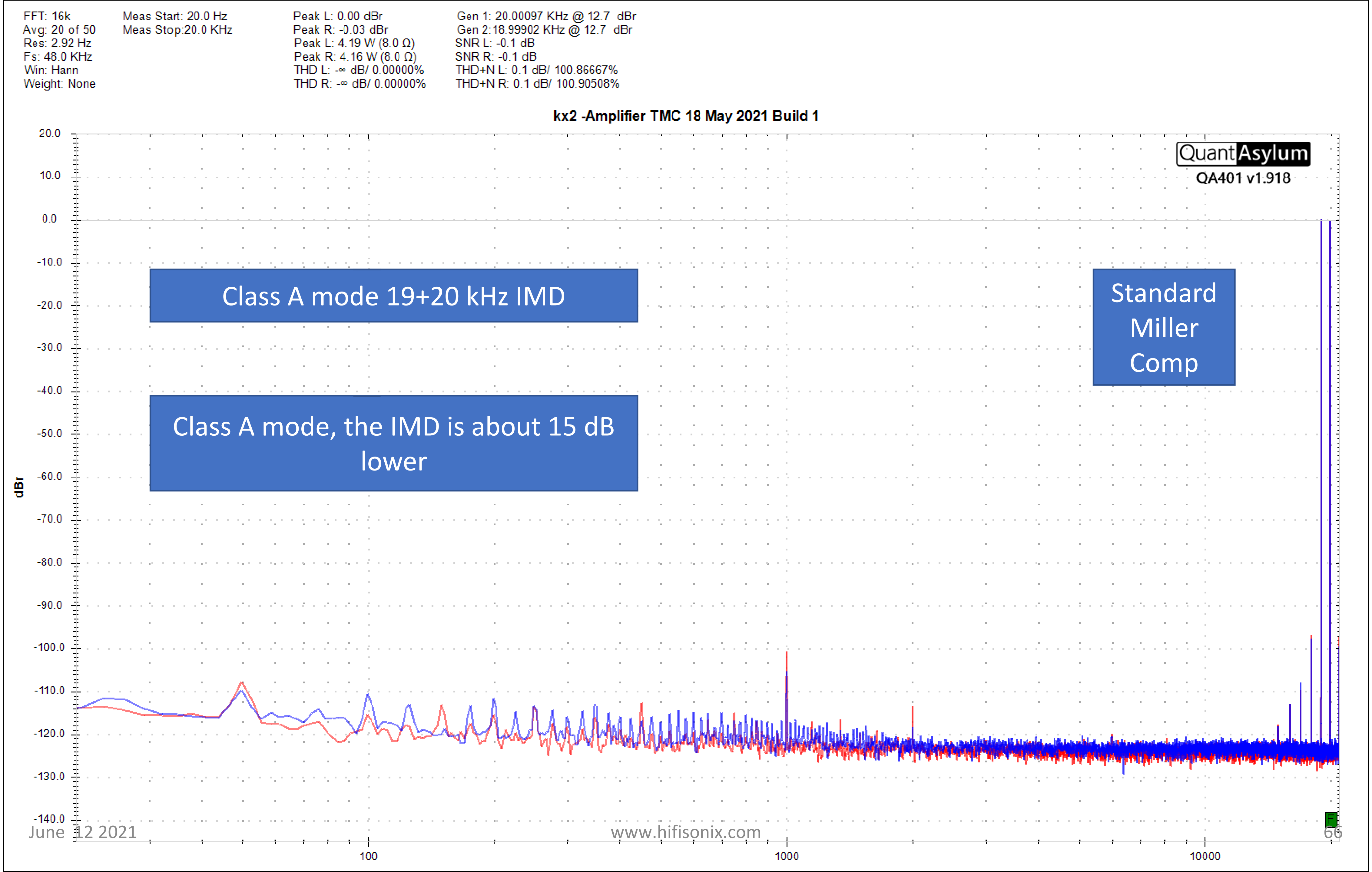
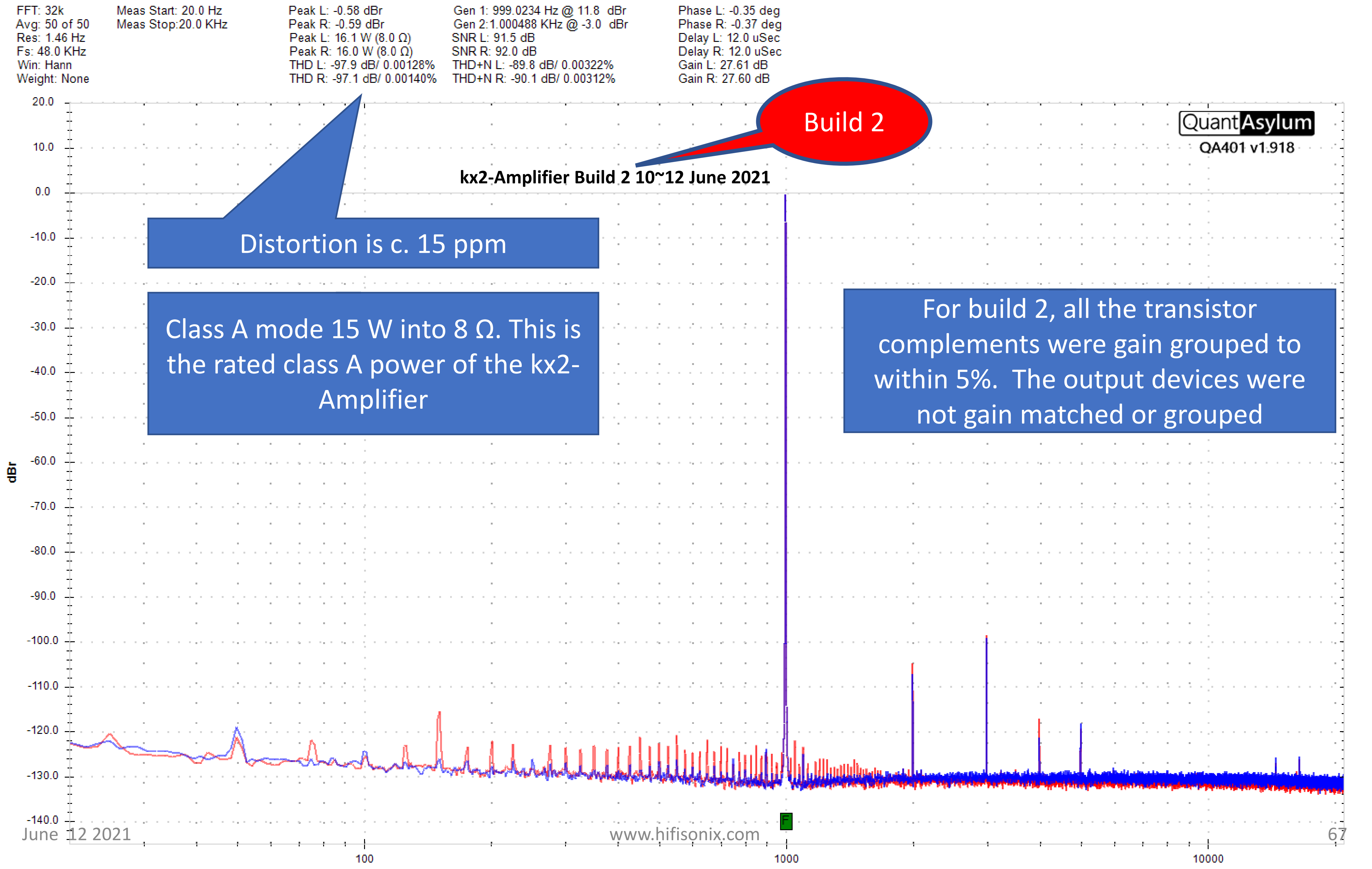

FFT: 16k
Avg: 23 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -5.04 dBr
Peak R: -5.04 dBr
Peak L: 5.50 W (8.0 Ω)
Peak R: 5.50 W (8.0 Ω)
THD L: -90.8 dB/ 0.00288%
THD R: -89.3 dB/ 0.00342%
Gen 1: 999.0234 Hz @ 7.5 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 88.6 dB
SNR R: 89.4 dB
THD+N L: -86.0 dB/ 0.00500%
THD+N R: -85.9 dB/ 0.00504%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.45 dB
Gain R: 27.44 dB
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Class AB mode 5 W into 8 Ω
Standard Miller Comp
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: 16k
Avg: 26 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -2.54 dBr
Peak R: -2.55 dBr
Peak L: 9.78 W (8.0 Ω)
Peak R: 9.77 W (8.0 Ω)
THD L: -89.2 dB/ 0.00345%
THD R: -87.4 dB/ 0.00429%
Gen 1: 999.0234 Hz @ 10.0 dBr
Gen 2:20.00097 KHz @ 6.5 dBr
SNR L: 90.0 dB
SNR R: 91.0 dB
THD+N L: -86.2 dB/ 0.00490%
THD+N R: -85.5 dB/ 0.00531%
Phase L: -0.42 deg
Phase R: 179.54 deg
Delay L: 12.2 uSec
Delay R: 512 uSec
Gain L: 27.44 dB
Gain R: 27.44 dB
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Class AB mode 10 W into 8 Ω
Standard Miller Comp
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: 16k
Avg: 49 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.03 dBr
Peak L: 4.19 W (8.0 Ω)
Peak R: 4.16 W (8.0 Ω)
THD L: -∞ dB/ 0.00000%
THD R: -∞ dB/ 0.00000%
Gen 1: 20.00097 KHz @ 12.7 dBr
Gen 2:18.99902 KHz @ 12.7 dBr
SNR L: -0.1 dB
SNR R: -0.1 dB
THD+N L: 0.1 dB/ 100.86656%
THD+N R: 0.1 dB/ 100.90497%
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Class AB mode 19+20 kHz IMD
Standard Miller Comp
dBr
100
1000
10000


FFT: 16k
Avg: 20 of 50
Res: 2.92 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.03 dBr
Peak L: 4.19 W (8.0 Ω)
Peak R: 4.16 W (8.0 Ω)
THD L: -∞ dB/ 0.00000%
THD R: -∞ dB/ 0.00000%
Gen 1: 20.00097 KHz @ 12.7 dBr
Gen 2:18.99902 KHz @ 12.7 dBr
SNR L: -0.1 dB
SNR R: -0.1 dB
THD+N L: 0.1 dB/ 100.86667%
THD+N R: 0.1 dB/ 100.90508%
kx2 -Amplifier TMC 18 May 2021 Build 1
QuantAsylum
QA401 v1.918
Class A mode 19+20 kHz IMD
Class A mode, the IMD is about 15 dB lower
Standard Miller Comp
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

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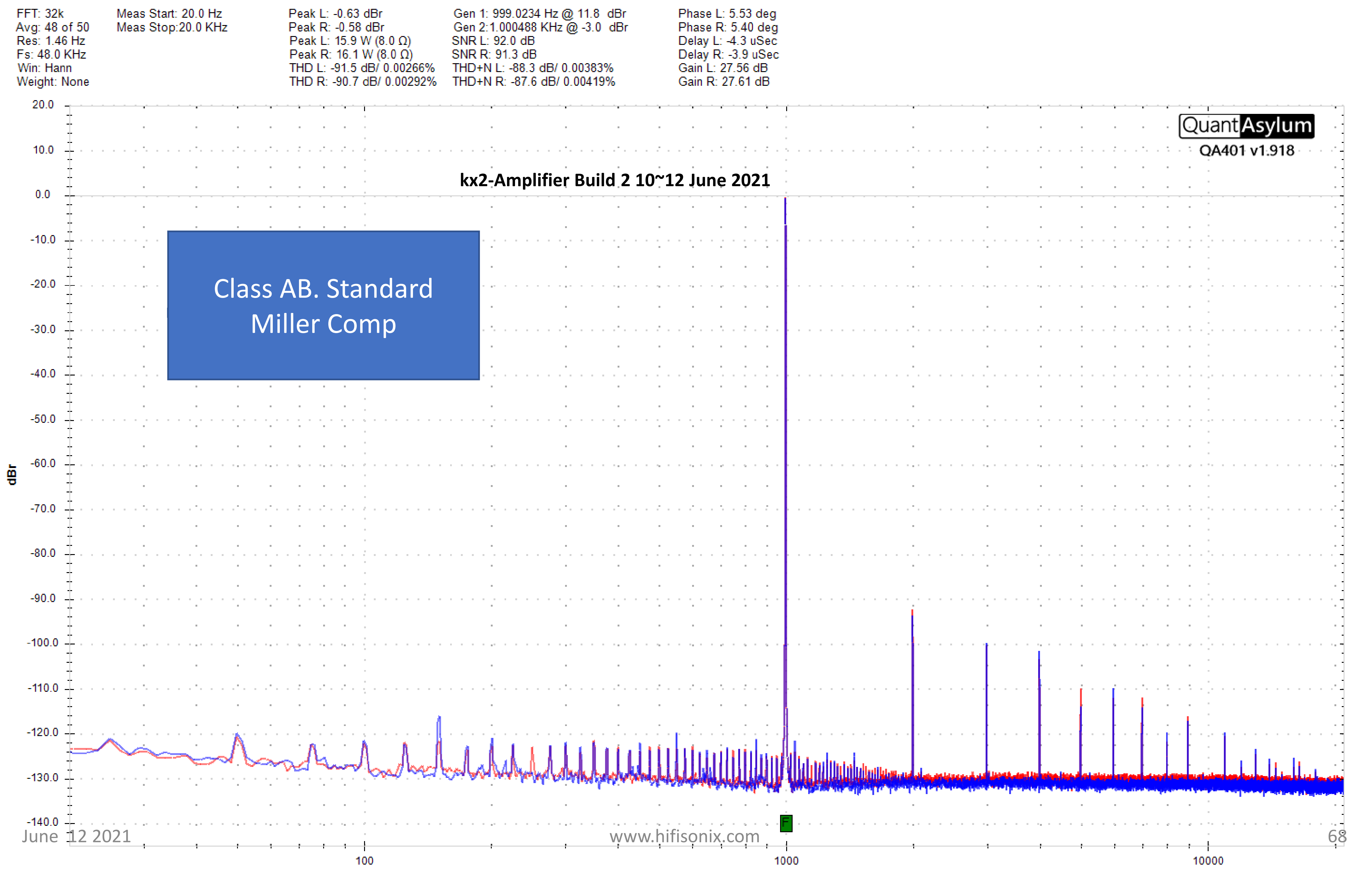
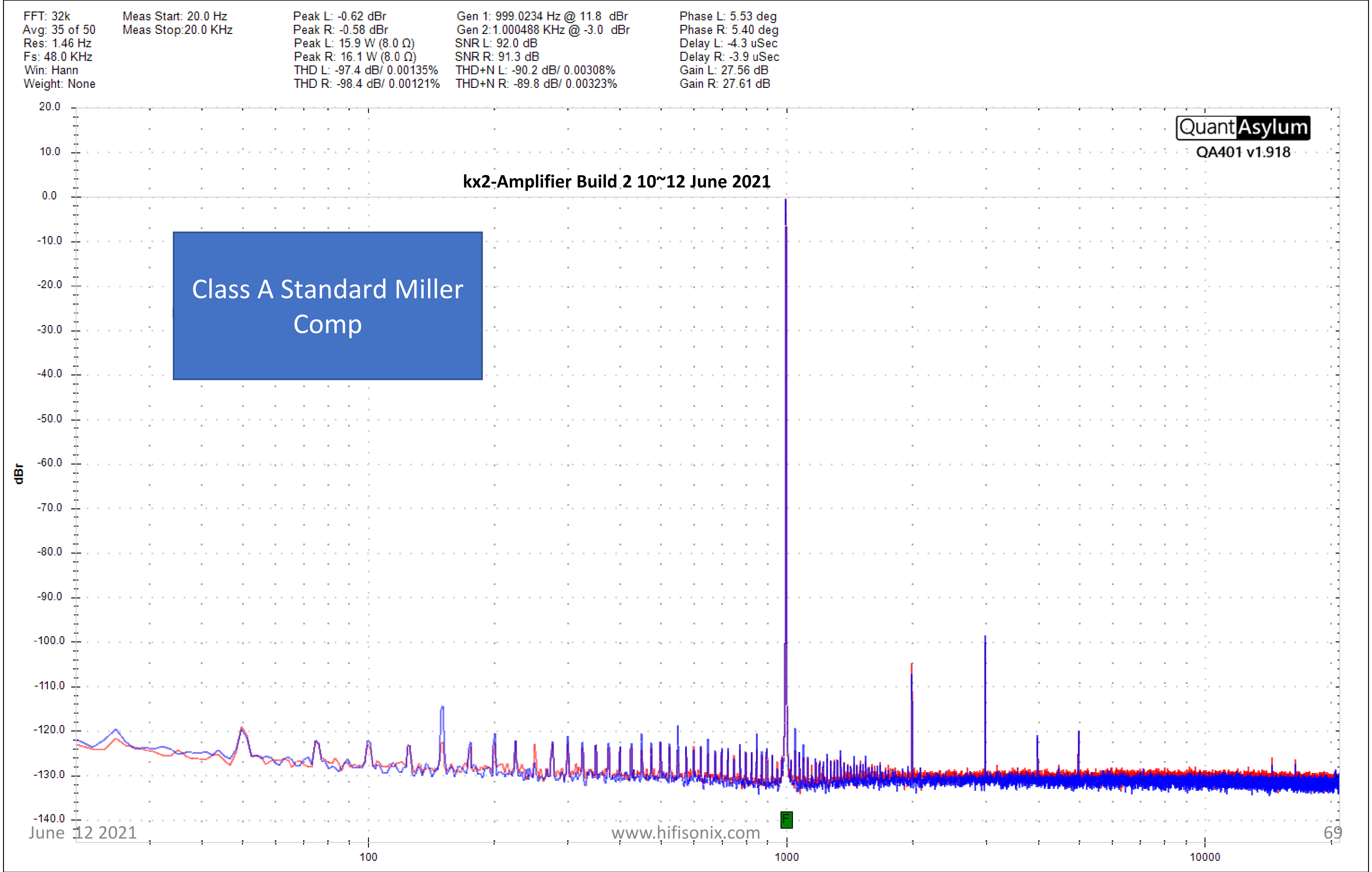
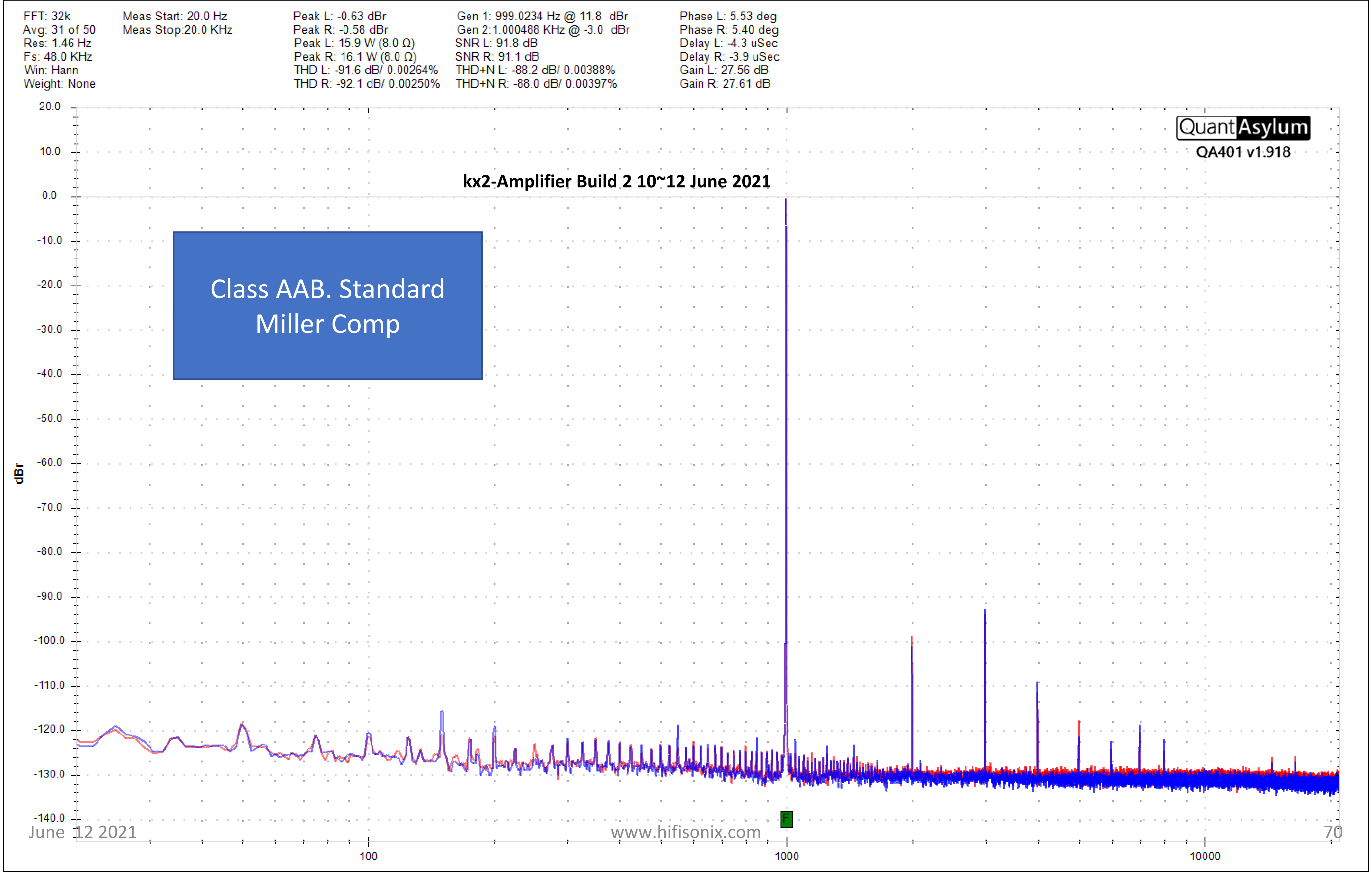

FFT: 32k
Avg: 48 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.63 dBr
Peak R: -0.58 dBr
Peak L: 15.9 W (8.0 Ω)
Peak R: 16.1 W (8.0 Ω)
THD L: -91.5 dB/ 0.00266%
THD R: -90.7 dB/ 0.00292%
Gen 1: 999.0234 Hz @ 11.8 dBr
Gen 2:1.000488 KHz @ -3.0 dBr
SNR L: 92.0 dB
SNR R: 91.3 dB
THD+N L: -88.3 dB/ 0.00383%
THD+N R: -87.6 dB/ 0.00419%
Phase L: 5.53 deg
Phase R: 5.40 deg
Delay L: -4.3 uSec
Delay R: -3.9 uSec
Gain L: 27.56 dB
Gain R: 27.61 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class AB. Standard
Miller Comp
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: 32k
Avg: 35 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.62 dBr
Peak R: -0.58 dBr
Peak L: 15.9 W (8.0 Ω)
Peak R: 16.1 W (8.0 Ω)
THD L: -97.4 dB/ 0.00135%
THD R: -98.4 dB/ 0.00121%
Gen 1: 999.0234 Hz @ 11.8 dBr
Gen 2:1.000488 KHz @ -3.0 dBr
SNR L: 92.0 dB
SNR R: 91.3 dB
THD+N L: -90.2 dB/ 0.00308%
THD+N R: -89.8 dB/ 0.00323%
Phase L: 5.53 deg
Phase R: 5.40 deg
Delay L: -4.3 uSec
Delay R: -3.9 uSec
Gain L: 27.56 dB
Gain R: 27.61 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class A Standard Miller Comp
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: 32k
Avg: 31 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.63 dBr
Peak R: -0.58 dBr
Peak L: 15.9 W (8.0 Ω)
Peak R: 16.1 W (8.0 Ω)
THD L: -91.6 dB/ 0.00264%
THD R: -92.1 dB/ 0.00250%
Gen 1: 999.0234 Hz @ 11.8 dBr
Gen 2:1.000488 KHz @ -3.0 dBr
SNR L: 91.8 dB
SNR R: 91.1 dB
THD+N L: -88.2 dB/ 0.00388%
THD+N R: -88.0 dB/ 0.00397%
Phase L: 5.53 deg
Phase R: 5.40 deg
Delay L: -4.3 uSec
Delay R: -3.9 uSec
Gain L: 27.56 dB
Gain R: 27.61 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class AAB. Standard Miller Comp
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
June 12 2021
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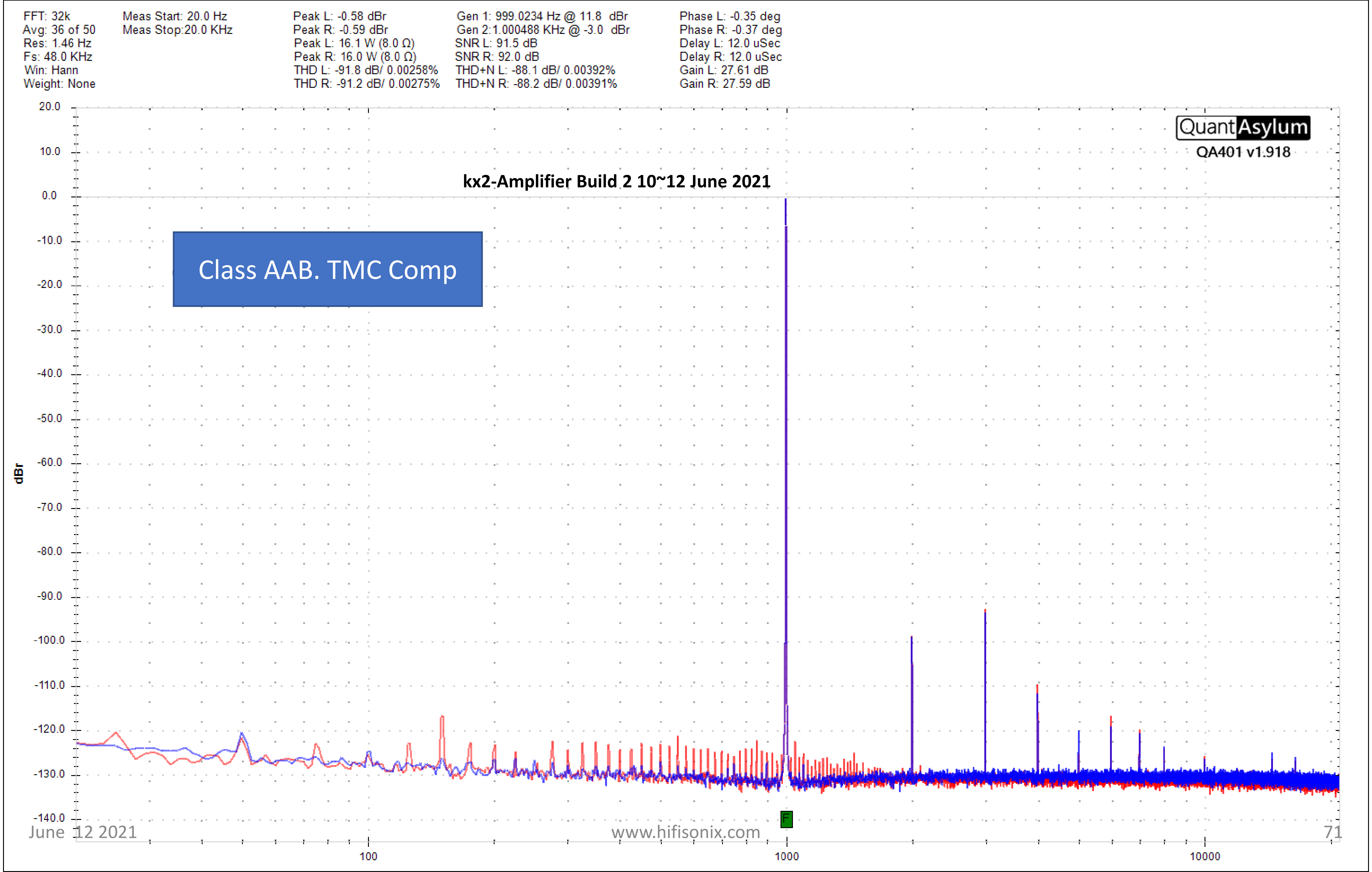
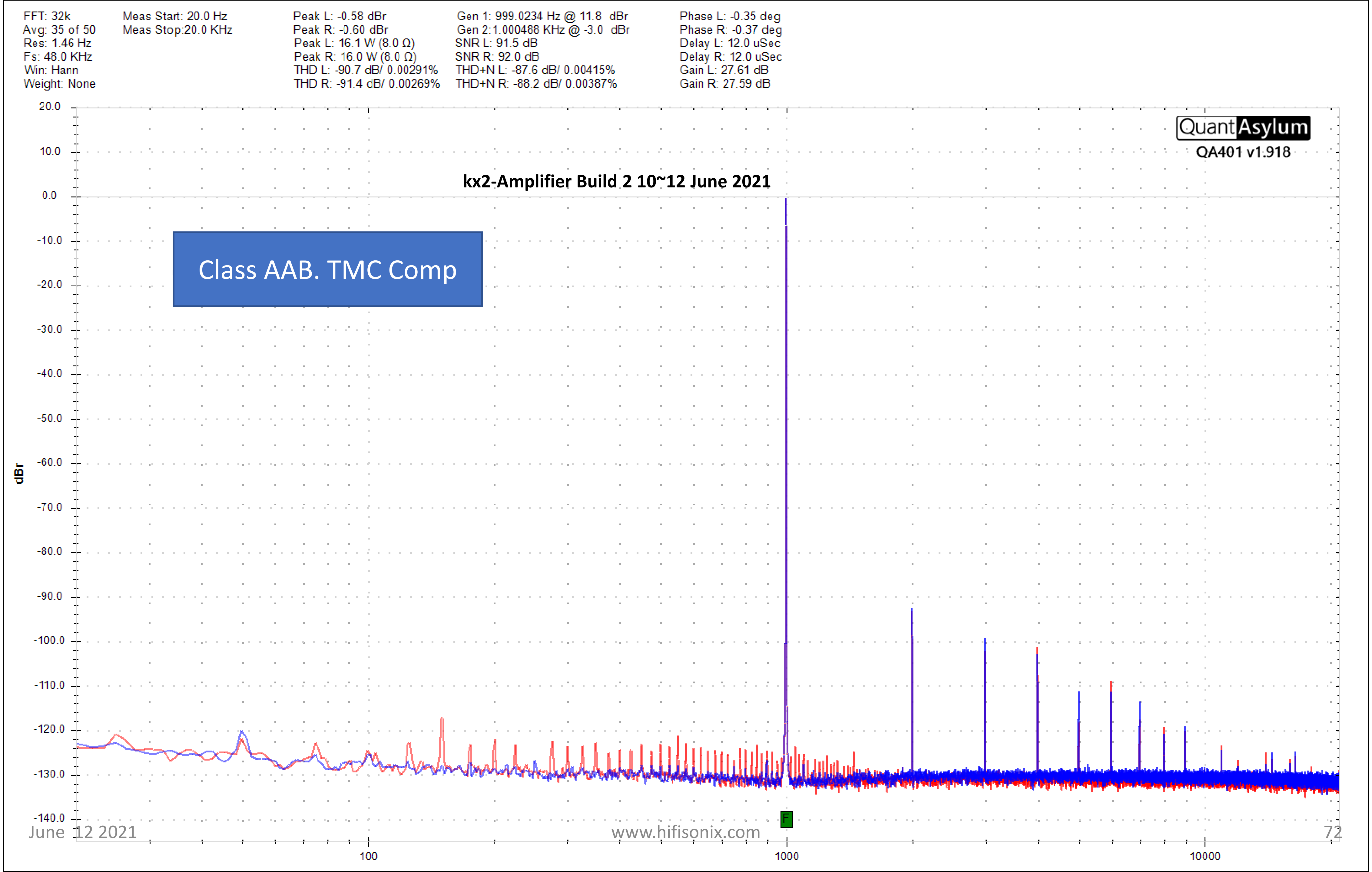

FFT: 32k
Avg: 36 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.58 dBr
Peak R: -0.59 dBr
Peak L: 16.1 W (8.0 Ω)
Peak R: 16.0 W (8.0 Ω)
THD L: -91.8 dB/ 0.00258%
THD R: -91.2 dB/ 0.00275%
Gen 1: 999.0234 Hz @ 11.8 dBr
Gen 2:1.000488 KHz @ -3.0 dBr
SNR L: 91.5 dB
SNR R: 92.0 dB
THD+N L: -88.1 dB/ 0.00392%
THD+N R: -88.2 dB/ 0.00391%
Phase L: -0.35 deg
Phase R: -0.37 deg
Delay L: 12.0 uSec
Delay R: 12.0 uSec
Gain L: 27.61 dB
Gain R: 27.59 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class AAB. TMC Comp
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: 32k
Avg: 35 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.58 dBr
Peak R: -0.60 dBr
Peak L: 16.1 W (8.0 Ω)
Peak R: 16.0 W (8.0 Ω)
THD L: -90.7 dB/ 0.00291%
THD R: -91.4 dB/ 0.00269%
Gen 1: 999.0234 Hz @ 11.8 dBr
Gen 2:1.000488 KHz @ -3.0 dBr
SNR L: 91.5 dB
SNR R: 92.0 dB
THD+N L: -87.6 dB/ 0.00415%
THD+N R: -88.2 dB/ 0.00387%
Phase L: -0.35 deg
Phase R: -0.37 deg
Delay L: 12.0 uSec
Delay R: 12.0 uSec
Gain L: 27.61 dB
Gain R: 27.59 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class AAB. TMC Comp
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
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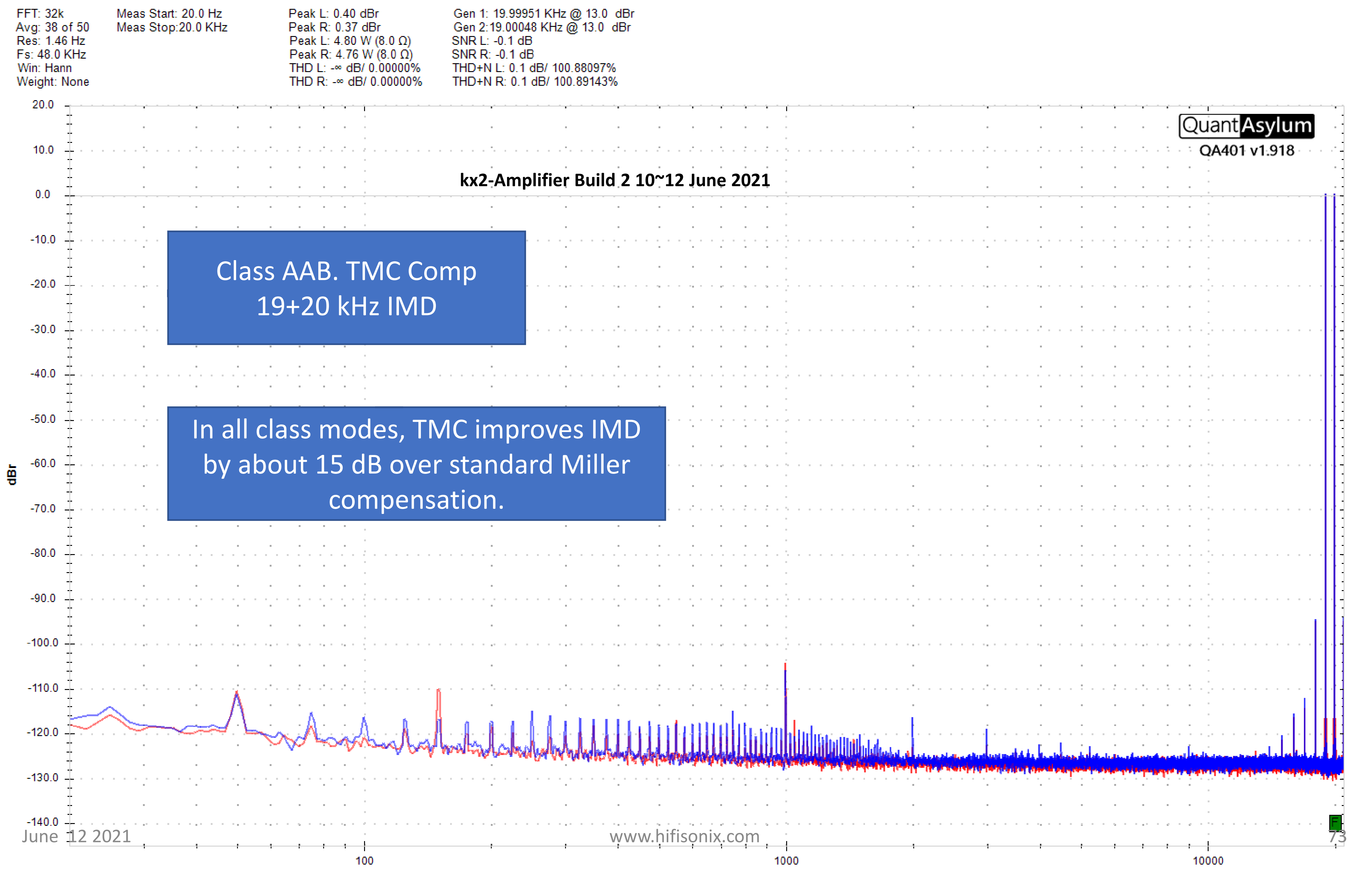
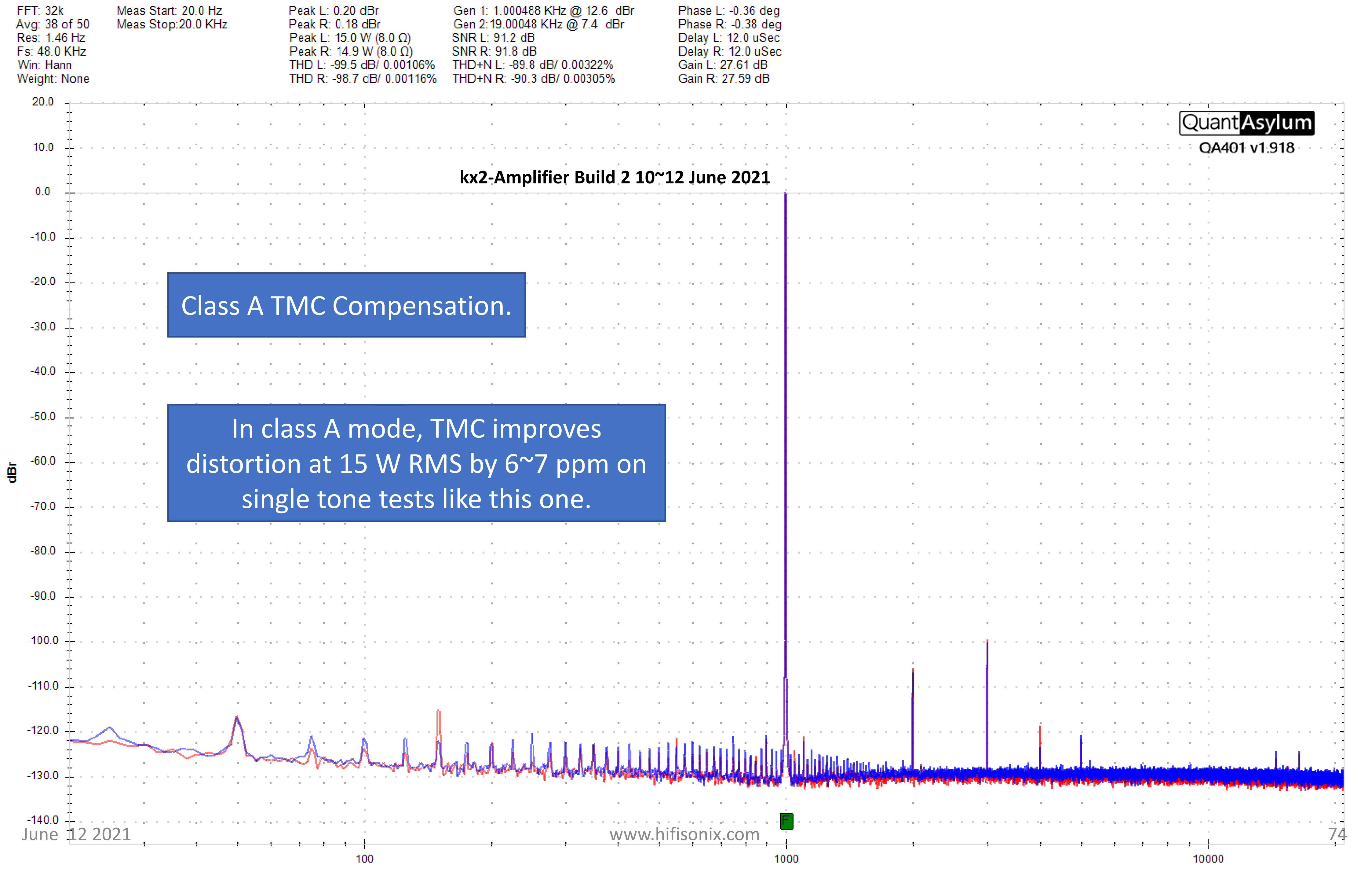

FFT: 32k
Avg: 38 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.40 dBr
Peak R: 0.37 dBr
Peak L: 4.80 W (8.0 Ω)
Peak R: 4.76 W (8.0 Ω)
THD L: -∞ dB/ 0.00000%
THD R: -∞ dB/ 0.00000%
Gen 1: 19.99951 KHz @ 13.0 dBr
Gen 2:19.00048 KHz @ 13.0 dBr
SNR L: -0.1 dB
SNR R: -0.1 dB
THD+N L: 0.1 dB/ 100.88097%
THD+N R: 0.1 dB/ 100.89143%
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class AAB. TMC Comp
19+20 kHz IMD
In all class modes, TMC improves IMD by about 15 dB over standard Miller compensation.
dBr
100
1000
10000



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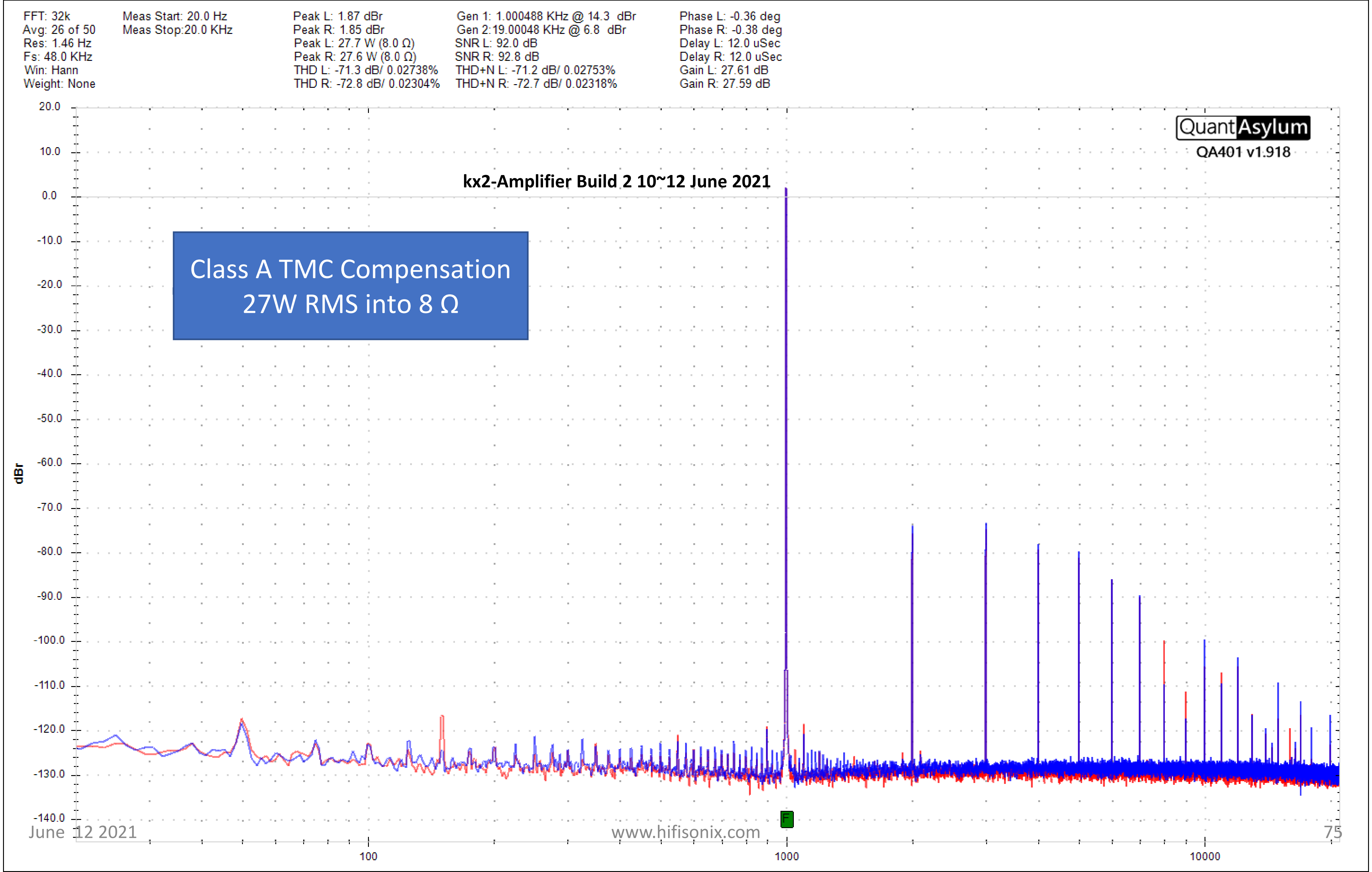

FFT: 32k
Avg: 26 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 1.87 dBr
Peak R: 1.85 dBr
Peak L: 27.7 W (8.0 Ω)
Peak R: 27.6 W (8.0 Ω)
THD L: -71.3 dB/ 0.02738%
THD R: -72.8 dB/ 0.02304%
Gen 1: 1.000488 KHz @ 14.3 dBr
Gen 2:19.00048 KHz @ 6.8 dBr
SNR L: 92.0 dB
SNR R: 92.8 dB
THD+N L: -71.2 dB/ 0.02753%
THD+N R: -72.7 dB/ 0.02318%
Phase L: -0.36 deg
Phase R: -0.38 deg
Delay L: 12.0 uSec
Delay R: 12.0 uSec
Gain L: 27.61 dB
Gain R: 27.59 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class A TMC Compensation
27W RMS into 8 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
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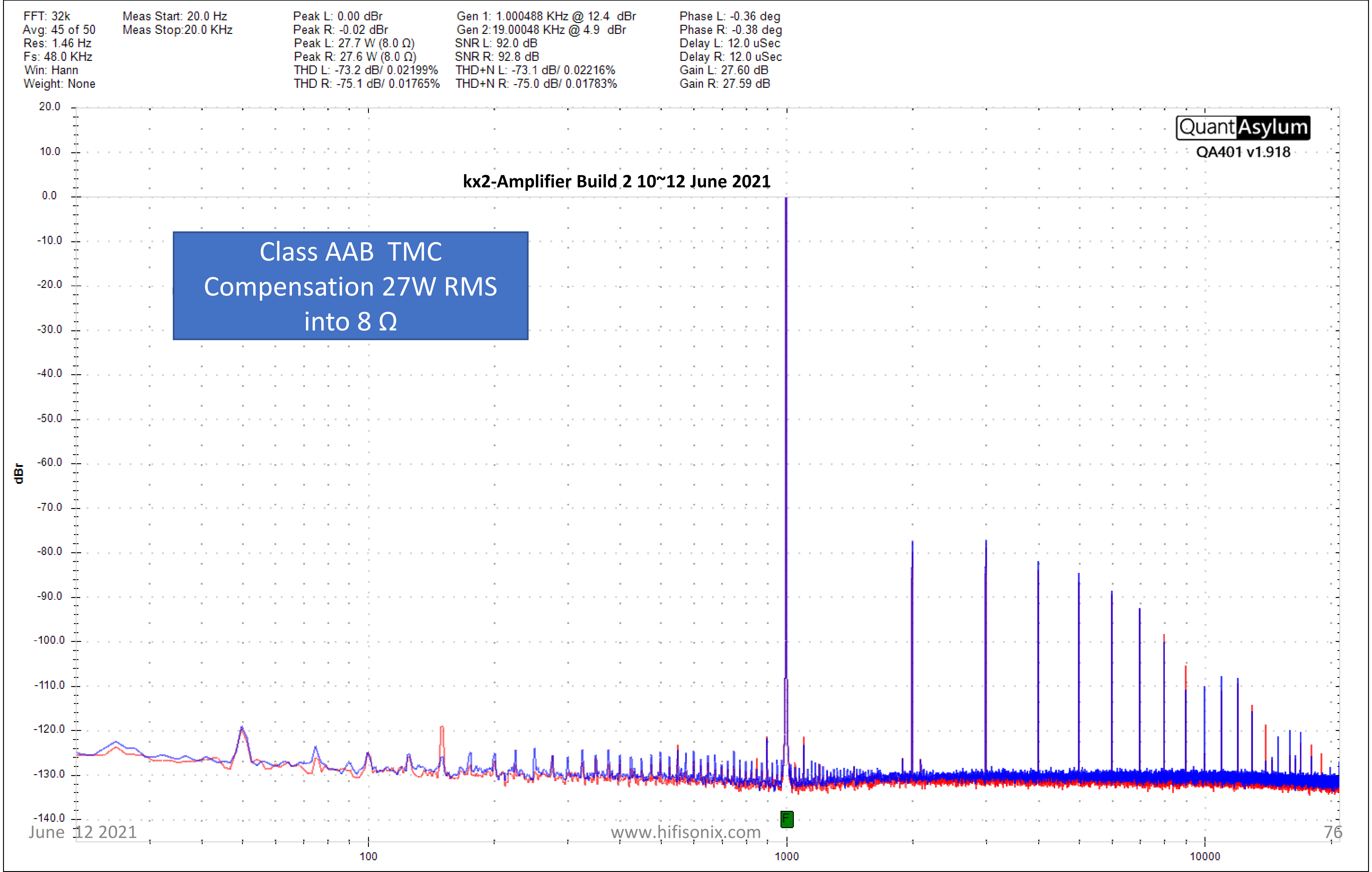
FFT: 32k
Avg: 45 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 27.7 W (8.0 Ω)
Peak R: 27.6 W (8.0 Ω)
THD L: -73.2 dB/ 0.02199%
THD R: -75.1 dB/ 0.01765%
Gen 1: 1.000488 KHz @ 12.4 dBr
Gen 2:19.00048 KHz @ 4.9 dBr
SNR L: 92.0 dB
SNR R: 92.8 dB
THD+N L: -73.1 dB/ 0.02216%
THD+N R: -75.0 dB/ 0.01783%
Phase L: -0.36 deg
Phase R: -0.38 deg
Delay L: 12.0 uSec
Delay R: 12.0 uSec
Gain L: 27.60 dB
Gain R: 27.59 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class AAB TMC
Compensation 27W RMS
into 8 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
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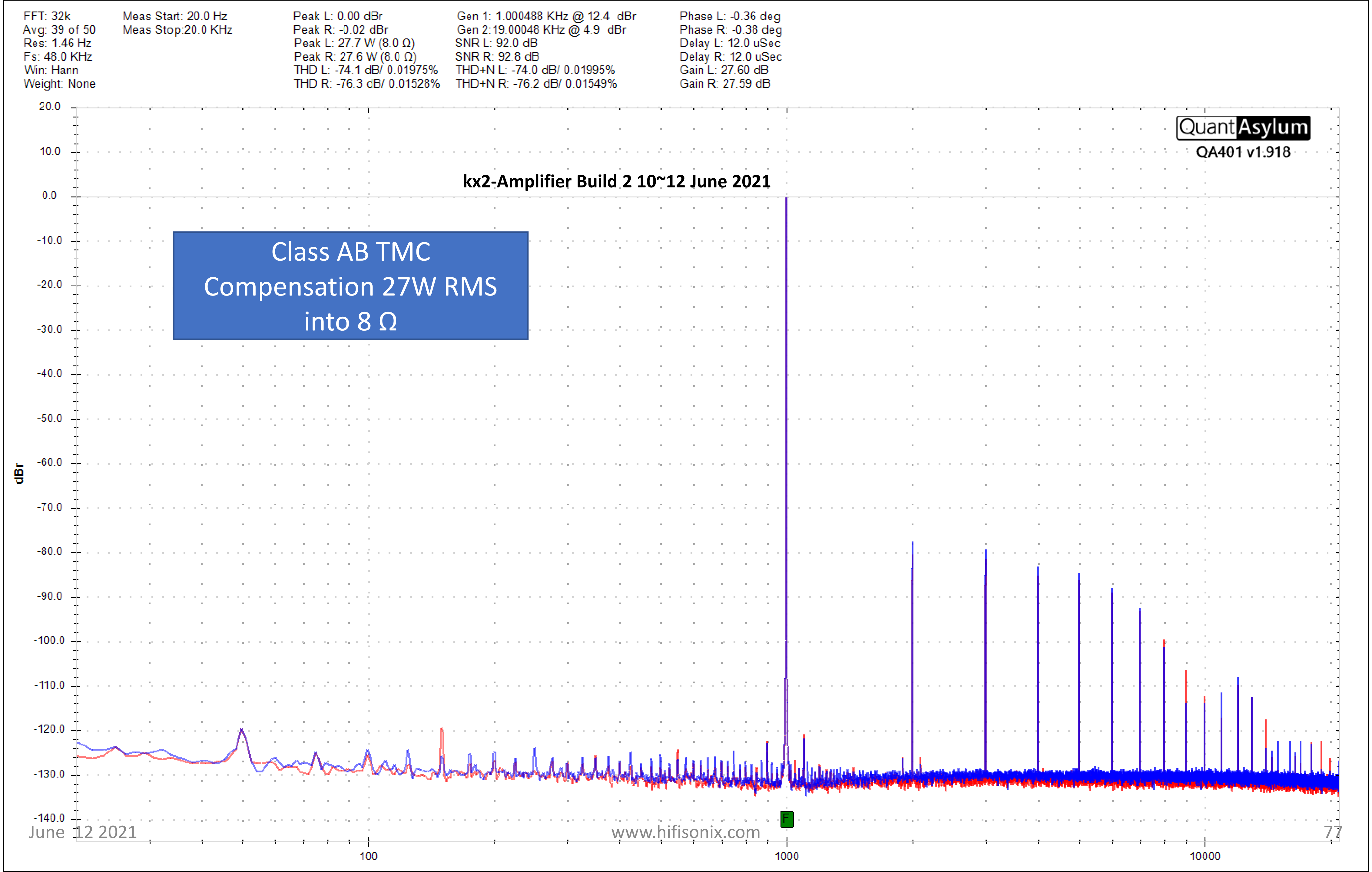
FFT: 32k
Avg: 39 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 27.7 W (8.0 Ω)
Peak R: 27.6 W (8.0 Ω)
THD L: -74.1 dB/ 0.01975%
THD R: -76.3 dB/ 0.01528%
Gen 1: 1.000488 KHz @ 12.4 dBr
Gen 2:19.00048 KHz @ 4.9 dBr
SNR L: 92.0 dB
SNR R: 92.8 dB
THD+N L: -74.0 dB/ 0.01995%
THD+N R: -76.2 dB/ 0.01549%
Phase L: -0.36 deg
Phase R: -0.38 deg
Delay L: 12.0 uSec
Delay R: 12.0 uSec
Gain L: 27.60 dB
Gain R: 27.59 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
Class AB TMC Compensation 27W RMS into 8 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
June 12 2021
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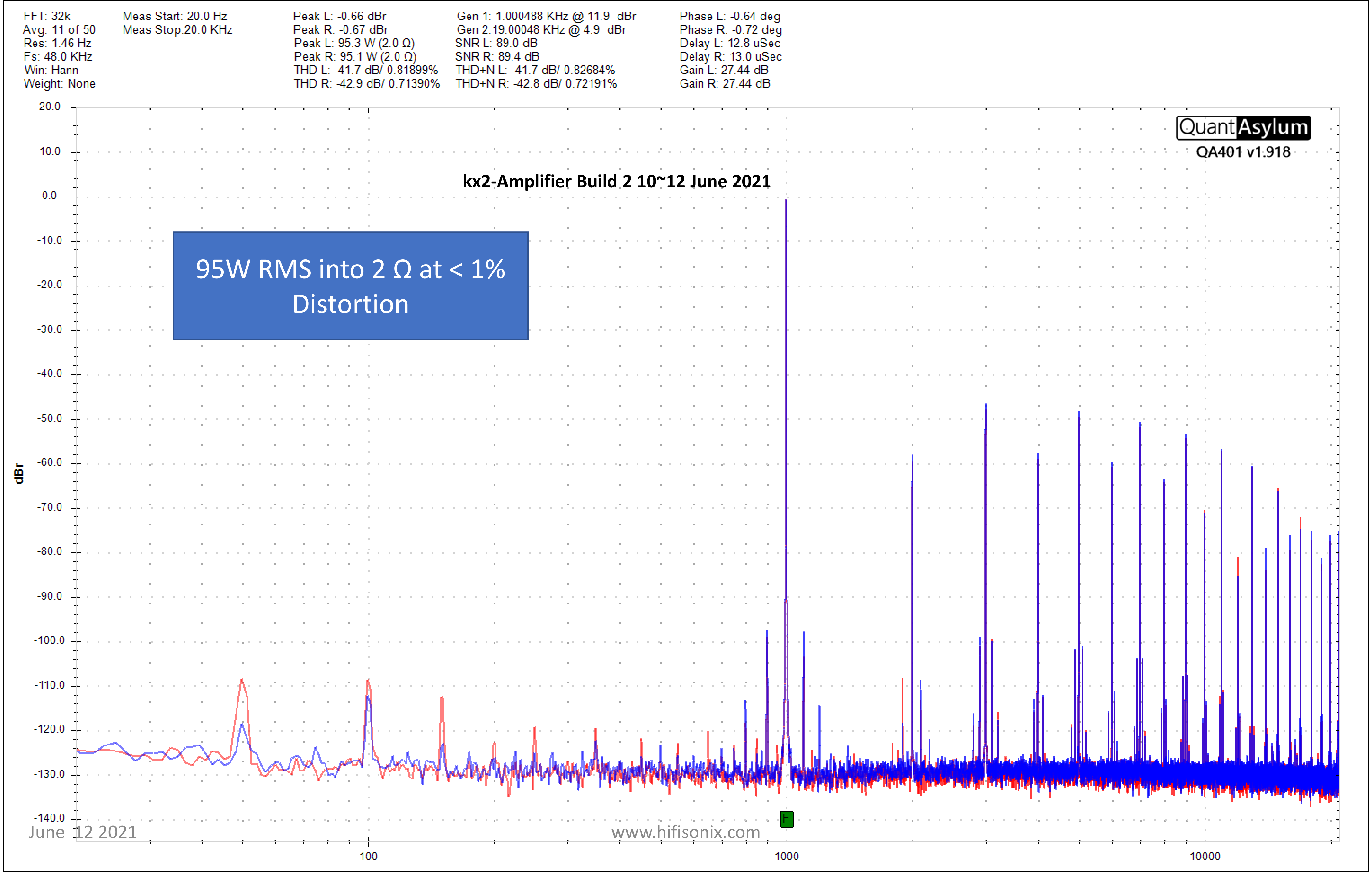
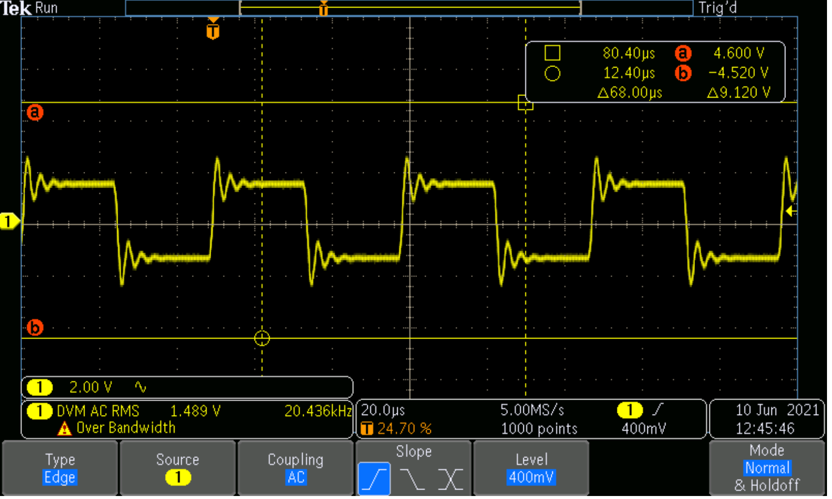
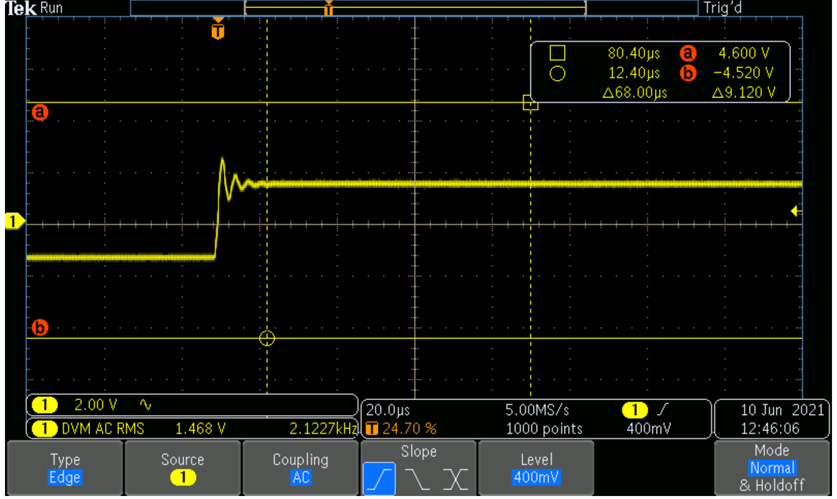
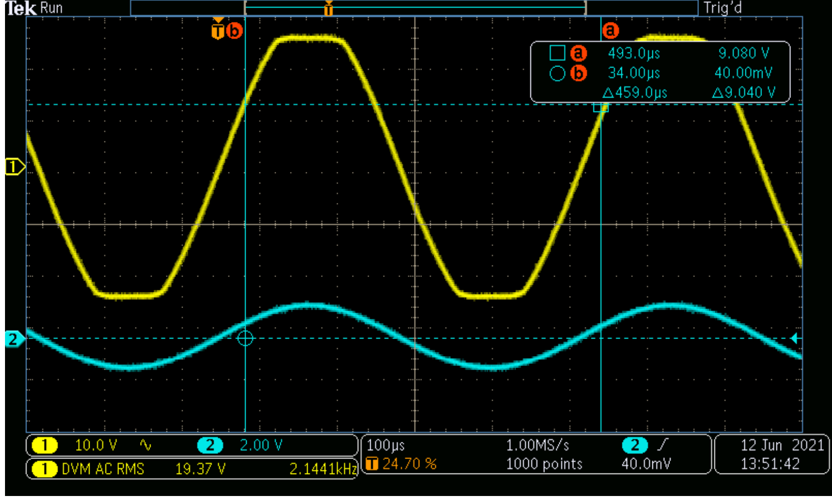

FFT: 32k
Avg: 11 of 50
Res: 1.46 Hz
Fs: 48.0 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.66 dBr
Peak R: -0.67 dBr
Peak L: 95.3 W (2.0 Ω)
Peak R: 95.1 W (2.0 Ω)
THD L: -41.7 dB/ 0.81899%
THD R: -42.9 dB/ 0.71390%
Gen 1: 1.000488 KHz @ 11.9 dBr
Gen 2:19.00048 KHz @ 4.9 dBr
SNR L: 89.0 dB
SNR R: 89.4 dB
THD+N L: -41.7 dB/ 0.82684%
THD+N R: -42.8 dB/ 0.72191%
Phase L: -0.64 deg
Phase R: -0.72 deg
Delay L: 12.8 uSec
Delay R: 13.0 uSec
Gain L: 27.44 dB
Gain R: 27.44 dB
QuantAsylum
QA401 v1.918
kx2-Amplifier Build 2 10~12 June 2021
95W RMS into 2 Ω at < 1% Distortion
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



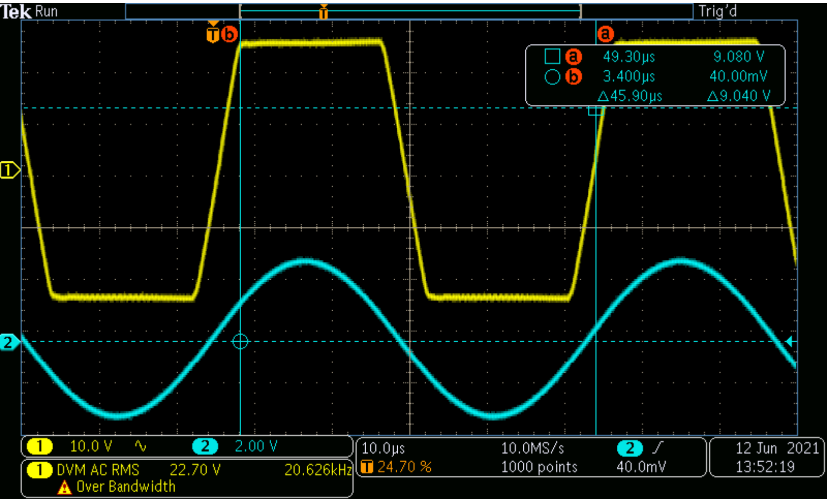

8 Ω Load in parallel with 0.3uFc. 20 kHz



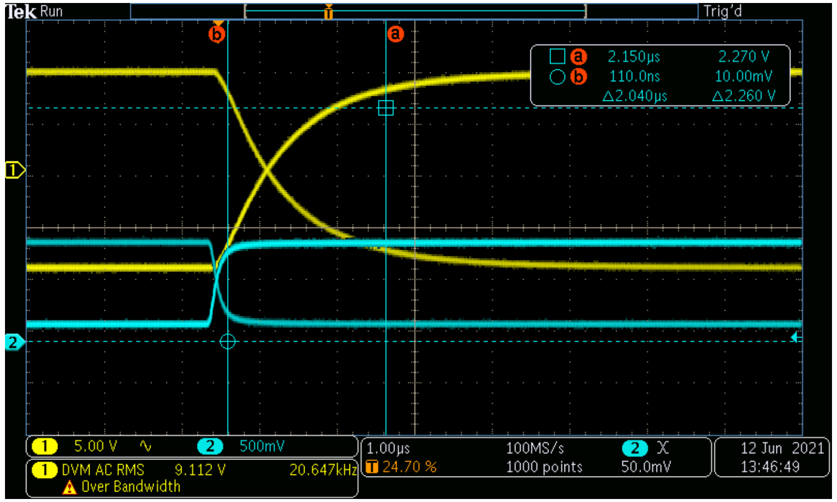

8 Ω Load in parallel with 0.3uF c. 2kHz




Soft clipping into 8 Ω Load 50V pk~pk at 2kHz




Hard overdrive into 8 Ω Load 50 V pk~pk at 20 kHz




Rise/Fall time is ~2.1 us 10% to 90%

# Some Notes About Class A Amplifiers

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# Some Notes on Class A Amplifiers 1/2

Over the last 40 years, three class A DIY amplifiers stand out :- (1) JLH's 10 Watt Class A design published in 1969 in Wireless World, (2) Jean Hiraga's 20W amplifier published in the French DIY magazine l'Audiophile in the 1980's. Remarkably, JLH's design used only 4 transistors (optionally increased to 5 to improve the current control of the upper output transistor), while Hiraga's used 8, although it delivered double the rated output power. Both Hiraga and JLH's designs are wide bandwidth* – using modern transistors, the JLH amp is flat out to 100's of kHz with attendant high slew rates. (3) Nelson Pass's DIY class A amplifiers, (many different designs over a 25-year period) are another popular choice amongst DIY'ers, feature mosfet output stages and have included both push pull and single ended current source loaded OPS designs with low or no global feedback.

The sx-Amplifier, which I first published in 2012 on diyaudio.com, used 11 transistors and delivered 28 Watts peak class A power into 8 Ω on +-22V supply rails. I think with class A amplifiers, its better to talk about peak class A power, since what we are really interested in is 'up until what point does the output stage remain in class A'. Simulated distortion levels on all three amplifiers (JLH, Hiraga and sx-Amp) are about -60 dB down on the 20 kHz test signal fundamental. The sx-amp and Hiraga are DC coupled although this is on the assumption that the source has no DC offset, or its output is capacitively coupled (same for the 100W class AB nx-Amp by the way). The thermal management on the sx-Amp is considerably better than both JLH and Hiraga's designs since in both the sx-Amp, the earlier kx-Amp and the new kx2-Amp, two pairs of output devices are used, allowing the heat dissipation to be more easily spread on the heatsink. This means the output devices are less stressed and the result is a more reliable amplifier. Pass's high power class A designs often use paralleled output mosfets in order to address the thermal management challenges, but matching mosfets is not an undertaking for the faint-hearted, or those with DIY budgetary challenges. Some of Pass's designs, feature 15 to 20A OPS standing current – also not something to take lightly in terms of heatsink requirements and transformer ratings.

*note: this assumes that in a practical amplifier using modern devices, no additional compensation is required

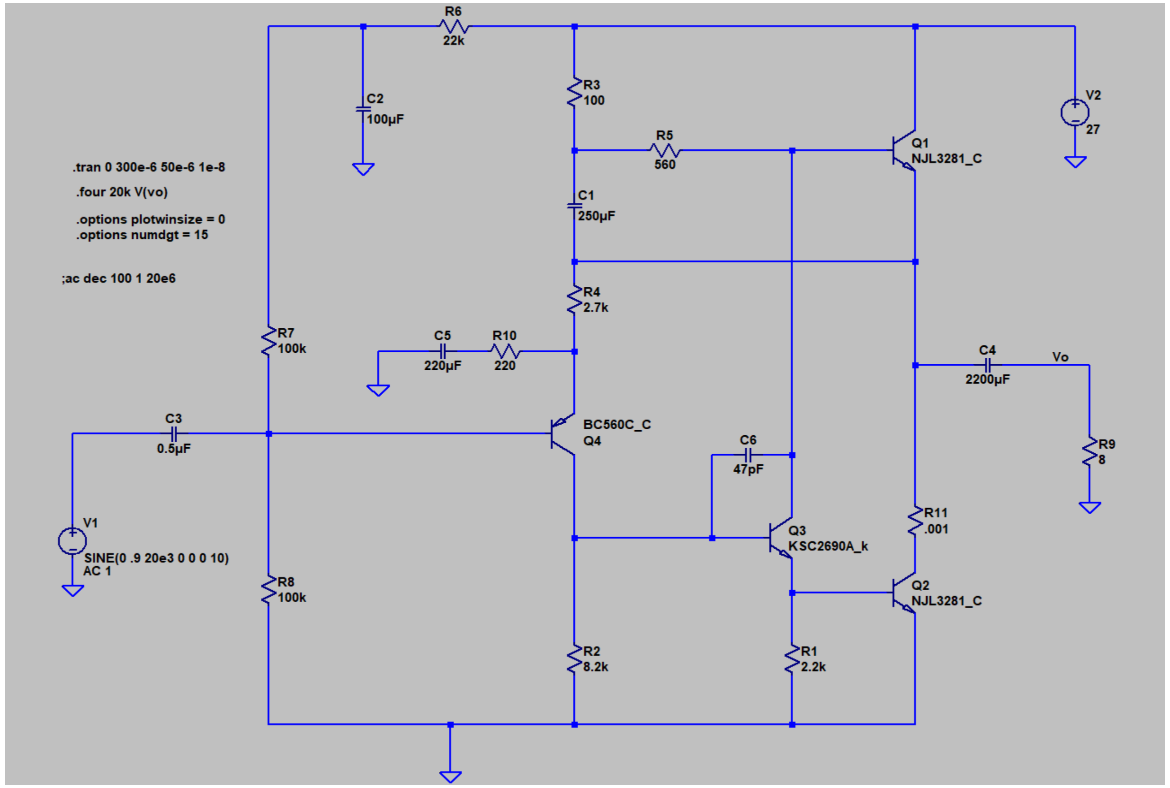
# Some Notes on Class A Amplifiers 2/2

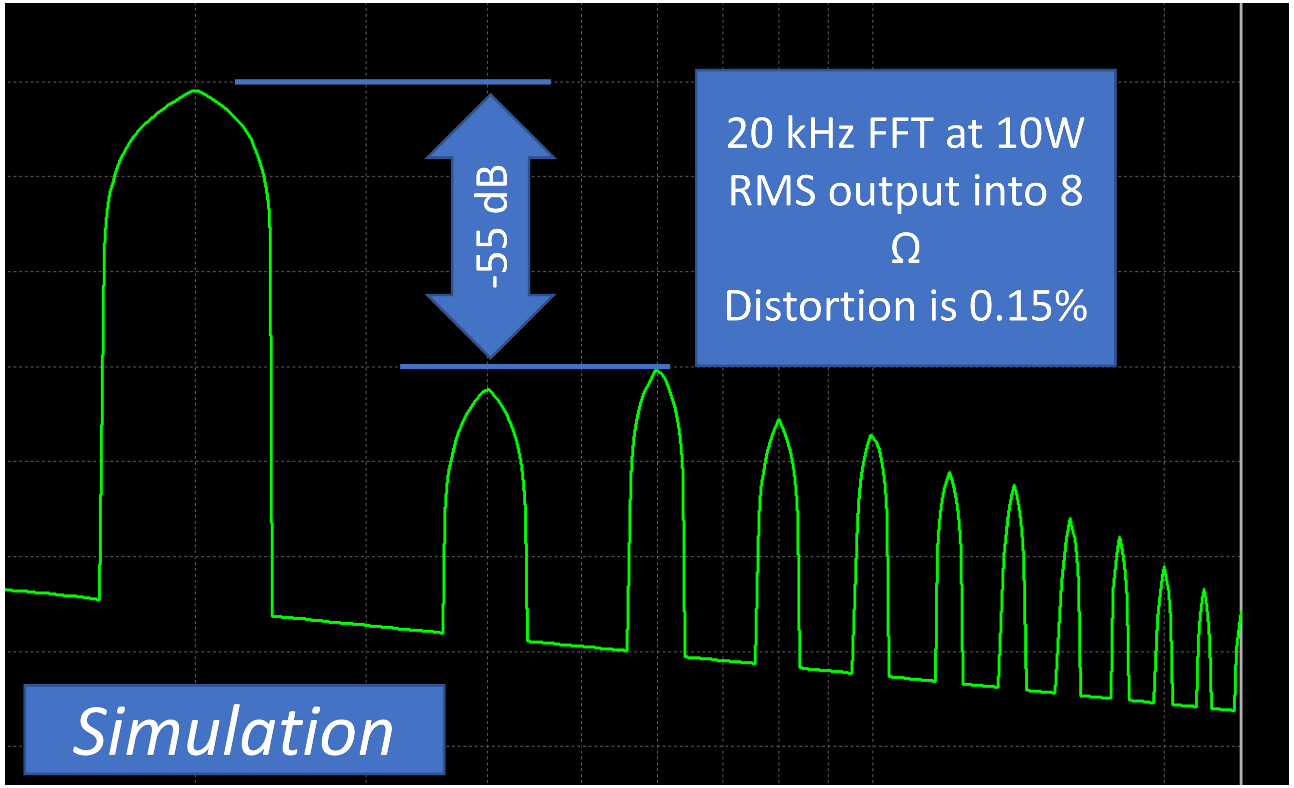
JLH's 10 Watter is a bit like a tube amplifier in that it has to be configured for the speaker load impedance – in a tube amp, you usually have to select a speaker impedance tap on the output transformer. In JLH's design, R1, R2 and C1 are changed to suit the speaker load impedance. The sx and kx, and kx2 amplifiers fair much better in this regard, and simply transition from class A to class AB mode, where they will deliver about 50W RMS class AB into a 4 Ω load. However, on the sx-Amplifier, the distortion increases rapidly at low speaker impedance loads primarily due to the lack of current gain in the OPS – an area addressed in the kx and kx2-Amplifiers through the addition of a driver stage. Clipping behaviour on both amplifiers is soft with no overhang or rail sticking, and in this regard, considerably better than simulations of JLH and Hiraga amplifiers seem to indicate.

A comparison of the harmonic structure of the distortion components on the sx-Amp, JLH and Hiraga designs is given in the pages that follow (LTspice simulations)

The kx and kx2-Amplifiers are somewhat different to all of the other amplifiers. They are undoubtedly more complex because of the added OPS driver and the beta enhancer transistors used in the VAS (aka transimpedance stage or TIS) which provide a 30 dB increase in loop gain. Further, TMC (the earlier kx-Amp used TPC) compensation is used which provides an additional >20 dB loop gain at HF compared to standard single pole (aka Miller) compensation. However, the result of this added complexity is that 20k simulated distortion goes from about 1000 ppm (0.1%) at rated power on the older designs (JLH, Hiraga, sx-Amp) to about 30 ppm – so a 60 fold improvement at 15 W class A. At output power levels below about 8 watts, the 20 kHz distortion is at the single digit ppm level i.e. <0.001% . All THD components are < 90 dB ref rated output power. At >95 W RMS into 2 Ω, the measured distortion are about 0.5%, so heavy speaker loads are handled with ease. This, coupled to the high slew rates and wide bandwidth results in a superb sounding amplifier in my subjective view.

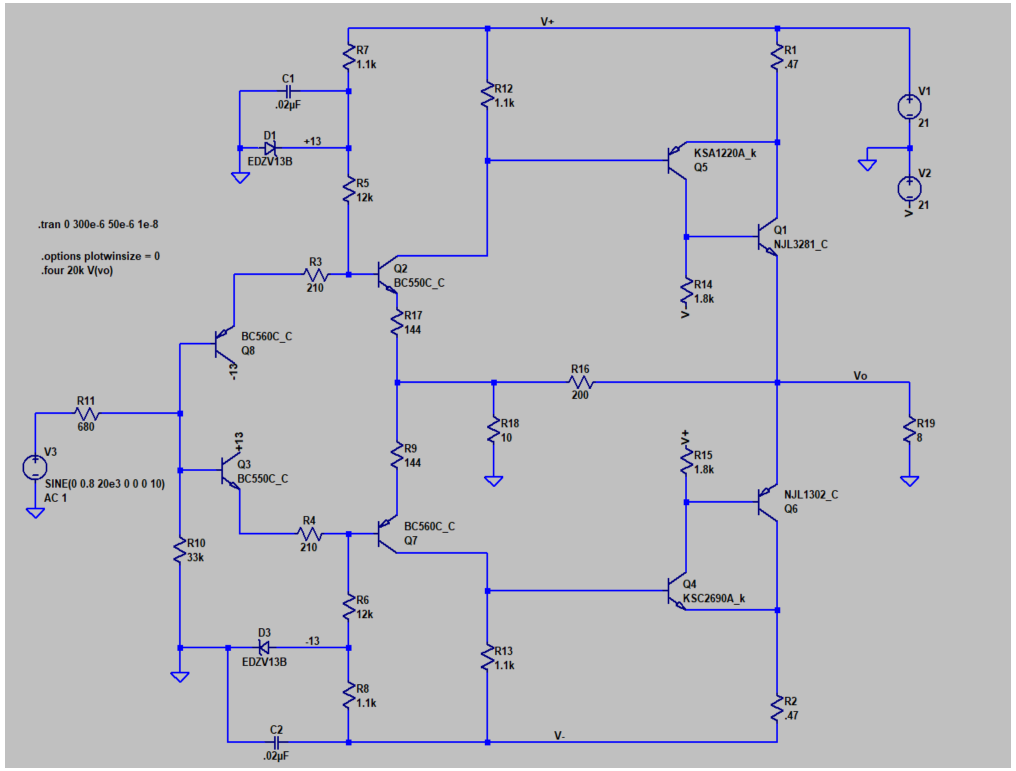
# JLH 10 Watt  8 Ω Performance at 20 kHz

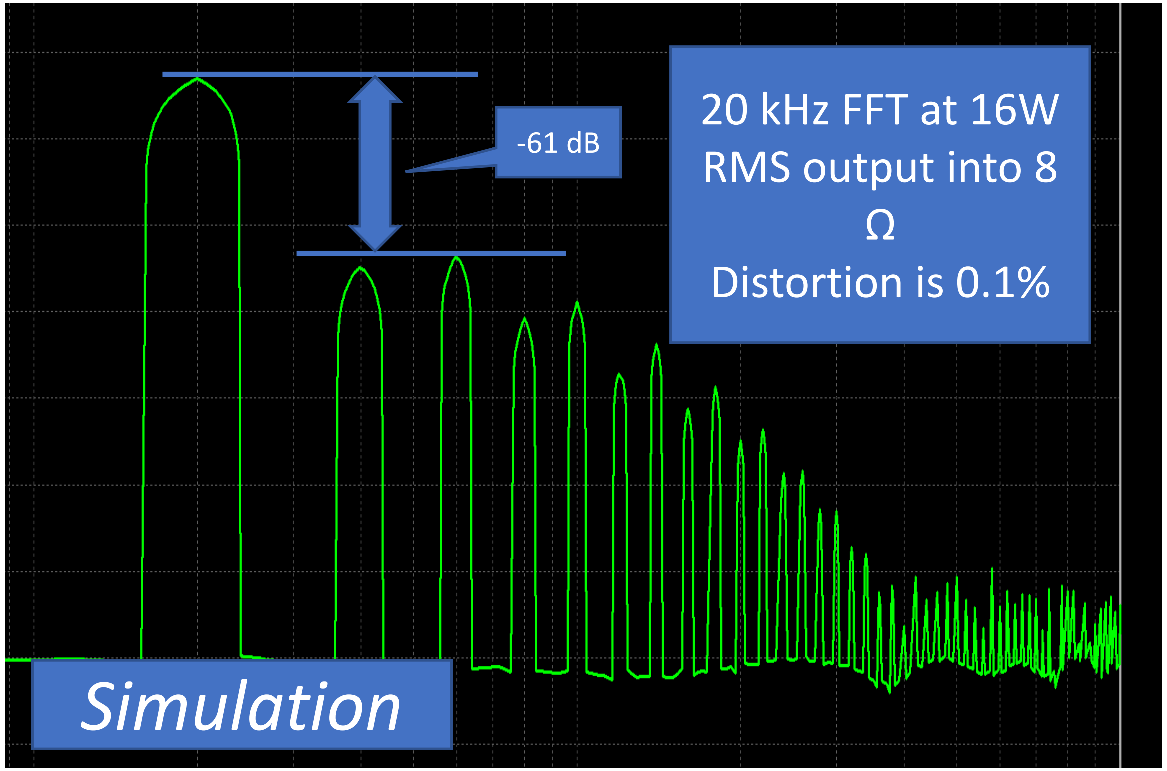



The original JLH 10 Watt amplifier set up for 8 Ω on a 27V supply rail. Distortion is typically 0.15% at 20 kHz and about 0.06% at 1 kHz with a monotonic decline in distortion harmonics after H3. R11 is not part of the original design, but included to measure the OPS standing current, which is 1.2A for the 8 Ω version shown here. The JLH amplifier clips more cleanly than Hiraga's, but not as cleanly as either the sx or kx2-Amplifier. This is one of the simplest 'hi fi' designs you will find anywhere and a testament to JLH's design skills.

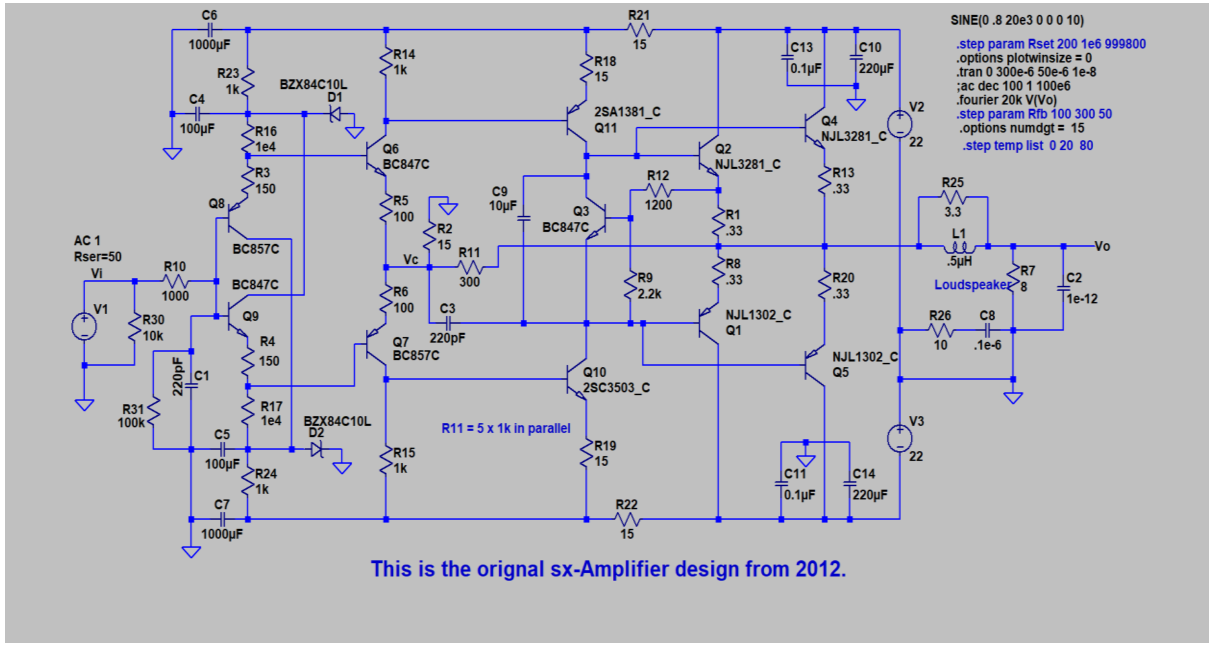
# Hiraga 20 Watt  8 Ω Performance at 20 kHz

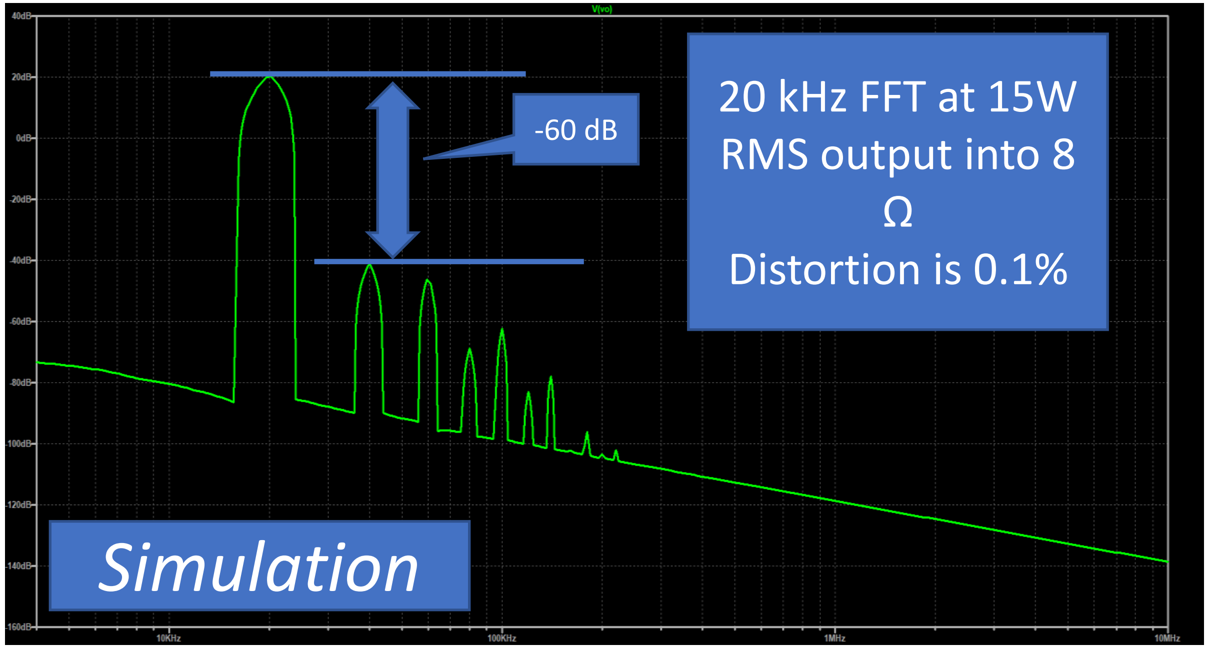



The Hiraga 20 Watt amplifier set up for 8 Ω. The distortion plot was done with +-23V rails.  This amplifier has very high distortion, which seems not to have bothered Hiraga who was happy with the fact that it rose with output power without initially declining and rising steeply at or near full power. This was due to the fact that the baseline distortion is high and well above the noise floor of any reasonable test instrument – at 0.75W output its 20k THD is already 100ppm.  The Hiraga amp does not clip as cleanly as the sx-Amplifier. Very high harmonics will give this amplifier a sweet, rich sound not too dissimilar to a tube amplifier.

# sx-Amplifier 15 Watt  8 Ω Performance at 20 kHz




At 28W peak class A, the  sx-Amplifier produces 0.1% distortion at 20 kHz and harmonic components are primarily 2nd and 3rds.  This design clips softly and exits clipping cleanly without rail sticking or any current and voltage anomalies. It is considerably faster (slew rate and bandwidth) than the previous designs in their original forms owing to the use of fast modern power devices and LTspice to optimize the loop compensation design – both not available to JLH or Hiraga given the vintage of those designs. The design requires that Q10 and Q11 are matched for $h_{FE}$.  A significant improvement in LF distortion can be had by connecting  a 220uF 6.3V electrolytic capacitor from the base of Q3 (-ve) to the collector of Q3 (+ve).

# kx2-Amplifier Build Document Release History

June 2021 – initial release

January 2022 – added amplifier standing current vs supply voltage graph (slide 20)

November 20th 2022 – Q7 errata added to schematic.  The PCB silks screen and schematic called up a BC560 which is wrong – it must be a BC550 or similar NPN. Schematic and overlays in this document corrected and take precedence over the PCB silk screen.

November 25th – corrected formula on Slide 18 – R1 and R8 transposed in the 3rd term ii it should read (R1+R8)/R8 and not (R1+R8)/R1