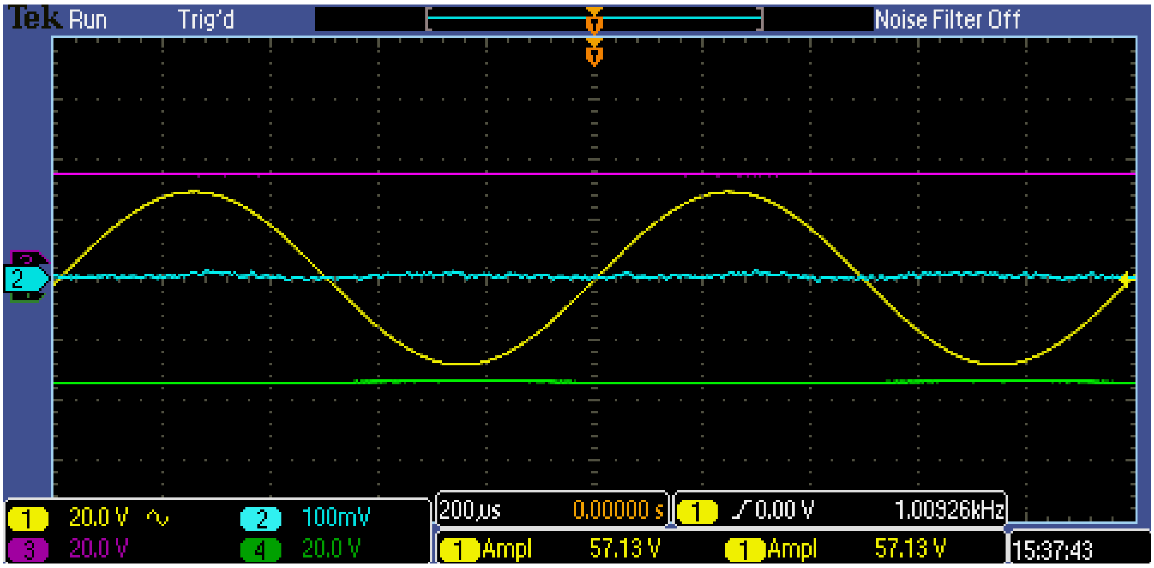
The Technologies Behind the A49

The Arcam A49 is the result of distilling 40 years' experience of audio amplifier design into one compact state of the art package, with the aim of inaudible distortion at all listening levels within the amplifier's power envelope, whatever the loudspeaker load.

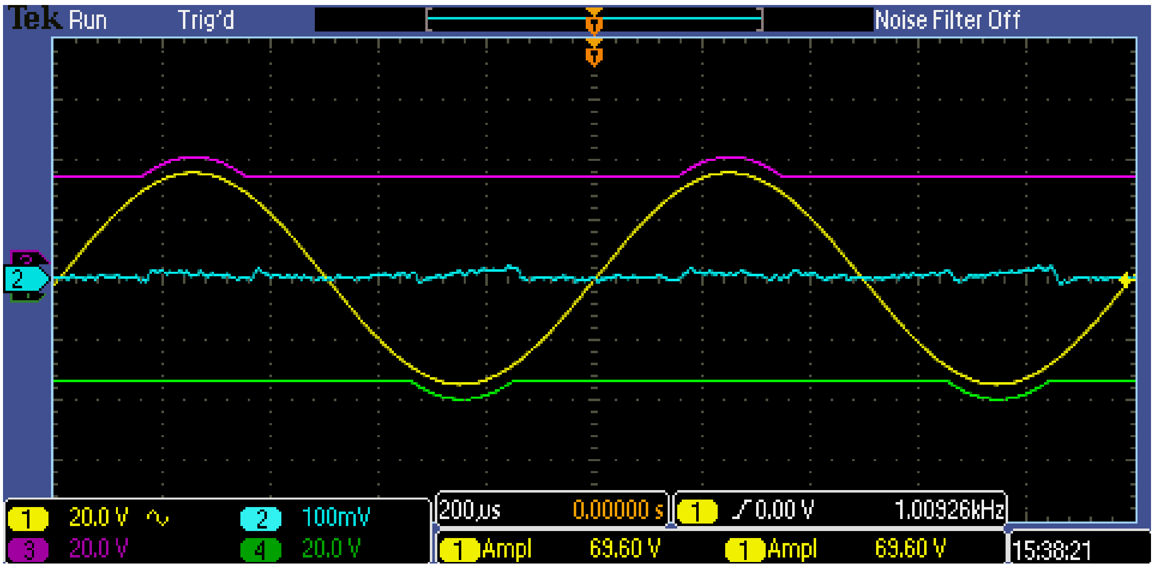
In technical terms the task we set ourselves was a continuous output power of over 200 Watts per channel into 8 ohms, nearly doubling into 4 ohms and with the capability of fully driving loads down to 2 ohms on programme material. At all power levels any distortion produced by the amplifier (harmonic or intermodulation) had to be inaudible. To ensure this we aimed for THD (total harmonic distortion) of typically 1ppm (1 part per million) at power levels of up to 50W into 8 ohms, coupled with minimal high order harmonics above the relatively benign 2nd and 3rd harmonics. This is very demanding and meant effectively eliminating crossover distortion, a particularly audible type of "edgy" and "rough" sounding distortion, which affects the vast majority of class AB audio power amplifiers to a greater or lesser extent.

At the same time, and to fit everything into a reasonable sized case without intrusive cooling fans, we required greater efficiency and cooler running than competitive designs. The solution was to adopt the proven class G technology from Arcam's AVR600 and AVR750 7 channel receivers in the amplifier's output stages. Here two separate sets of positive and negative power supplies are used to feed the output transistors; in the A49 the no-load voltages are +/- 35V for the lower supplies and +/- 65V for the higher ones. The higher supplies are only used when the situation requires it, at the loudest listening levels of above 50W into 8ohms, and are then smoothly blended in as and when required, accurately following the envelope of the signal, so that the operation is inaudible.

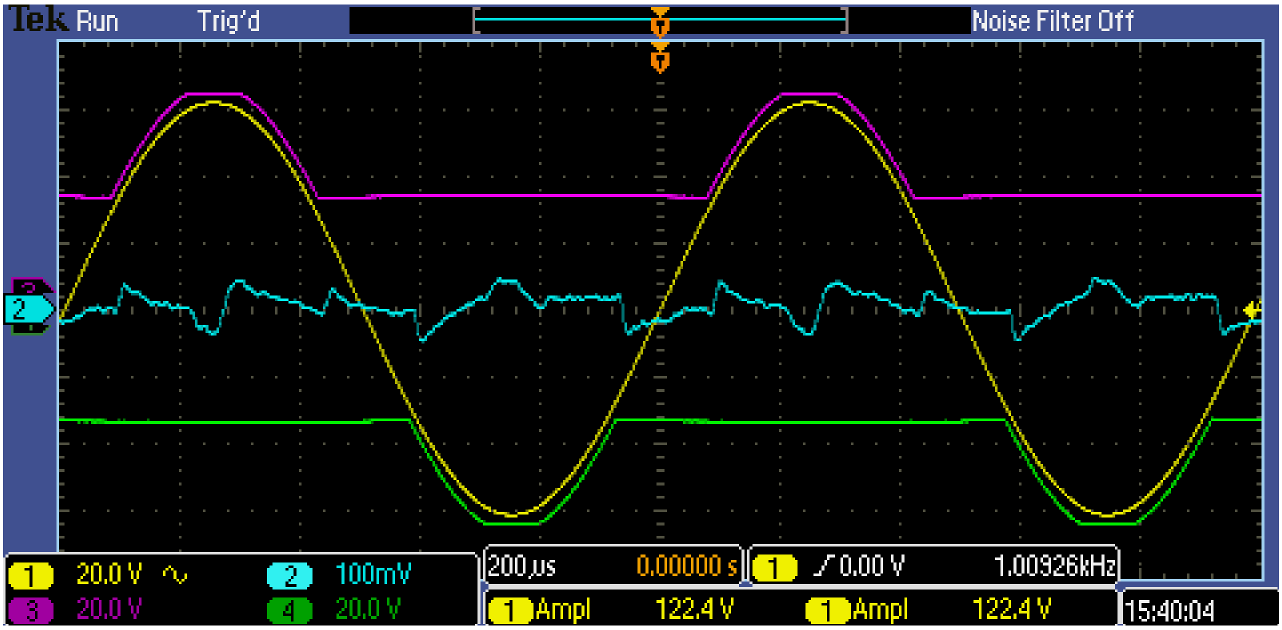
Class G operation illustrated



A49 output transistor collector voltages (Purple +35V, green -35V) at 50W/8 ohms (yellow). The distortion residual is the cyan trace. No class G operation.



A49 output transistor collector voltages at 75W/8R. This shows partial class G operation, for about 40% of the time, with a small increase in distortion due to rail switching. In the class G region about 5V is always present across the collector-emitter junctions of the output transistors to ensure linear operation.



A49 output transistor collector voltages at 230W/8R – just before clipping. The amplifier is in class G for most of the time. The envelope follower operation can clearly be seen and the output stage is still in its linear region, although the transistors have only 2-3V across them on the signal peaks. Distortion is higher but still only a few parts per million (<0.001%) and since it only occurs at the signal peaks it will be masked and thus inaudible.

A49 system overview

It is no good having a great power amplifier without an equally good preamplifier. Just like the power amplifiers, this should have an extremely flat frequency response, very low noise levels and vanishingly small amounts of distortion at normal signal levels. This can be quite challenging when the preamp circuitry is in the same case as nearby power amplifiers and their necessarily large mains driven power supplies, as in all integrated amplifiers. In the A49 preamp, a 4 layer fibreglass PCB is used, with separate ground and power planes, for optimum tracking of the signal traces. The preamp's power supplies are provided by a dedicated toroidal power transformer, entirely separate from the massive 1.5kVA one used for the power amplifiers. The transformer feeds a total of 10 separate regulated supplies for the preamplifier and its control switches. A separate winding also provides isolated +6V and +12V DC outputs for Arcam's various rSeries DACs.

Surface mount components are used extensively, both for a compact design and to minimise loop areas and thus unwanted interference and crosstalk. In addition, the low level audio signals are run in balanced mode throughout the preamplifier (unbalanced input signals are converted immediately after the input selector switching) to minimise common mode interactions with the high swinging currents in the power amplifiers and their power supplies.

The switching itself is electronic, using solid state multiplexers, for silence and reliability. These switches can introduce small amounts of distortion at high signal levels – in the A49 this is kept to typically below 1ppm at normal signal levels. This is achieved by operating them at very high supply voltages and by incorporating similar extra switches, in the feedback loops of the amplification stages in the preamp's circuitry, to perform distortion cancellation.

The A49's volume control is also electronic, using ladders of resistors inside a specialist IC, the Texas Instruments PGA2311UA. This completely eliminates the imbalances and long term wear found in even the very best rotary potentiometers. One stereo volume control is used for each channel in the A49; its two channels are run in parallel, to lower internally generated noise by 3dB, and in anti-phase, to cancel even-order harmonic distortion. The result is again negligible THD levels, below 1ppm, and a very low residual noise floor from the preamp outputs and thus the power amplifiers (typically about -116dB A-weighted referred to full output).

Component selection to achieve this performance level is critical – all resistors in the main signal path are 0.1% thin film surface mount parts. This ensures accurate channel matching and, more importantly, avoids the modulation of the resistor values by the signal voltage found in normal thick film parts. No series coupling capacitors are used in the signal path as these can colour the sound – DC servos at the input to the volume controls and around the power amplifiers ensure that DC offsets are negligible and protect the loudspeakers in case of gross DC being applied to any input from an errant source component. All capacitors that shunt the signal path, mainly to control the amplifier's ultrasonic frequency response, are either film types or highly linear C0G ceramics.

A high quality, low noise phono stage for MM cartridges is provided, based around TI LM4562 op-amps. This includes a 3 pole active high pass filter with its -3dB point set at 20Hz, to provide effective isolation of tone arm resonances and turntable rumble. This is essential to avoid possible damage to ported loudspeakers, given the high voltages and currents available from the A49's power amplifiers.

The active components used are just as critical in achieving ultra-low distortion levels; the input switches and volume control have already been mentioned. The buffer amplifiers are all LM4562s, with extremely low noise and distortion figures, and the high voltage driver for the power amplifiers is the excellent TI LM4702. The output transistors in each power amplifier comprise 3 complementary pairs of 200W OnSemi ThermalTrack bipolar devices, with built in temperature sensing, giving very tight control of the output stage biasing whatever the temperature and load on the output stages. In addition these devices maintain their gain at high output currents, minimising odd order distortion into low impedance loads. Long term overcurrent protection is set at +/- 32 Amps, with a programmed time delay to allow larger short term transients to pass safely.

In a normal class AB amplifier there is an optimum bias current which minimises but does not eliminate variations in output impedance with output current. It is these small but relatively sharp changes which occur at low levels near the crossover point, between the NPN and PNP output transistors, which cause the insidious and audibly unpleasant phenomenon of crossover distortion. The brute force way to eliminate this is to run the output stages in class A, which requires a very high standing current of several amps. This makes the output impedance virtually constant for output currents up to twice the chosen standing current but dissipates huge amounts of power at all times; this is very inefficient, requires huge amounts of heatsinking and is definitely not green! The A49's output stage includes a proprietary error correction circuit that modulates the modest standing currents in the output stage and ensures a near-constant output impedance for peak currents of up to about +/- 4 amps, corresponding to well over 50W in to 8 ohms. The A49 thus behaves exactly like a classical class A amplifier up to this power level in terms of performance but without the heat penalty.

An example of crossover distortion plus distortion data for the A49 at several operating levels into a 4 ohm load, which is twice as demanding as the traditional 8 ohm load, are shown in the appendices at the end of this paper.

The total power consumption of the A49 at nominal mains voltages, including the preamp, display etc., is about 70W quiescent and 220W when delivering 50W per channel into 8 ohm loads – these are very low figures for an amplifier of this overall performance and power rating. Consumption when in standby is less than 0.5W.

The lifter devices that provide the collector voltages to the output transistors (the class G part of the design) comprise 6 paralleled matched MOSFETs per rail, mounted directly on a common anodised aluminium heat shunt for close thermal tracking. When switching between the 35 and 65V power supplies, these lifters are capable of turning on and off as much as 60 amps peak in well under a microsecond without misbehaving – no mean task! This requires very careful PCB layout on a 4 layer board.

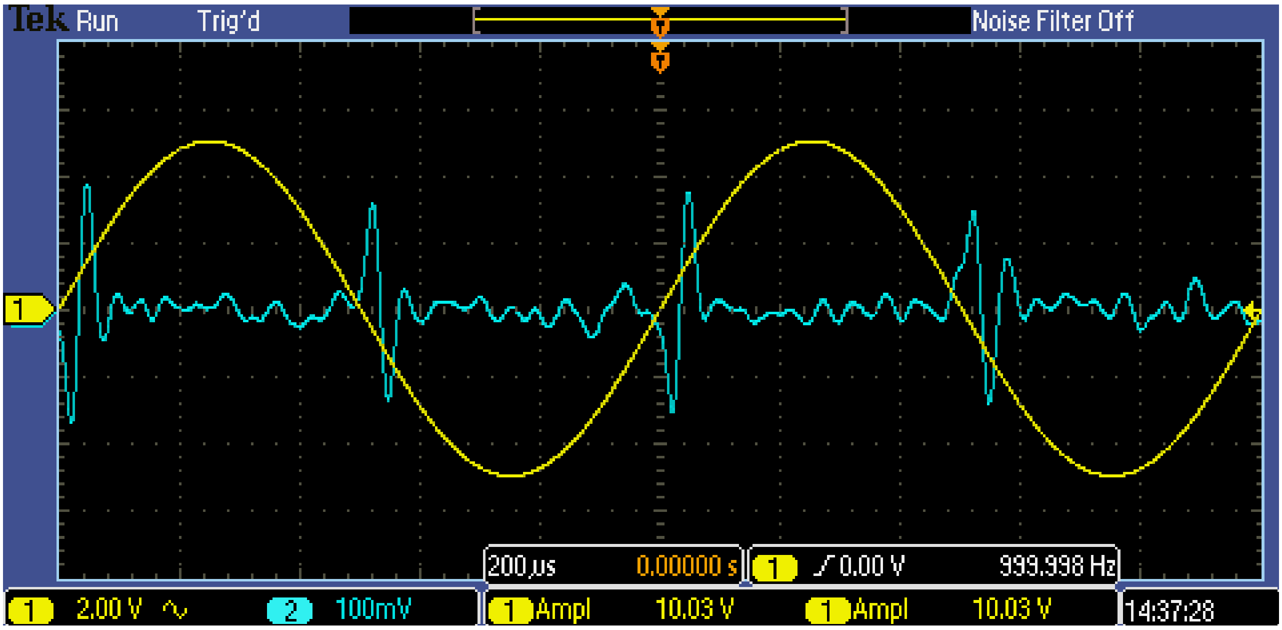
A separate high quality headphones amplifier is fitted to the front panel PCB and is fed via a balanced feed from the preamplifier PCB to minimise interference. It has a very low output impedance (less than 1 ohm) to drive low impedance ear bud type headphones properly, without altering their frequency response, and enough voltage output (>4V rms) to drive the highest quality over the ear headphones to a decent level.

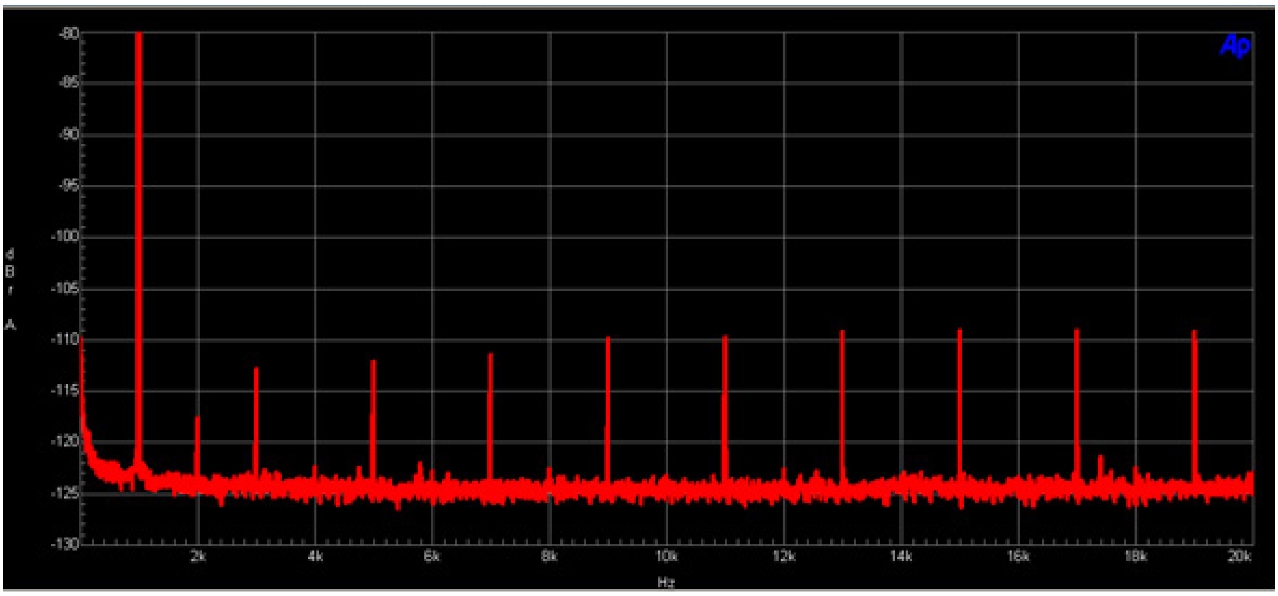
Finally the front panel display, button operation and general housekeeping, including overload protection, is under the control of a microprocessor housed at one end of the preamp PCB. This is fed from the +5V standby power supply and is thus well isolated from the sensitive analogue electronics.

Appendix 1 - Crossover distortion example

The oscillogram and FFT (Fast Fourier transform) plot below is of a 1kHz tone at a power of 2 Watts (2.83V) into a 4 ohm load where 0dBrA on the Y-axis of the FFT equals 2W. This blue trace is the output from the Audio Precision AP2 analyser after the 1kHz fundamental has been removed, and with a 22kHz bandwidth. This clearly shows what crossover distortion looks like. The plots were averaged 64 times to make this clear. It was obtained by deliberately and grossly underbiasing an A49.

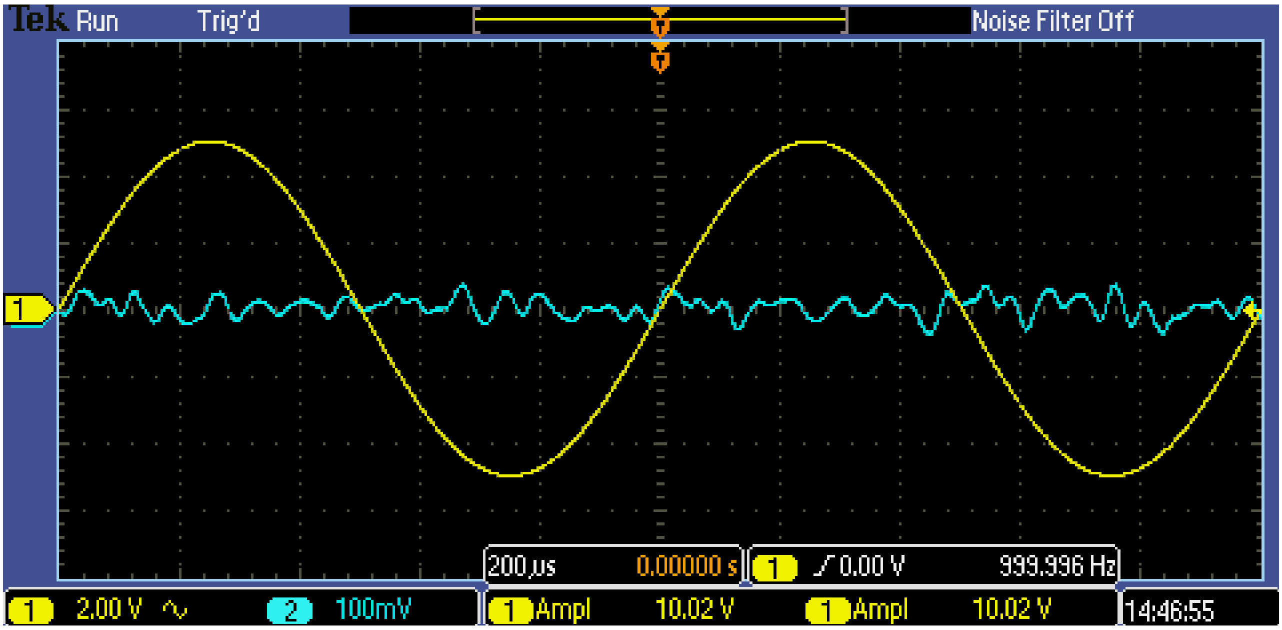
Crossover distortion is due to non-linearity in the output stage whenever the signal crosses through 0V and is thus present all the time, at whatever level music is played. Note the nature of the distortion is odd harmonics whose amplitude does not decrease with the order of the harmonics, so that these are not masked by the fundamental signal.

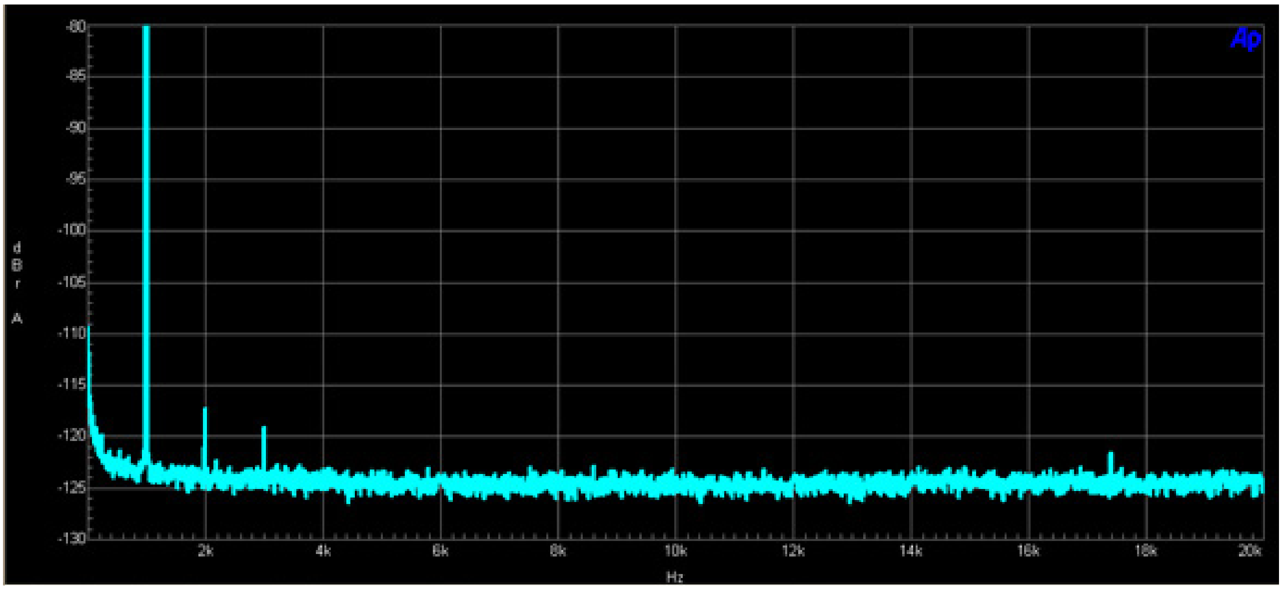




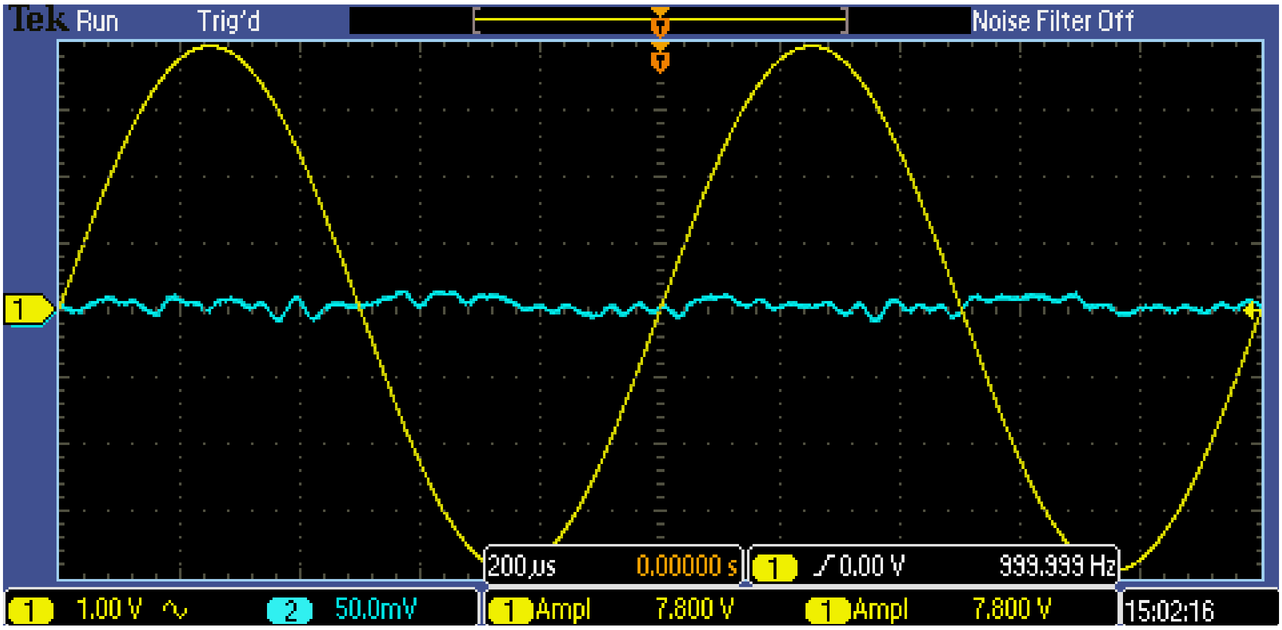
Appendix 2 - A49 distortion behaviour into 4 ohms

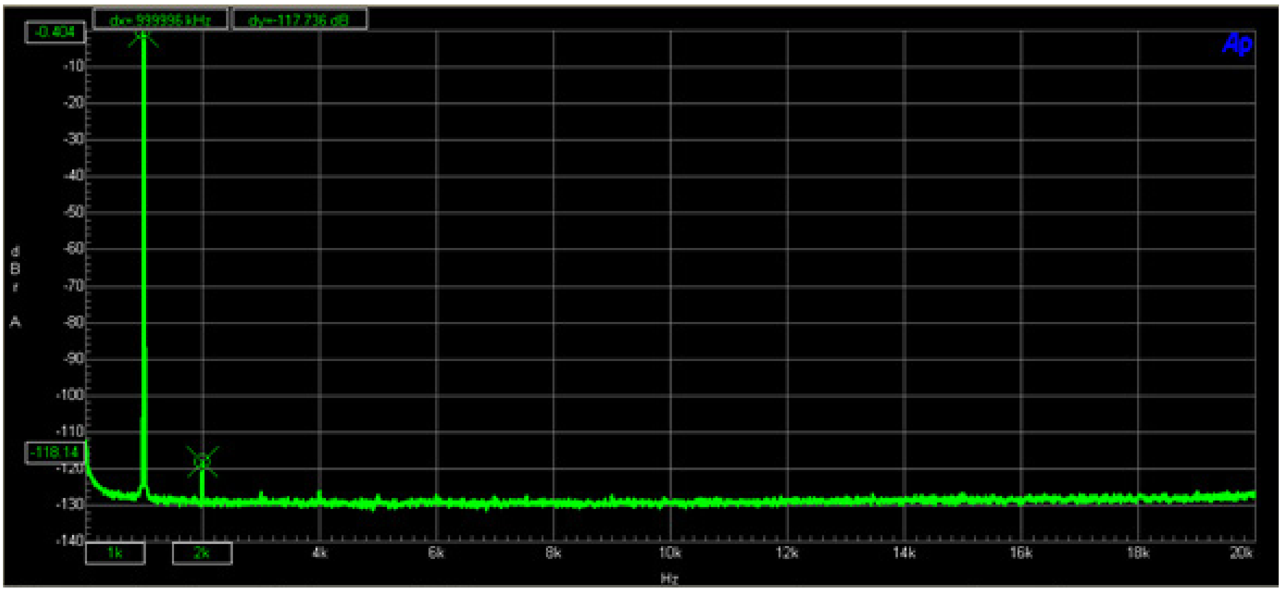
This pair of pictures show exactly the same A49 amplifier, now correctly biased, delivering 2W into 4 ohms as before. Note no distortion is discernible on the oscillogram, only noise. Similarly only traces of second and third harmonics are seen on the FFT, at around -117 and -119dBr respectively; this is actually a limitation of the AP2's analogue to digital converters and the true harmonic distortion of the A49's power amplifier at this level is well below -120dBr or 1 ppm.





The linearity of the A49 with increasing power output is exceptional and this oscillogram and FFT plot shows the same channel of the same A49 delivering 80 Watts into 4 ohms (approximately 18V rms) at 1kHz. This was measured with the same amplitude of input signal, 1.08V, but with a higher setting on the volume control (58 instead of 38). 0dBrA on the FFT is 18V rms.





Note the full dynamic range is shown on this FFT, with an improved noise floor due to the higher output power (the AP's A/D converter is the limiting factor).The residual second harmonic is approximately -118dBr or 1.3ppm, with all other harmonics are well below -126dBr or 0.5ppm. Harmonics of the 50Hz power supply are well suppressed.

Finally the effect of the class G lifters on the residual distortion are shown below, with one channel of the A49 now running at 200W into 4 ohms at 1kHz (approximately 28.3V rms). 0dBrA is 28.3V. Note the bandwidth of the AP's distortion analyser has been increased from 22kHz to 80kHz to show the residual "lifter spikes" more clearly whenever the amplifier switches between the 35V and 65V supply rails. The distortion spikes are still small and in terms of the overall THD residual the high order harmonics contribute much less than the relatively benign 2nd and 3rd harmonics. In any case these will only occur on the loudest transients in music and will thus be totally inaudible in practice.