HALCRO TECHNICAL PAPER

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It is extremely difficult to provide technical details in a white paper without significantly disclosing Halcro's patents and intellectual property, currently hidden from public view. I apologise for withholding some fundamental technical details.

I have loved music all my life, been keenly interested in electronics since about 11 years old, and have very unusual ears; I can hear up to 23kHz in one ear and 21kHz in the other.

In the '70s, I did not convert to transistors, unlike all my audiophile fashionable friends, even when valves were highly passe'. As you can imagine, I was teased mercilessly about this idiosyncratic behaviour. However, I thought that the transistor sound of the day was ghastly; very harsh. (I owned a pair of Mullard 5-20 amps with those wonderful Partridge output transformers!)

For many years I have been the Research & Development director and principal designer of several highly successful electronic companies, which have received many awards, but none of these embraced my passion for music and HiFi.

About 10 years ago, I decided to try to eliminate the harsh sound from transistor amplifiers, for my own pleasure. I think I have succeeded. The result is now manifest in the Halcro amplifiers which exhibit harmonic and IM distortion levels many hundreds of times lower than the typical lowest distortion amplifiers. The best dm68 so far produced measured <25 parts per billion harmonic distortion at 1kHz (!), and the worst unit is a mere 600 parts per billion at 20KHz at full power, a frequency where most amplifiers exhibit very poor behaviour.

Only after I succeeded in producing a satisfactory prototype did it occur to me that I had a worthwhile product that many audiophiles would desire.

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The Halcro specs, which many of our competitors have stated must be absurd nonsense, have been twice independently verified; once by a university commissioned by TAS as stated in a review of a dm58 in the Jan/Feb 2001 issue No 128, and on another occasion by another university as a pre-requisite examination when our company won a business award.

As you can imagine, in order to achieve these ultra-low levels of distortion, all aspects of standard low distortion circuitry required considerable conceptual change; about 12 fundamental conceptual changes in all.

Every stage of every circuit I have ever seen will increase distortion if swapped with the "equivalent" stage in the Halcro amps. Hence there is not even a small bit of the Halcro circuitry that is at all similar to the conventional low distortion high quality circuits. It definitely would take the average amplifier designer quite some time to recognise the circuit as that of an amplifier if presented with no direct clue as to its purpose. I don't think that any designer would guess that the parts list was that of an amplifier if seen in isolation.

The very basic stages can be categorised into a standard "D. Self" format, which is of course the most common architecture:

differential input voltage-to-current converter;

current mirror;

voltage amplifying stage (VAS) incorporating the amplifier's dominant pole which, like the standard circuits, acts as a current-input-to-voltage-output integrator;

and a unity voltage gain power output stage.

The circuit is not fully symmetrical simply because there is absolutely no such thing! The reality is that substantially different transfer characteristics of so called "complementary devices," especially power FETs, utterly overwhelm any attempts at symmetric behaviour.

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By definition, a genuinely symmetric circuit will exhibit distortion from odd harmonics only, with zero contribution from even harmonics; the very antithesis of most designers' wishes! So, I would think that most designers should avoid symmetric circuits if the aim is to have less odd harmonic distortion than even. (Of course the single ended valve circuit is the "ultimate" example of a non-symmetric circuit.) Hence Halcro circuits do not follow the current fashion of so called "symmetry."

The Halcro amplifiers use power FETs in the output stage because the snap-off of minority carriers in BJTs produces cross-over distortion too great to overcome in order to attain the ultra-low distortion of the Halcro amplifiers.

The quiescent current is higher than usual in the Halcro amps so that any cross-over distortion is a relatively low component in the overall distortion (that is ultra low!!). 99% of so called class-A or class-AB amps are, in reality, either class B or barely AB at best. Some do not allow the output current in the output devices to turn off completely and thus the designers feel justified in the A-class claim. However, whatever the circuitry, except for the very rare genuinely class-A "heater!" amplifiers, all commercial amplifiers exhibit significant cross-over distortion at the point where the output current is steered mostly from the one bank of output devices to the other, even in the circuits in which no device actually turns off completely.

Each stage in the Halcro has a bandwidth substantially higher than the conventional circuits, except for the output stage, which only has a slightly above average bandwidth. This was not designed so that more overall negative feedback could be applied, which is not the case, but is a by-product of minimising non-linear parametric effects.

As already stated, each stage has considerably lower distortion than the standard lowest distortion stages. In addition, other parameters of the Halcro design are substantially improved upon compared to the standard low distortion stages, such as:

Input stage: wider bandwidth, higher intrinsic input impedance;

VAS: wider open loop bandwidth, much higher intrinsic open loop input impedance, far more accurate closed loop input "virtual earth";

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Output stage: higher input impedance, lower open loop output impedance.

This is not achieved by any single technique but by a combination of design changes.

Firstly, great care is taken in minimising intrinsic non-linear effects found in all semiconductor characteristics such as variable capacitance, gain and frequency dependence on voltage and current etc. Where possible, the circuit is designed to almost eliminating such effects altogether by ensuring very near constant conditions; for example, the voltage across and current through semiconductors. Many variable components of a signal are absorbed by semiconductors which contribute far less to these non-linear effects owing to the particular design.

Secondly, any residual non-linear effects which are unavoidable are corrected by compensating circuits, but in such a way that they do not intrinsically affect parameters such as gain, bandwidth, phase transfer etc.

For example, the Halcro output stage has very typical frequency response/phase characteristics found in most N/P-FET complementary voltage follower outputs, but in all other respects it

is nearly ideal, having ultra-low intrinsic distortion and nearly infinite input impedance and low output impedance as already stated. Similarly, the basic integrating gain constant of the Halcro VAS is typical of most high quality amplifiers, being about -6.7 kV/microsecond/A.

The power stage is separated from the input stage by a substantial eddy current screen so that any non-linear magnetic fields generated by the output power devices are isolated from the input stage. It would be impossible to achieve the very low distortion without this feature. The power output PCB is a six layer PCB and is designed to:

cancel non-linear magnetic fields;

improve upon the output stage bandwidth and stability;

and to accurately define references such as earth, output signal, etc.

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A very substantial gold-plated solid copper co-axial transmission line connects the input stage to the output. The loudspeaker output terminals are connected to an extension of this coaxial line, once it has passed through the input PCB. The input PCB is a 4-layer board so that output, earth, etc potentials are well defined.

The circuits include much protection; for example, the inputs are clamped to be within certain voltage limits.

The actual instantaneous power dissipated in each bank of output devices is calculated by means of a calculating circuit, then averaged. This, together with the measured heatsink temperature, is fed to another calculating circuit which determines whether the output devices are being stressed. If so, this circuit will gradually reduce the maximum available current output. In practice, the heatsink has to be very hot and the output power very high before this occurs, and this is in reality a protective feature which acts only when conditions are extreme. Another circuit senses both d.c. offset and average output current. If either is unreasonably high, the unit will shut off. This is an independent circuit which will still operate even if other faults exist, such as that which may have caused the unreasonable d.c. offset in the first place.

The Halcro power supply is housed in a separate compartment to the amplifier. It has "active power factor correction" which means that it "looks like a resistor to the mains". That is, the mains current waveform is undistorted, unlike the case

for 99.9% of all mains electronic products which use peak rectification power supplies that produce highly distorted current waveforms.

Unlike all other power factor correction circuits (found in industry) that operate over a large mains supply voltage range, the Halcro electronics has a fixed switching frequency which is above 100kHz regardless of load conditions or mains voltage. All other competitive devices have variable frequencies which usually get into the audio range, an obviously undesirable feature.

No mains potential semiconductor power device in the power supply is mounted onto the chassis; all are completely physically isolated. The common practice of mounting the semiconductor chassis at mains potential is not only dangerous, but is prone to generating electromagnetic interference.

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It could be said that the skill of an acute audiophile ear resides in its ability to perceive false signals among desired signals. One obvious aim of the Halcro technology is to reduce false signals to such a low level that they are quite inaudible. The international specified intermodulation tests (IHF-IM and SMPTE-IM) are indicative of the extent to which false tones are generated by an amplifier.

These tests apply, simultaneously, different inharmonic tones to the amplifier, as is the case with music (chords for example). The level of false inharmonic tones is then measured. The threshold of hearing of the human ear is attained when a pure tone (1kHz) of about 10microV is applied to a typical high-end loudspeaker (90dB @ 1W @ 1m) at a typical listening distance. All Halcro products produce false tones at considerably lower levels than this threshold at typical loud listening levels. No other amplifier company can make this claim.

It is often assumed that if the distortion of a product is less than the measured noise, then it is necessarily inaudible. This is not necessarily so. As is well known, ears behave much more like spectrum analysers for short periods rather than time-domain analysers. It is thus also well known that ears can detect tones or specific frequency spectra in noise even if the noise is far greater in amplitude. Hearing a conversation in a noisy crowd is an example of this, where one's brain continually selects frequency spectra to optimise the signal to noise ratio. In order to measure the THD + N across the audio band, the measuring FFT analyser's bandwidth needs to be set to 100kHz to measure at least up to the 5th harmonic of 20 kHz.

If an amplifier has an input referred noise of, say, 10nV/sqrt(Hz) and a gain of 30, then the measured noise is 10nV/sqrt(Hz) x sqrt(100,000) x 30 = 100microV; that is substantially more than audible 10 microV referred to above.

Even though this noise voltage is far greater than the 10microV tone limit of a human ear, it is interesting to note that the same ear would be quite incapable of detecting this noise, simply because the noise density is low: the human ear can easily hear a difference of 1Hz at 1 kHz, and the noise density in a 1Hz band is, of course, 10nV/sqrt(Hz) x 30 = 0.3microV only.

It therefore seems strange to me that distortion is measured to include noise, as one can definitely hear signals of amplitude substantially less than the noise measured in the distortion + noise measurements.

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The reason, I assume, is historic: Early THD analysers simply measured THD + N, whereas it is now possible to measure arbitrary low noise floors depending on the ability to notch out the fundamental and the frequency point spacing in the FFT analysis.

However, to what extent a good ear can hear below the measured amplifier noise when music is produced is difficult to assess. These sorts of arguments pervade discussions in the industry. For example, all cables and interconnects contribute lower measured distortion than even the Halcro amplifiers, without exception, and yet many audiophiles claim to be highly aware of the difference between cables. I am proud to have the unique claim stated above, namely that the Halcro amplifiers produce less false IM or harmonic signal than the measured threshold of the human ear.

In this industry, we are continually reminded that the ultimate test is the listening test. In this regard, many companies can provide a list of acclamations which they have accumulated over many years. We have been in production for only 6 months, yet we already have been awarded a "Golden Ear," received an excellent review in the Jan/Feb edition of TAS, won best high end amplifier in the Singapore show and have been selected by DTS as their preferred amplifier with which to demonstrate their digital format.

The DTS demonstration room at the 2001 Las Vegas CES was voted best sound and vision for the show by all of the major audio publications, and some commented that it was the greatest combination of equipment ever assembled in hi-end audio-visual. Every loud speaker manufacturer that has auditioned the Halcro amplifiers to date has commented that we bring out the best in their products.

We hope you agree with the growing consensus that Halcro designs the world's superior audio amplification electronics.

Bruce Halcro Candy

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