SPOTFIRE Fusion35 Amplifier Measurements - Draft Prototype Measurements

The SPOTFIRE Fusion35 is a fusion between a two-stage 12AU7 tube preamplifier and a very low distortion generic Texas instruments TPA3255 Class-D amplifier module.

Although the TPA3255 has excellent performance specifications similar to the best amplifiers available today, the Fusion 35 design intentionally adds second-harmonic distortion in order to make the listening experience more engaging and interesting.

By placing the volume control after the tube preamplifier gain-stage, the harmonic distortion level is determined by input signal level, rather than the setting of the volume control.

This placement of the volume control in the circuit after the 12AU7 gain-stage means the volume-control adjustment does not affect the distortion profile, so it does not change the ‘flavour’ of the sound.

The ratio of clean Class-D sound to the warmer tube sound of the preamplifier can be selected by the configuration control. The 12AU7 preamplifier and its following attenuator are relay switched in and out of circuit using a push-on/push-off button on the top of the amplifier chassis. The distortion variation is about 0.4-0.8%.

The following tests were performed in three different configurations.

1. Class-D power amplifier module only
2. 12AU7 cathode follower driving the Class-D power amplifier module
3. 12AU7 preamplifier, 12AU7 cathode follower, and Class-D module.

The distortion profiles show the total harmonic distortion (THD) and intermodulation distortion (IMD) in each of these configurations.

Intermodulation distortion is caused by the mixing (modulation) of signals. When two or more signals are passed through a non-linear device, new signals will be generated at frequencies which are at the sum (addition) and difference (subtraction) of the original signals, producing a complex distortion spectrum.

The same non-linear mechanism that produces harmonic distortion also produces intermodulation distortion - they go hand in hand but can be quite different in presentation. A tube amplifier with modest harmonic distortion would generally be

expected to have modest intermodulation distortion under comparable operating conditions.

Instrumentation

THD, frequency response, noise, and isolation measurements were performed using an HP8903B Audio Analyser, (20Hz - 30kHz using internal HP filters).

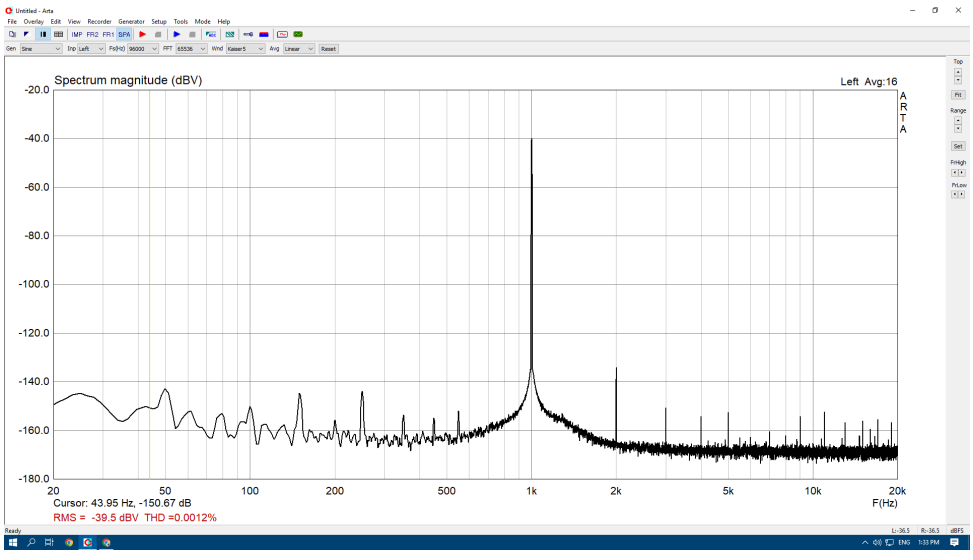
A balanced low pass filter was used in the speaker output leads to remove any residual Class-D switching component which could otherwise affect the measurement , (filter comprising 2x 100 Ohm in each output and 2x 47nF to signal ground).

All graphical presentations and IMD measurements use Arta Software and Focusrite Claret+ Pro DSP. (fs 96kHz, FFT 65,536, Kaiser 5, linear averaging 16, 20Hz - 20kHz)

Intermodulation tests are to DIN 45043 (250 Hz and 8 kHz at a 4:1 amplitude).

Instrumentation Noise Floor

The graph shows the residual distortion of the measurement equipment with the output of the signal generator connected directly to the input of the measuring equipment. Residual measurement distortion is 0.0012%.



Loop-back Test - output of the signal generator connected to the distortion analyser. Vertical scale is 20dB per division.

1. Class-D Module Only

Total Harmonic Distortion (THD) 20Hz to 30kHz

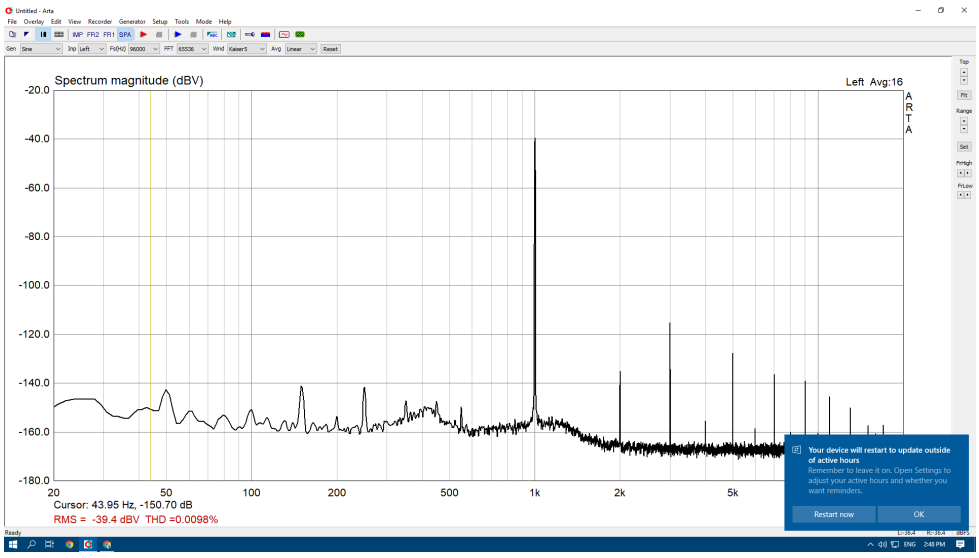
The Texas Instruments datasheet for the TPA3255 shows the Total Harmonic Distortion (THD) to be well below 0.01%. They state a major contributor to distortion is often the speaker output low-pass filter.

These tests were run on the generic Class-D module, with the additional radio frequency (RF) filter in the Fusion 35 amplifier (using 4.7uH SMD inductors) both connected and disconnected.

Watts RMS	THD % - no RF filter	THD % - with RFI Filter
1	0.007	0.012
5	0.009	0.019
25	0.028	0.03
35	5	5

As expected, there is a small increase in distortion at low levels, though this is swamped by the total circuit distortion and of no concern in this design.

The chart below shows the THD for the Class-D amplifier module only, with the additional output RFI filter connected. The graph shows that the distortion is predominantly odd-order harmonics with the 3rd and 5th harmonics dominant.



@ 5WRMS - 0.01% distortion. Odd-order harmonics dominate about 20dB above even-harmonics

Intermodulation Distortion (IMD)

Power output	IMD%
1W	0.08%
5W	0.16%

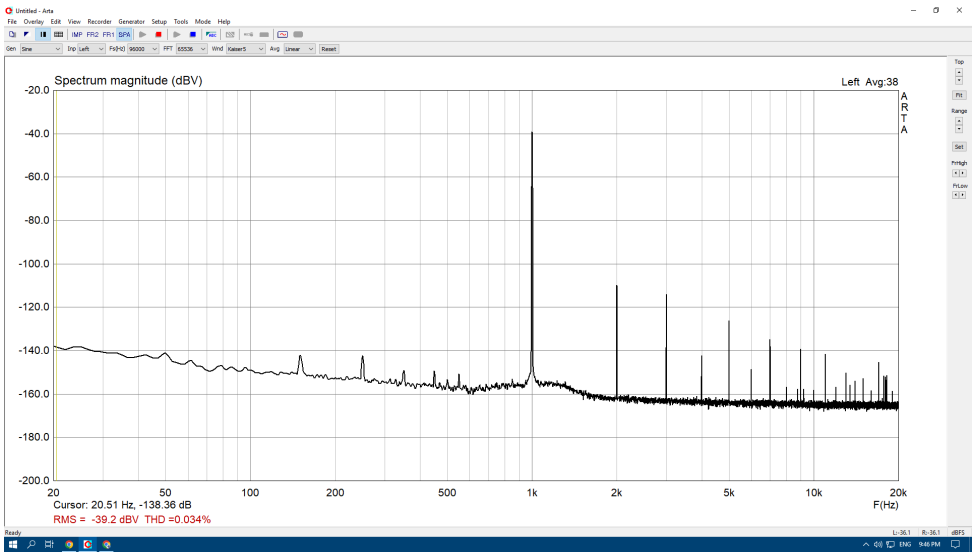
2. 12AU7 Cathode-Follower Driving Class-D Module

In this configuration the 12AU7 gain stage is bypassed.

Total Harmonic Distortion (THD) 20Hz to 30kHz

Watts Output	100Hz	1kHz	10kHz
1	0.05	0.025	0.05
5	0.11	0.035	0.06
25	0.24	0.08	0.3
35	5	5	5

The distortion is higher because it is a combination of the 12AU7 cathode follower driver stage and the Class-D power amplifier.



@5Watts RMS, 0.035% distortion

Intermodulation Distortion (IMD)

Power output	IMD%
1W	0.08%
5W	0.16%

3. Full Fusion 35 Amplifier with 12AU7 Gain Stage

In this mode the 12AU7 gain stage is active and is the major contributor to the distortion profile.

Total Harmonic Distortion (THD)

Test 1 - The following measurements were taken with a constant input of 0.8V and by **adjusting the volume control**. The distortion levels are consistent with having the volume control placed after the input gain stage, with minute distortion contribution from the Class-D output stage.

Power RMS	Distortion
1W	0.8%
5W	0.6%
25 W	0.5%

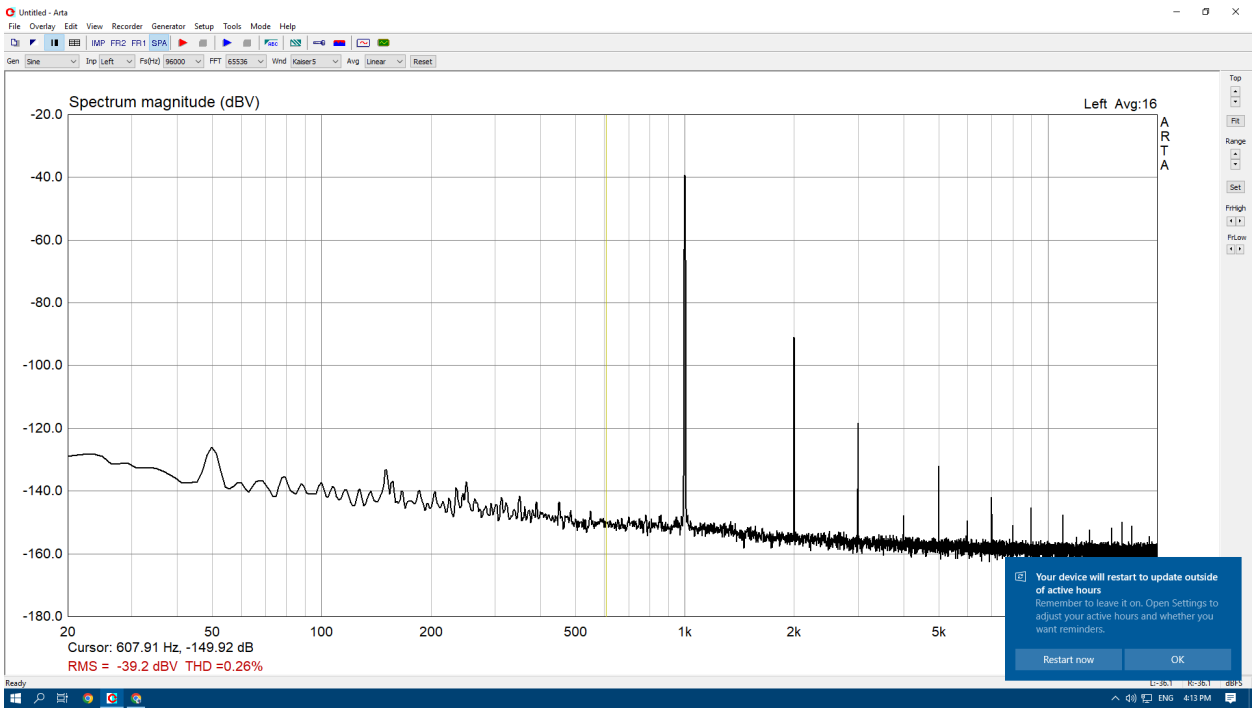
As expected, the distortion remains relatively constant throughout the volume range for a given signal input.

Test 2- The Distortion was then measured by varying the signal input while keeping **Volume and gain/balance controls fixed at half rotation**. The distortion is consistent with the varying level from the source to the 12AU7 gain-stage.

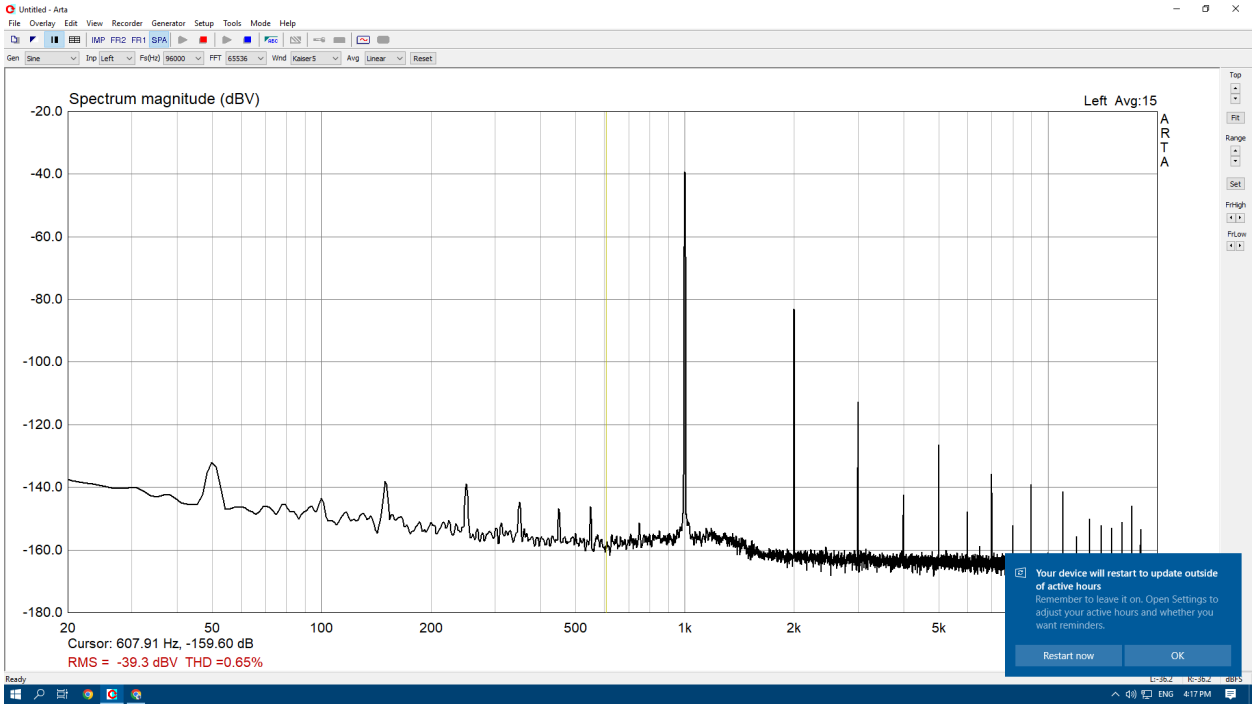
Distortion with power Output and Frequency

Watts Output	100Hz	1kHz	10kHz
1	0.23	0.27	0.26
5	0.52	0.62	0.55
25	1.0	1.3	1.3
35	5	5	5

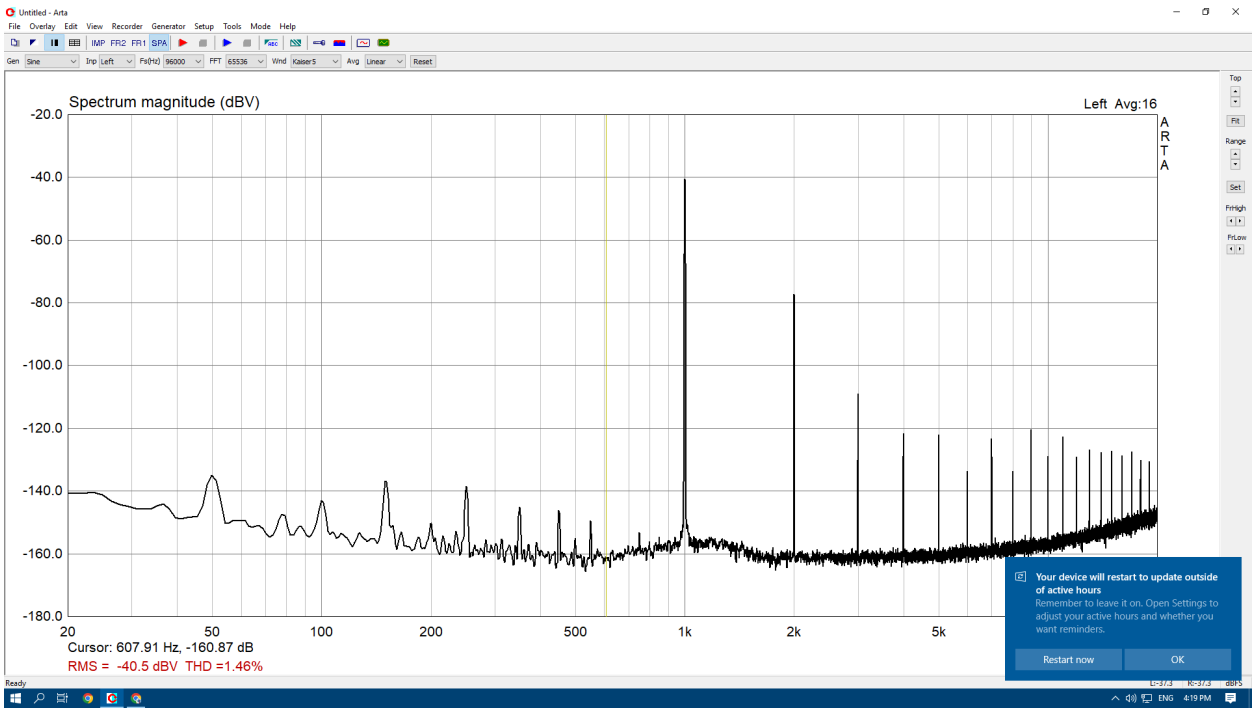
The graphs below show the distortion component at 1kHz at various power levels. At all levels up to about 30 Watts the second harmonic is more than 40dB above the third harmonic and (unlike the Class-D module by itself) even-order harmonics dominate.



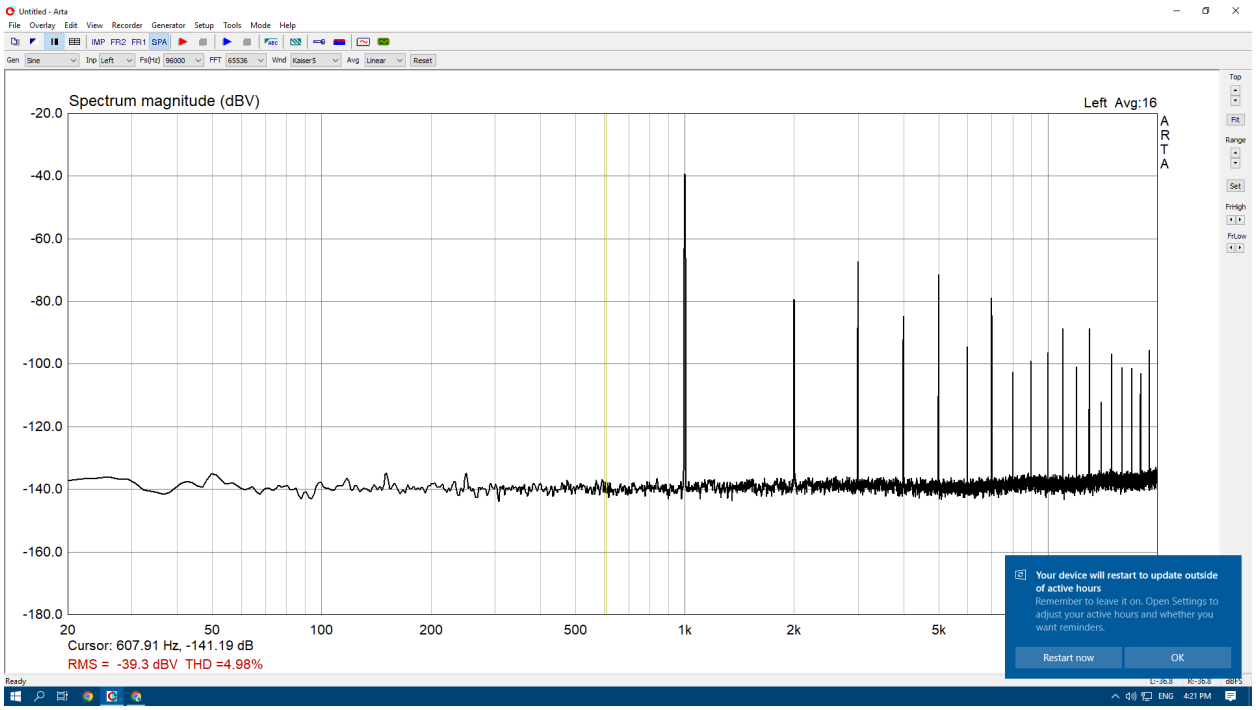
@ 1Watt RMS, 0.25% distortion



@5Watt RMS, 0.65% distortion



@ 25Watt RMS, 1.5% Distortion



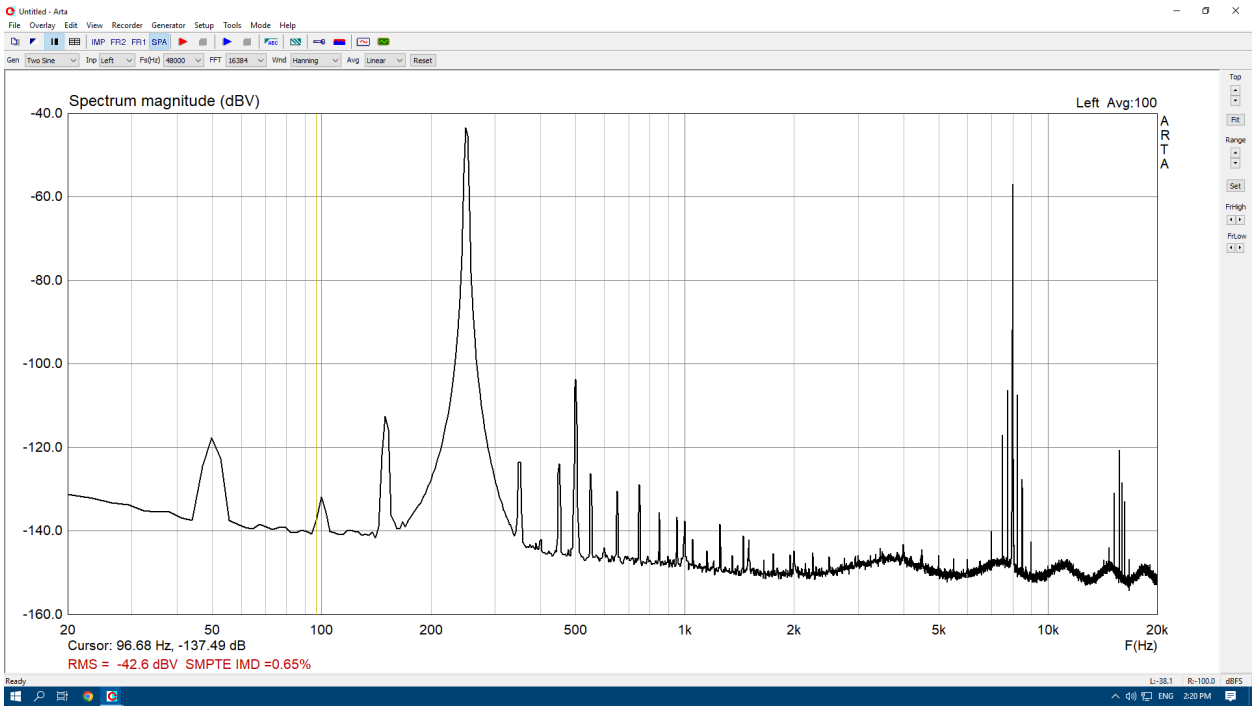
Full Power, 5% Distortion.

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Intermodulation Distortion (IMD)

IMD was measured at 50% volume and balance control settings. (250 Hz and 8 kHz test tones, 4:1 amplitude ratio, per. DIN 45043).

Output Power RMS	**IMD**
1 Watt	0.55%
5 Watt	0.65%



@5Watts RMS, IMD 0.65%

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Frequency Response

To gauge the full low frequency performance measurements were made at 25W RMS output

Response	**Range**
-1dB	25Hz to >50kHz
-3dB	16Hz to >50kHz

Due to the Q of the output filters into an 8ohm load, there is a 0.3dB peak in the output response at 20kHz.

Noise 20Hz - 30kHz

0.6mV RMS unweighted
(-85dB on full output)

Approx. 0.4mV (-88.5 dB) A-Weighted

Adjacent Channel and Cross Input Separation at 1kHz

Other channel terminated in 10K:

Cross Input	-84dB
Adjacent Channel	-70dB

Output Impedance and Damping Factor

Output impedance:	approx. 0.15 Ω at 100 Hz.
Damping factor:	approx. 53 wrt. 8 Ω at 100 Hz.

Square Wave Testing and Overshoot Phase Margin

To come

Power Supply Limiting at Full Power

Both channels were driven to the point of clipping. Channel A was connected to an 8 Ohm load and Channel B left disconnected. Channel A was measured for power output reduction when Channel B was connected to an 8 Ohm load. The output reduction was recorded.

Output decreases by just 0.02 dB

Input Sensitivity for Full Output

0.5V RMS

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These specifications are of the prototype and can change without notice.