

Improving kx-Amp LF distortion with the 'Rallyfinen Capacitor'

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Background . . .

- John Atkins ('JA') of Stereophile tests amplifiers using a low frequency (c. 50 Hz) stimulus. I asked him why on one of the magazine's forums and he replied that it was to stress the power supply and then look at the resultant amplifier behaviour – a trick he learnt from reviewer Martin Colloms.
- In most cases, amplifiers are tested at 1kHz and IMD tests are done at 19+20 kHz. Other than JA I am not aware that anyone else stresses amplifiers at LF to LF measure distortion.
- I decided to try this test on the kx-Amp to see how the PSU hum and noise impinged upon the signal at LF.
- My tests showed high distortion at LF and much less at 1 kHz under the same stimulus levels
- My sims at 1kHz did not show any particular problem. I have never looked at LF distortion on either sims or measurements – always 1 kHz and IMD using 19+20 kHz test tones
- Some of you may recall kx-amp builder Andreas (aka 'Rallyfinen') from Sweden reported here on diyAudio in December 2020 that the standing current across the kx-Amplifier emitter degeneration resistors was not clean, but showed high levels of harmonic distortion.
- The next four slides show what I found, comparing performance at 65 Hz and 1 kHz in both class A and class AB modes

FFT: 64k
Avg: 16 of 16
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None

Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz

Peak R: -0.65 dBr

Gen 1: 64.45312 Hz @ -8.2 dBr
Gen 2: 2.000976 KHz @ -61.5 dBr

Phase R: 0.99 deg

Peak R: 15.1 W (8.0 Ω)

SNR R: 91.7 dB

Delay R: 15.4 mSec

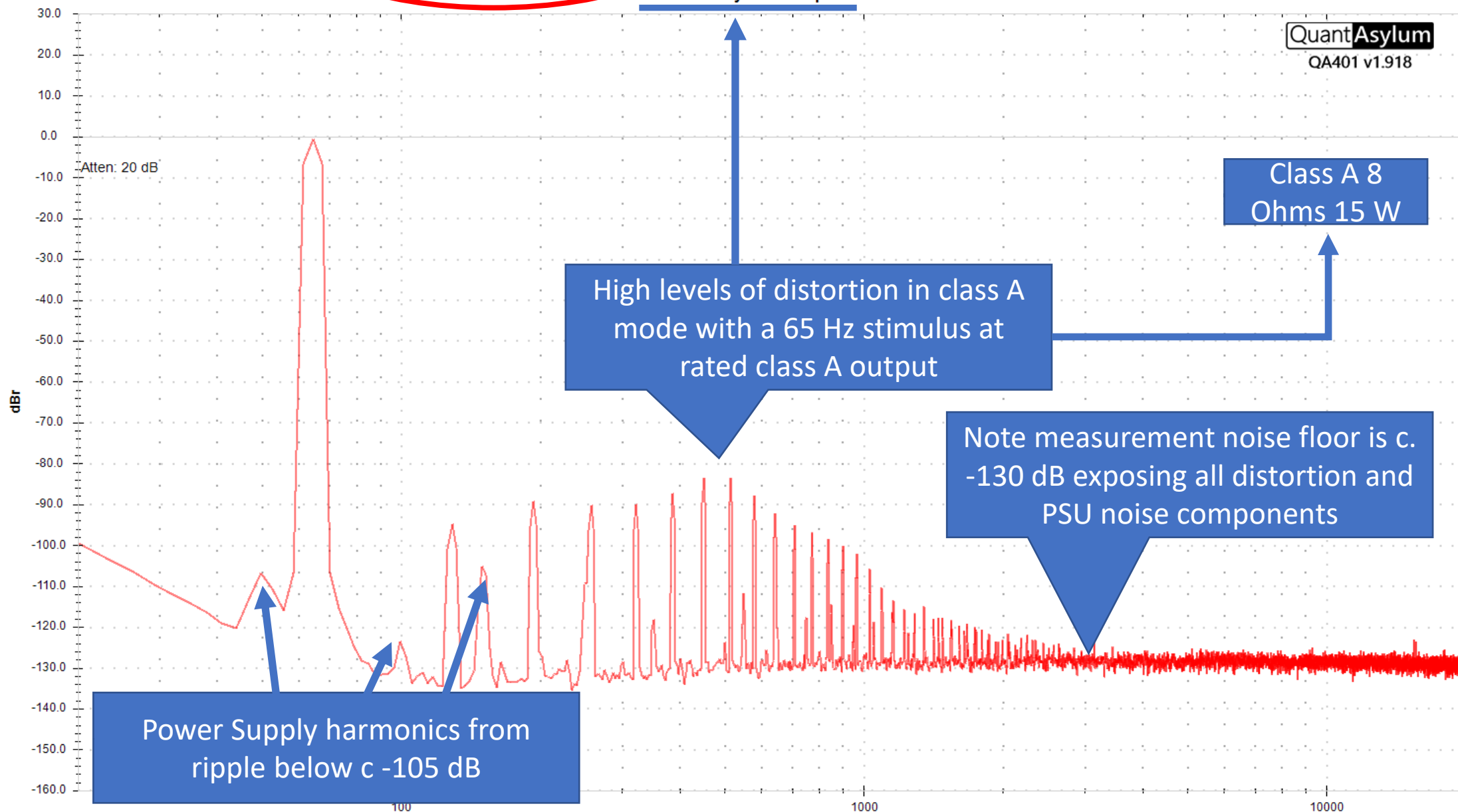
THD R: -76.4 dB/ 0.01506%

THD+N R: -77.3 dB/ 0.01359%

Gain R: 27.56 dB

With NO Rallyfinnen Capacitor

QuantAsylum
QA401 v1.918



FFT: 64k
Avg: 16 of 16
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None

Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz

Peak R: -0.64 dBr

Gen 1: 999.0234 Hz @ -8.2 dBr
Gen 2: 2.000976 KHz @ -61.5 dBr

Phase R: -0.48 deg

Peak R: 15.2 W (8.0 Ω)

SNR R: 91.8 dB

Delay R: 11.4 uSec

THD R: -91.7 dB/ 0.00261%

THD+N R: -88.3 dB/ 0.00384%

Gain R: 27.57 dB

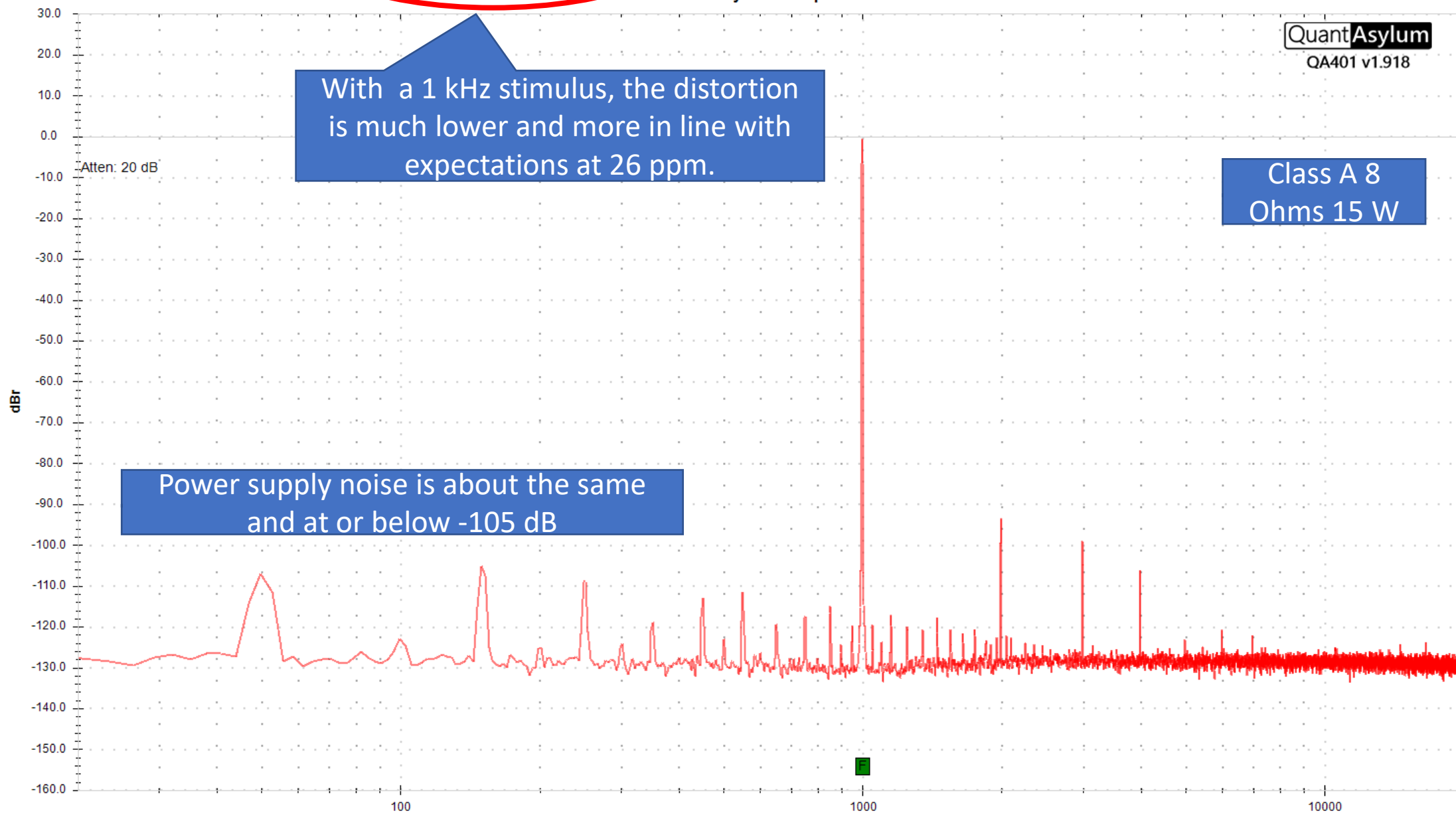
With NO Rallyfinnen Capacitor

QuantAsylum
QA401 v1.918

With a 1 kHz stimulus, the distortion
is much lower and more in line with
expectations at 26 ppm.

Class A 8
Ohms 15 W

Power supply noise is about the same
and at or below -105 dB



FFT: 64k Meas Start: 20.0 Hz
Avg: 16 of 16 Meas Stop: 20.0 KHz
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None

Peak R: -0.26 dBr

Gen 1: 64.45312 Hz @ -7.8 dBr
Gen 2: 2.000976 KHz @ -63.5 dBr

Phase R: 0.99 deg

Peak R: 26.3 W (8.0 Ω)

SNR R: 85.3 dB

Delay R: 15.4 mSec

THD R: -68.3 dB/ 0.03849% THD+N R: -69.5 dB/ 0.03364%

Gain R: 27.55 dB

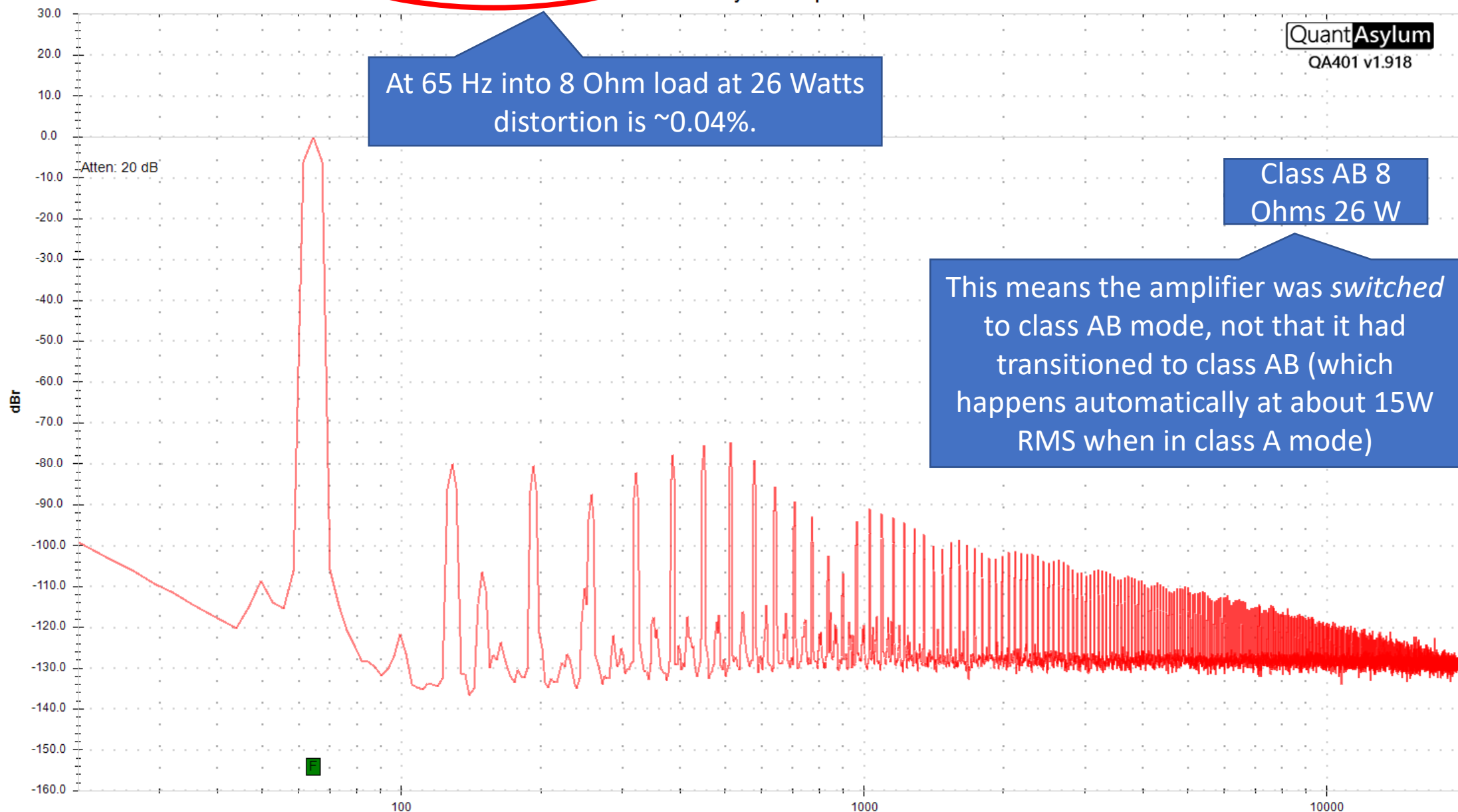
With NO Rallyfinnen Capacitor

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At 65 Hz into 8 Ohm load at 26 Watts
distortion is $\sim 0.04\%$.

Class AB 8
Ohms 26 W

This means the amplifier was *switched*
to class AB mode, not that it had
transitioned to class AB (which
happens automatically at about 15W
RMS when in class A mode)



FFT: 64k
Avg: 16 of 16
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None

Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz

Peak R: -0.65 dBr

Gen 1: 64.45312 Hz @ -7.8 dBr
Gen 2: 2.000976 KHz @ -63.5 dBr

Phase R: 1.01 deg

Peak R: 96.3 W (2.0 Ω)

SNR R: 78.2 dB

Delay R: 15.4 mSec

THD R: -58.7 dB/ 0.11642% THD+N R: -62.5 dB/ 0.07495%

Gain R: 27.16 dB

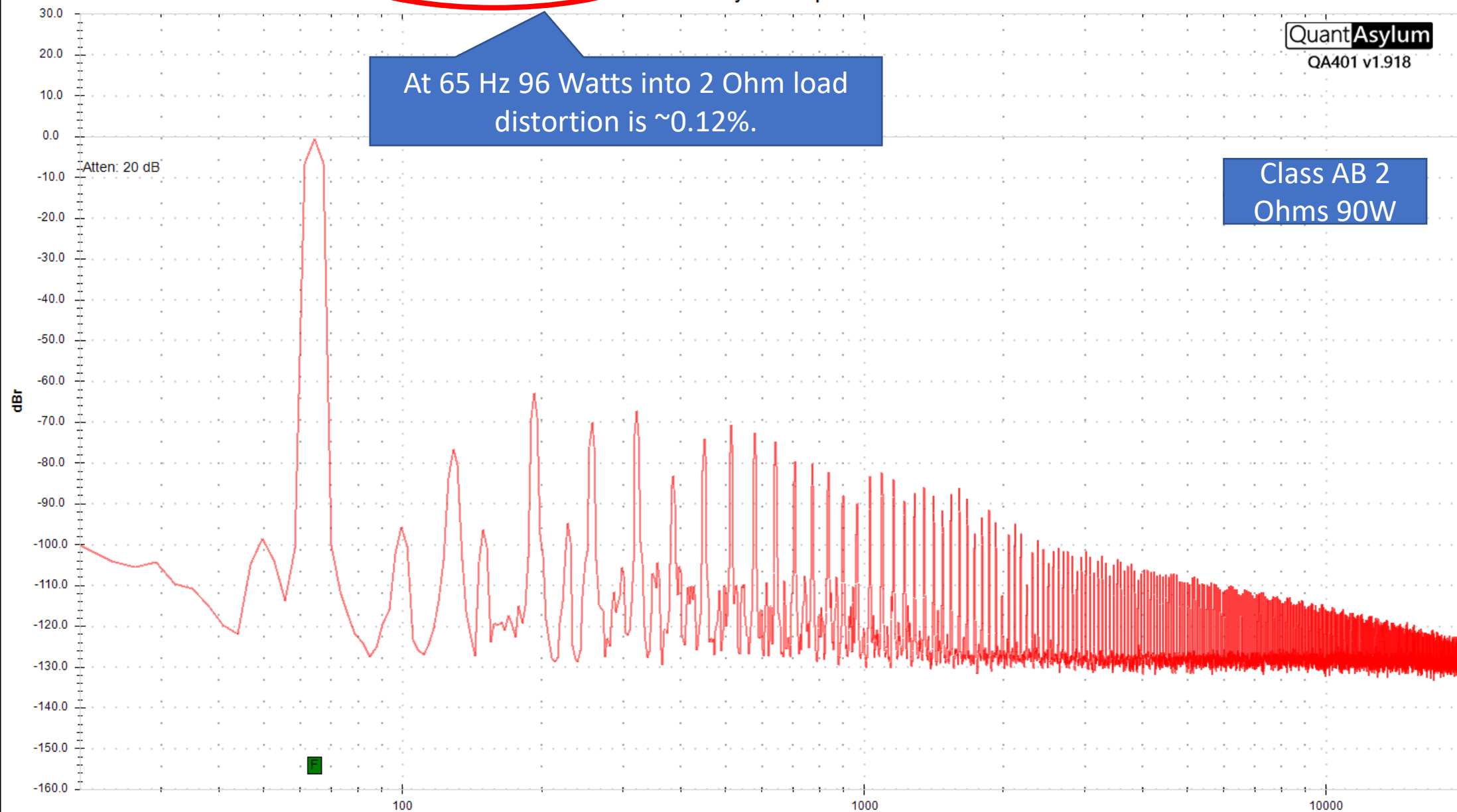
With NO Rallyfinnen Capcitor

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At 65 Hz 96 Watts into 2 Ohm load
distortion is $\sim 0.12\%$.

Class AB 2
Ohms 90W



FFT: 64k
Avg: 16 of 16
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None

Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz

Peak R: -1.04 dBr

Gen 1: 64.45312 Hz @ -8.2 dBr
Gen 2: 2.000976 KHz @ -61.5 dBr

Phase R: 0.96 deg

Peak R: 55.5 W (2.0 Ω)

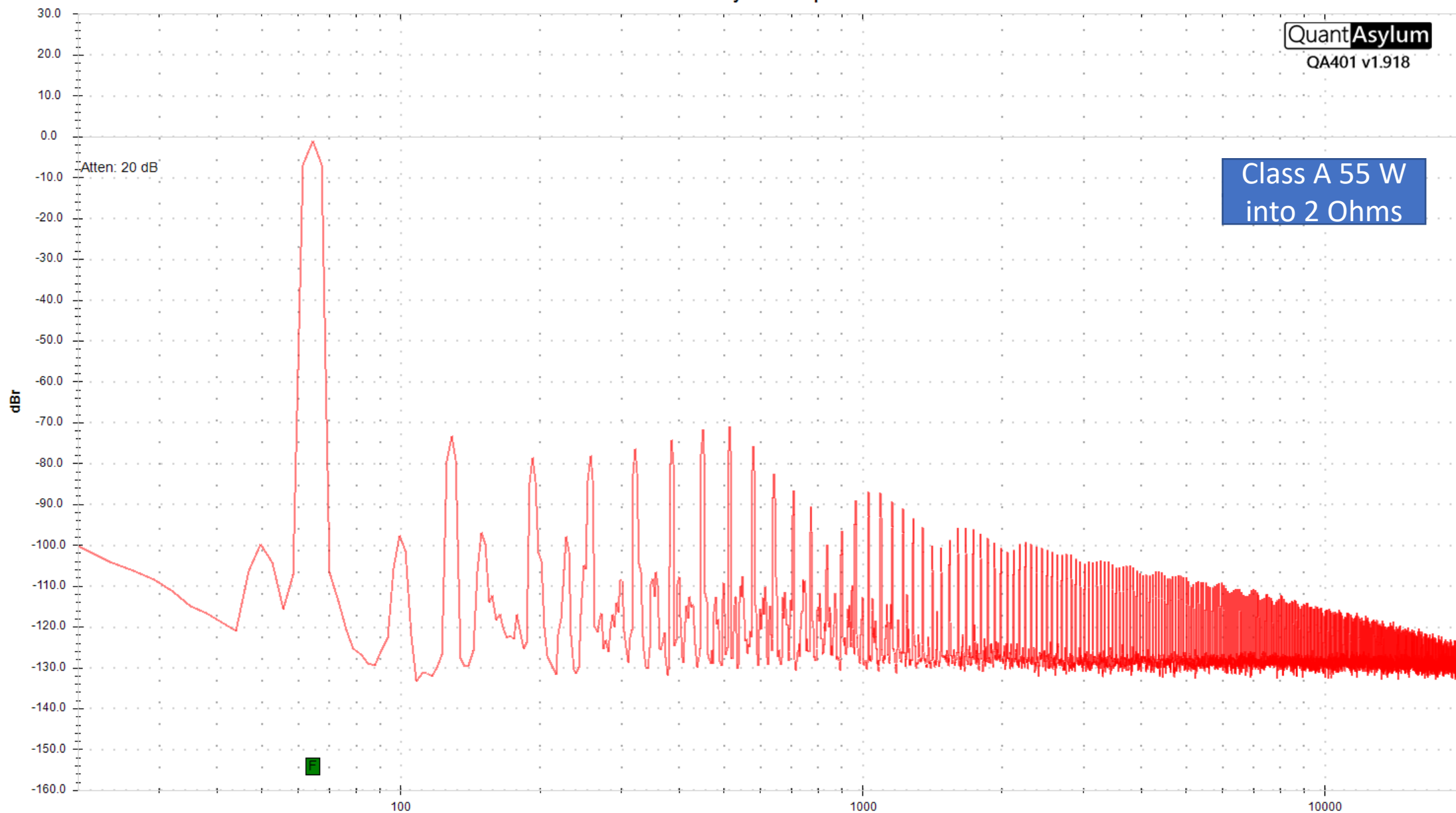
SNR R: 82.4 dB

Delay R: 15.4 mSec

THD R: -63.4 dB/ 0.06772% THD+N R: -64.9 dB/ 0.05710%

Gain R: 27.17 dB

With NO Rallyfinnen Capacitor

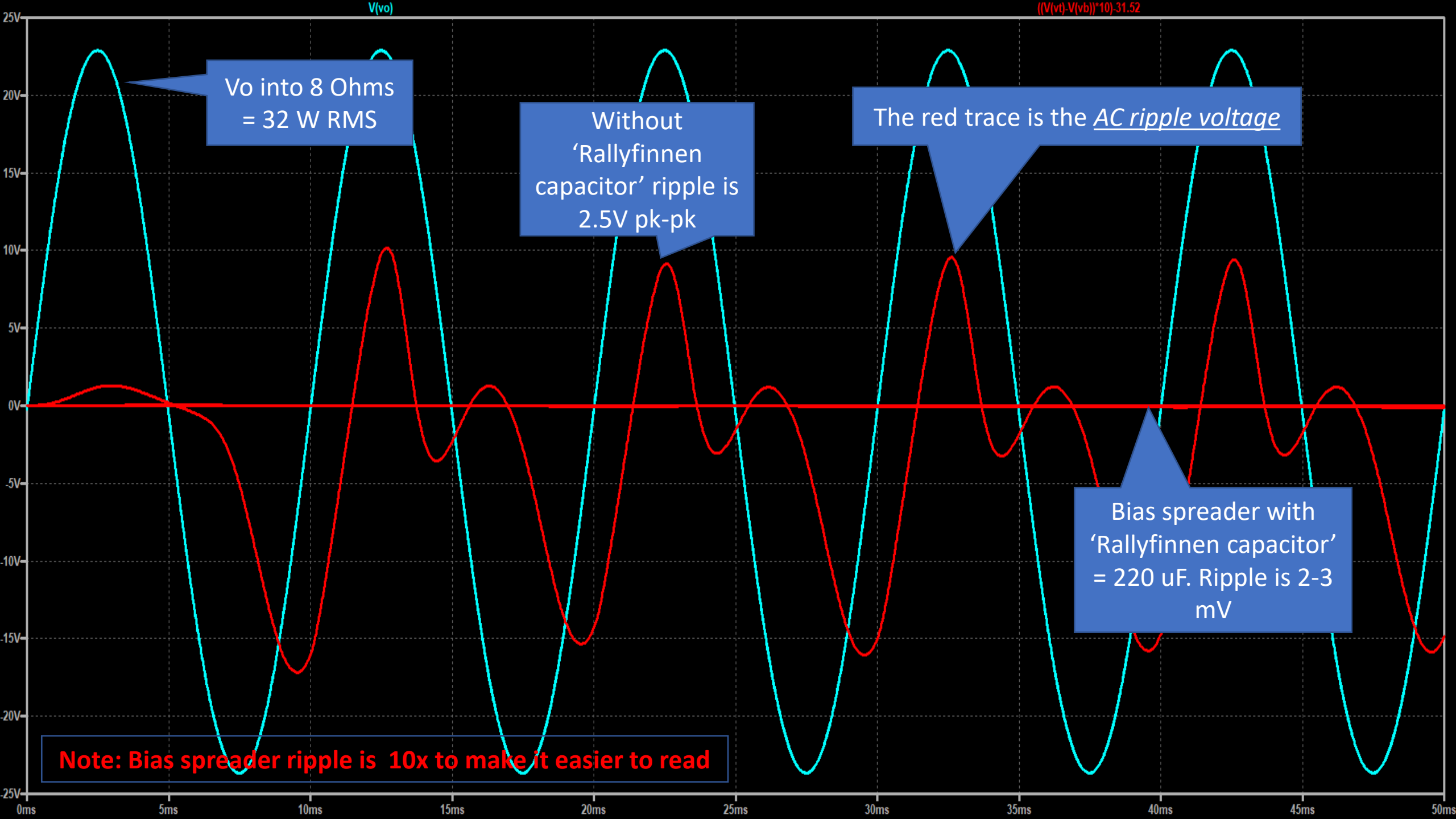


Observations

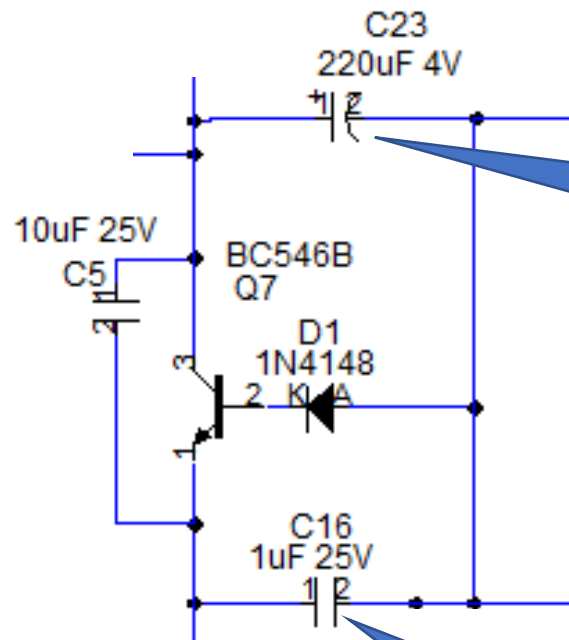
- At 15W RMS output, on 28 V supply rails, the amplifier is well away from clipping in both class A and class AB modes (the mode is selected with a switch at the bottom of my amplifier)
- At LF distortion is high in class AB mode at 15W RMS output
- Distortion at 1 kHz is much lower and more in line with expectations.
- In class A mode distortion is about 3x lower for the same output power, but still higher than expected at LF

Investigation and solution

- Investigations on LT spice showed that the issue was arising in the bias controller – see next slide for the results
- Quick LTSpice sim take away:
 - The OPS bias voltage swings c. $2.5V$ *pk~pk at LF* which is enough to push the amplifier well into class B mode even when class A mode is selected
 - At 1 kHz under the same drive conditions, the pk~pk swing across the bias spreader is about ***100 mV***, so about 25x lower and the OPS remains in class A, but the changes in bias are enough to cause additional distortion at higher power output levels
- To fix this problem, a capacitor of 220uF is placed between the anode of D1 and the collector of Q7 aka the 'Rallyfinnen' capacitor
- This reduces the bias controller ripple voltage by 1000x (60 dB) at LF



Test Results with added 'Rallyfinnen' capacitor



Added capacitor to kx-Amp and sx-Amp bias controller

Note that C16 is not needed with the addition of C23. However, all the sims were done with C16 in situ

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Win: Hann
Weight: None

Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz

Peak R: -0.65 dBr

Gen 1: 64.45312 Hz @ -8.2 dBr
Gen 2: 2.000976 KHz @ -61.5 dBr

Phase R: -178.02 deg

Peak R: 15.1 W (8.0 Ω)

SNR R: 91.9 dB

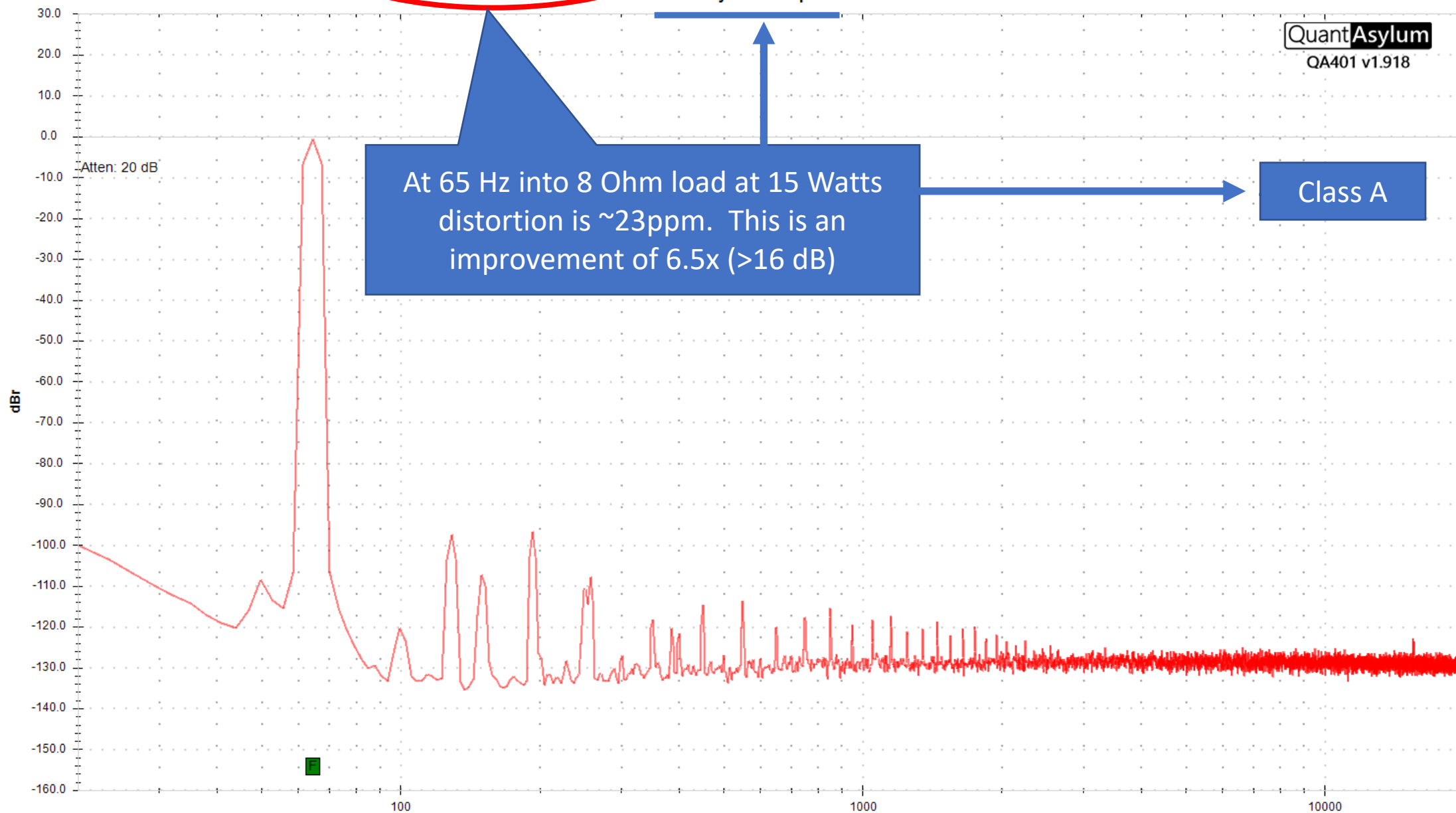
Delay R: 7.68 mSec

THD R: -92.8 dB/ 0.00229% THD+N R: -91.5 dB/ 0.00267%

Gain R: 27.56 dB

With Rallyfinnen Capacitor

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Avg: 16 of 16
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None

Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz

Peak R: -0.65 dBr

Gen 1: 64.45312 Hz @ -8.2 dBr
Gen 2: 2.000976 KHz @ -61.5 dBr

Phase R: -178.12 deg

Peak R: 15.1 W (8.0 Ω)

SNR R: 91.8 dB

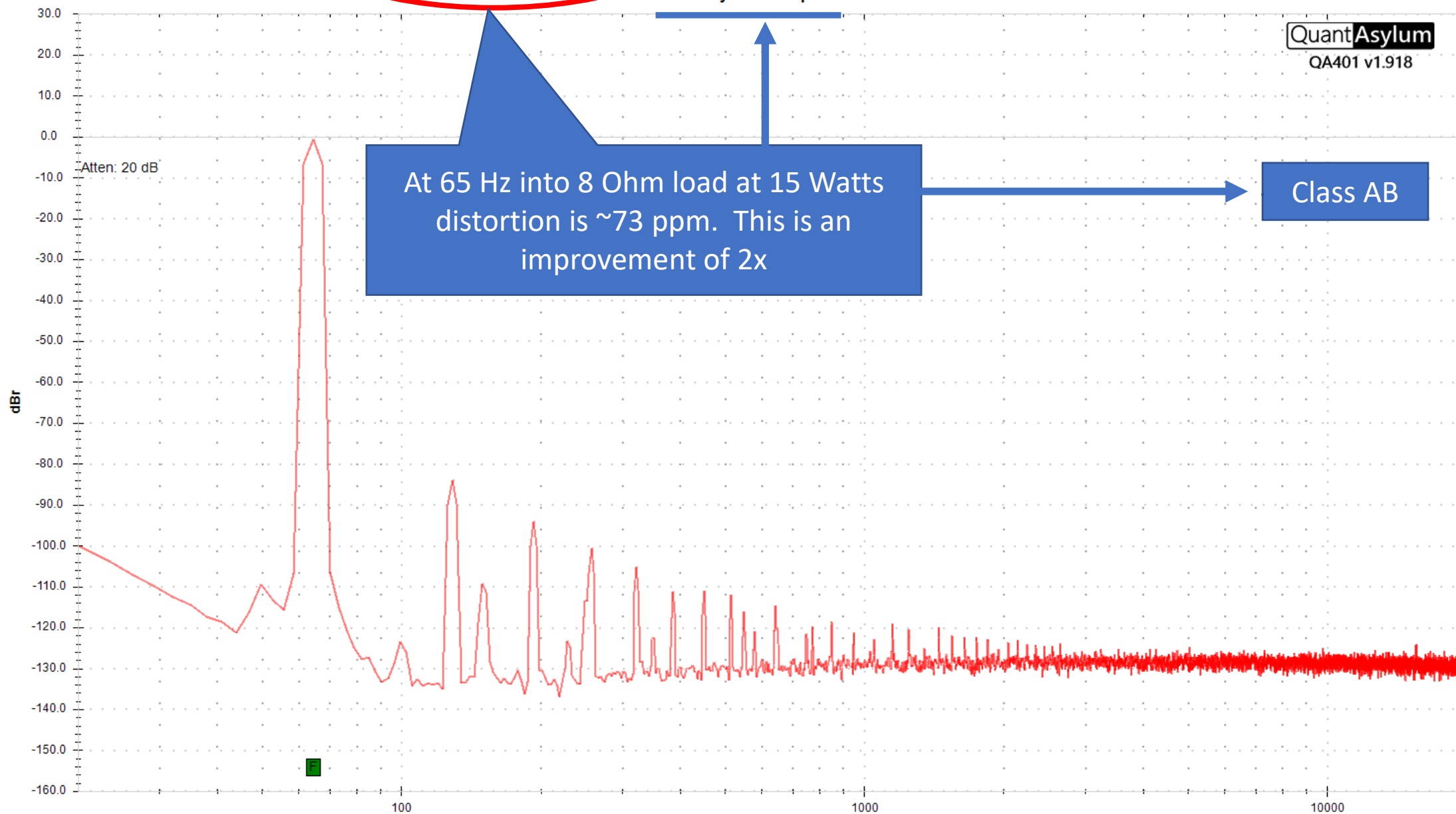
Delay R: 7.68 mSec

THD R: -82.7 dB/ 0.00731% THD+N R: -91.2 dB/ 0.00277%

Gain R: 27.56 dB

With Rallyfinnen Capacitor

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Avg: 16 of 16
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None

Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz

Peak R: -1.04 dBr

Gen 1: 64.45312 Hz @ -8.2 dBr
Gen 2: 2.000976 KHz @ -61.5 dBr

Phase R: -178.05 deg

Peak R: 55.5 W (2.0 Ω)

SNR R: 91.6 dB

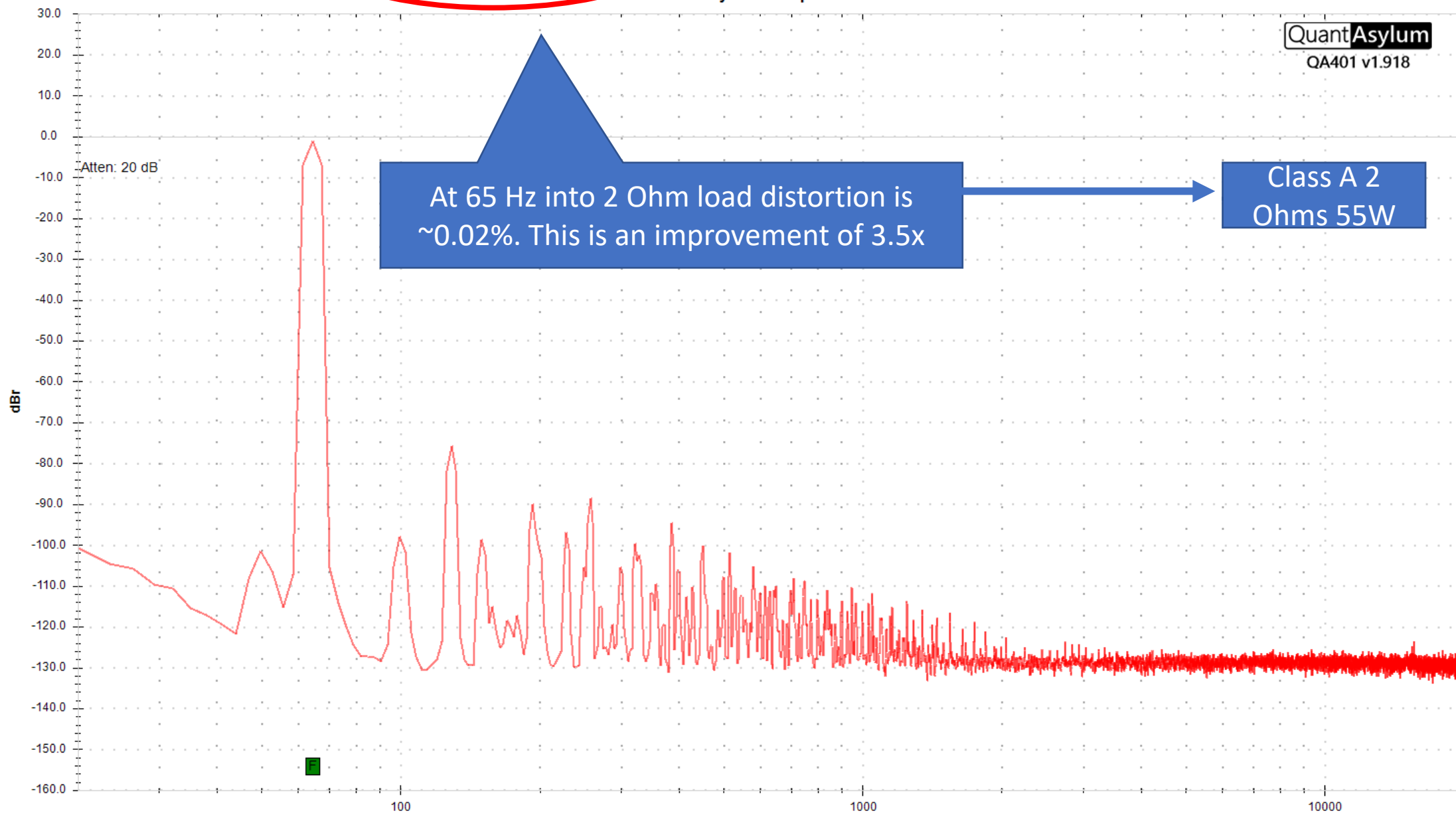
Delay R: 7.68 mSec

THD R: -74.2 dB/ 0.01958% THD+N R: -86.7 dB/ 0.00464%

Gain R: 27.17 dB

With Rallyfinnen Capacitor

QuantAsylum
QA401 v1.918



Conclusions from the investigation

- The cause in high distortion at LF on the kx-Amp (this will also manifest on the earlier class A sx-Amplifier which uses the same bias controller circuit) is due to the modulation of the bias spreader voltage at LF with large voltage swings
- At high output voltages and at LF, the spreader voltage decreases dramatically, reducing the output stage bias causing it go into class (A)B mode. This effect is largely reduced by 1 kHz, but still observable
- The addition of a 220uF 4V capacitor ('Rallyfinnen' capacitor) from the anode of D1 to the collector of Q7 reduces the bias spreader ripple voltage from c. 2.5 V to around 2-3 mV at LF – a 1000x (60 dB) reduction.
- Measurements show a >16 dB reduction in LF distortion with the added capacitor
- The 'Rallyfinnen' capacitor is therefore a good upgrade for the kx and sx class A amplifiers
- Note: standard class AB bias circuits like those used in the nx-Amplifier or similar designs do not suffer from this issue