HALCRO dm68

CONSTRUCTION OF THE POWER AMPLIFIER

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The Australian-made monaural power amplifier dm68 that drew attention at the Audio Show applies the latest technologies such as microwave technology, has powerful power section using switching power-supply, has thorough anti-noise measures, and has unique circuitry. This amplifier realises high power of 225W at 8Ω and super low distortion of 0.2ppm at 1kHz. This article looks into the innovative circuit of dm68.

Amplifier That Overturns the Pre-conceived Notions

Halcro dm68 (2,750,000 yen per unit) - Australia's monoblock power amplifier - was introduced for the first time in Japan at the 2001 Tokyo International Audio Show and drew significant attention.

A physicist of a metal detector manufacturer - Minelab - commercialised this amplifier under a private brand "HALCRO". You can see originality everywhere in this amplifier - such as a distinctive tower-type design, a power switch using an air pump, the output circuit using a coaxial pipe which is made of gold-plated copper tube as well as a gold-plated copper rod. Furthermore, its circuit construction and specifications will also surprise you.

This amplifier is equipped with a switching power-supply that has been avoided in the high-end audio industry as a noise-generating factor, but achieves high power of 225W at 8Ω and 1200W at 1Ω. Despite such a super high output amplifier, it achieves super low distortion and super low noise. For example, there is a very low equivalent input noise level of 5nv/√Hz, total harmonic distortion below 0.2ppm (0.00002%) at 1kHz and below 1ppm at 20kHz, and SMPTE inter-modulation distortion of below 1ppm. In addition, it is a high-speed amplifier with a high slew rate of 100V/µs at low signal and 65V/µs at the peak output.

The switching power-supply handles 85V-270VAC without a selector switch. There is no worry about contaminating the AC power source as the switching power-supply controls the AC current so that it always flows analogous to the voltage waveform without flowing in peak shape. This is an example of how this product overturns the pre-conceived notions of power amplifiers.

I had a chance to visit Harman International in early October and spoke with the visiting designer Mr Bruce Candy. Although much of details are protected as proprietary information, let me share with you what I could find out about the product.

Profiles of the Company and Its Product

Extraordinary Technology Pty Ltd in South Australia is an audio manufacturer that debuted under the "HALCRO" brand, and was founded in 1996 by Bruce Candy and David Pope (the President of Extraordinary Technology). Mr Candy is also the top physicist of Australia's metal detector manufacturer Minelab, which has 80% of the world share of mine detectors. The brand name "HALCRO" is Mr Candy's middle name.

Mr Candy was a Briton born in Durban, South Africa, in 1952. He received doctoral degrees in physics and applied mathematics, and taught at the University of Cambridge in the UK as well as universities in France and Australia. He immigrated to Australia in 1980 and engaged in work on microwave radar and satellite communications while teaching at a university. Eventually, he became known as "an engineer who is a physicist, but is familiar with the most advanced electronics as well as practical high-tech skills".

In 1985, Minelab was established by inviting him to develop and manufacture very high performance metal detectors.

Australia has no volcanoes and little forest and therefore has little deposit on the earth surface. For this reason, if you dig the ground a bit, you can mine various metals including gold. This creates a high demand for metal detectors. Looking at such demands, Minelab commercialised high performance metal detectors. Later, these same technologies were applied for commercialising mine detectors. The outstanding performance of their mine detectors are now widely known and even recognised by the United Nations, and their world market share in mine detectors is 70-80%.

While Mr Candy engages in development of such high-tech detectors, he is also a lover of classical music (including contemporary composers) as well as an audiophile. He is a DIY enthusiast and started building valve amplifiers at the age of 13. His favourite valves are KT88 and EL34. As he was not satisfied with off-the-shelf amplifiers, he began using valve amplifiers which he had built himself. Later, he began studying to build a "solid-state amplifier that supersedes valve amplifiers" by making use of the latest electronics technologies, such as countermeasures to noise that he nurtured through his development of microwave communications and detectors. As a result, he completed development of an innovative power amplifier using MOS-FETs. As the sonic performance of the amplifier was well-received by his audiophile friends, Extraordinary Technology Pty Ltd, which owns the Halcro brand, was established to commercialise this amplifier.

Halcro's debut model was a 200-watt MOS-FET monoblock amplifier in early 2000 and was named as the dm58, taking the acronym of the design firm, Design Makers, who did its industrial design. This model was exhibited for the first time at the CES in Las Vegas in January 2001. The dm68, which was exhibited at the Tokyo International Audio Show in September 2001, is a revised version of the dm58. In the dm68, both performance and features were improved – e.g., 8Ω output is raised to 225W, and speaker binding posts are changed to bi-amp compatible.

Mr Candy said that his attitude towards product development is "to pursue an amplifier that produces a sound that satisfies my standards, not an amplifier that beats other brands".

Due to the company's proprietary information policy, he could not reveal the details of the technologies, but I will share what technical information I was able to obtain about the product.

Overall Amplifier Construction

The dm68 is a tower-type monoblock amplifier with a height of 79cm. The power-supply and amplifier sections with independently sealed covers are placed between the two towers that resemble wings of aeroplane.

The chassis is skilfully designed so that the fastening screws are concealed from the front, rear and side views. The wood stand at the lower part of tower is not veneer, but solid wood block.

My assumption is that this is a separate power-supply type power amplifier of which the amplifier section and the power-supply section are layered with space in-between. This is to prevent mutual interference in magnetic induction, electro-magnetic induction, vibration, etc. while minimising its foot-print. By the way, even though this amplifier is a high-power amplifier with 225W at 8Ω, it was designed to be space-effective with a 40cm width and depth.

A very large and vertically long heatsink is housed in the left tower when looking at it from the front. Output stage MOS-FETs are installed on the heatsink. The wiring from the power-supply section to the amplifier section is hidden in the tower and invisible from the outside.

The power block, which is the lower one, has a 3-layered construction – 2 circuit boards are put on the aluminium base plate where parts are installed. The amplifier block, which is the upper one, has the input amplifier board above the approx. 15mm-thick aluminium dividing plate and the power amplifier board below the plate.

The output signal of the amplifier is wired with a coaxial pipe that consists of a gold-plated copper pipe, a gold-plated copper rod and a Teflon insulator. In addition, the output coil for preventing oscillation is not a separate piece, but is spirally made from approx. 6mm copper rod that is the centre conductor of the coaxial pipe.

This unit is designed to keep the mains power turned on constantly, and the switching power-supply is activated or de-activated by the power (stand-by) switch. Therefore, the amplifier power is turned on/off in daily usage by the power (stand-by) switch.

A remote terminal using a 5P Cannon connector is equipped with the amplifier to allow linking with a pre-amplifier so that the ON/OFF (stand-by) can be controlled via the dm10 or dm8 pre-amplifier, which will be available in the future.

1. Air-Pump Power Switch
A switch for power-on and stand-by is located at the bottom of the amplifier section shield box. This switch is not electrical, but is an air-pump for compressed air. Since the leading power wires create noise radiation from conductors, activation and de-activation of the switch for switching the power-supply is done by the micro-switch at the upper side of the bottom panel. The micro-switch is controlled by expansion and contraction of the balloon-like object which is at directly below the micro-switch. In the stand-by mode, pressing the air pump button turns on the amplifier power and pressing it again will stop the oscillating action of the switching power-supply and turn into stand-by mode.

2. Optical Transmission Indicator
Indicators which turn red or green depending upon operating status are located at the front and rear of the lower box, but these indicators do not use any electrical wiring. The reason for this is that if a wire connects the optical source of the indicator to the 2-colour LED, the wire will act as an aerial and pick up noises, thereby contaminating the environment as a secondary radiation.

In this unit, both LEDs are directly put on the AC/DC converter board, and optical fibre conducts the light to the display window.

Construction of the Power-supply Section

A rough construction of the power-supply circuit can be guessed. The AC power goes through the protector fuse, which is located in the vicinity of the AC inlet, and the mains power switch, and then noise is removed at the AC line filter.

1. Seventh Order Line Filter
The line filter is a 7^{th} order LC-type low-pass filter that uses the common mode filter using common mode choke coil, and the normal mode filter using independent choke coils in series connection. As this is a bi-directional filter using such a high 7^{th} order, both noise coming in from the AC line and noise going out from the switching power-supply to the AC line are effectively eliminated.

2. Switching Power-supply
A major characteristic of this unit is the use of a power-factor-controlled switching power-supply that maintains the similar waveforms between AC current waveform and AC voltage waveform.

This particular power-supply first converts the AC into DC while making it sure that current waveform and voltage waveform are similar, using a power-factor-controlled AC/DC converter. Then, the DC power is again switched by a DC/DC converter, and thus creates more stable DC power. Therefore, this switching method has 2 stages.

An ordinary switching power-supply directly rectifies the AC power and creates DC power. The DC is switched by the PWM (pulse width modulation)-controlled FET in order to create DC power. However, in this method, current will flow into the rectified circuit only in the vicinity of the peak of AC voltage. Therefore, as the solid line in the lower graph shows, pulse-like AC current with a large peak value flows through the circuit. The power-factor of this method is as low as 0.7.

The flow of AC current in a capacitor-input type rectifying circuit of common amplifiers is the same as above, and direct rectification of AC power will create a flow of sharp and high peak value current. This not only contaminates the AC power but also increases reactive power due to the low power-factor.

On the contrary, a power-factor-controlled switching power-supply has an active filter consisting of a series inductance and parallel switching FET in-between the bridge rectifier and the capacitor. This controls the AC current in the same waveform as the AC voltage – i.e. power-factor is maintained close to 1. By constantly monitoring the AC current and AC voltage, FETs are PWM-controlled in order to make the AC current be analogous in linear approximation to the AC voltage waveform at the vicinity of power-factor close to 1. The amplitude of the current is then either increased or decreased to stabilize the DC voltage. This DC power is then again switched by a DC/DC converter at the next stage, and subsequently rectified after going through an isolating transformer in order to create stable DC power. As the switching frequency is high, ripples of the rectified waveform become very low.

Furthermore, from the DC power-supply to the control circuit of the switching FET, feedback is normally applied via an insulated-type interface like a photo coupler.

In this unit, both converters are running synchronously at the fixed switching frequency of 115kHz, and the control circuit is in current mode operation. First, roughly stabilised 400VDC power is created by a AC/DC converter, and then this DC power is again switched by a DC/DC converter in order to supply approx. ±70VDC that is isolated from the AC line into the amplifier. Its power-factor is approx. 0.98.

When the power-factor is close to 1, the AC current waveform becomes the sine wave, which is analogous to the voltage waveform as in a pure resistor load. This has merits of a less polluted AC power and less reactive power.

The power-supply block is a 3-layered structure. An AC line filter in a shield case is installed on the upper surface of the bottom plate. The second layer contains the AC/DC converter board. The top layer has the DC/DC converter board.

Although this unit employs a switching power-supply, the power-supply section is quite large. My guess is that it is to secure the high DC voltage, which can supply 225W at 8Ω and can have the current supply capability of 1200W at 1Ω. This switching power-supply can accept such a wide range of 85-270V AC mains without any switching.

Construction of the Amplifier Section

Many parts of the amplifier section are also protected and undisclosed under the proprietary information policy. Model names of semi-conductors and types of chips (e.g. resistors, capacitors, and inductors) cannot be seen under the white anti-humidity paint. During the interview, only fragmented information was available.

The following are the key pieces of information I could get on this amplifier:

1. The basic structure of the amplifier consists of an input buffer, voltage amplification section, and power amplification section.
2. The voltage amplification section has a differential input and a single-stage amplifier with a current mirror circuit.
3. Numerous parts that cannot be imagined for use in audio amplifiers (such as 18GHz-bandwidth transistor for microwave circuit) are found in this amplifier.
4. Although minor-loop negative feedback is applied, overall negative feedback is not applied.
5. There are many ICs on the board, but many of them are for the protection circuit.

6. Six pieces of MOS-FET made by IR in the States are used in parallel at the output stage. N-channel FET is 400V IRFP340 and P-channel is 200V IRF9640.
7. The output stage is in Class AB close to Class A mode without complementary turn-off operation.

To supplement, the reason for the complementary symmetrical circuit not being employed in the amplifiers is as follows: The amplifier utilising the cancellation effect of even order distortions can of course achieve low distortion figures. However the amplifier contains more odd order distortions that create greater dissonance compared to the even order distortions, and results in a final performance that is audibly not preferable. The concept is that an amplifier with excellent sonic performance cannot be hoped for unless the amplifier achieves super low distortion without touching even order distortion that creates consonance.

The reason for the "single-stage amplification" is that multiple-stage amplification will create a complicated distortion which has high-order harmonics while single-stage amplification creates simple and easy-to-correct distortion.

There is the block diagram that Halcro has disclosed on their web site. The left side of the aluminium shield plate, which is indicated by the broken line, is the input amplifier board section and the right side is the power amplifier board section. According to this diagram, the front half of the voltage amplifier is at the input amplifier board side, and the rear half is at the power amplifier board side. Signal transmission is done between boards by balanced current transmission, and this makes it hard to be affected by induction noise.

Output signal returns once to the input amplifier board via the coaxial pipe, and then goes out from the speaker binding posts via the coaxial pipe. This is to operate the earth of the input amplifier board as a reference.

The input RF filter is a CR filter for bandwidth limitation, and the output RF filter would point the coil which is inserted into amplifier output in series.

Input terminals are a balanced input with 100kΩ + 100kΩ, a 100kΩ unbalanced input, a 660Ω minimal path voltage input, and a 50Ω unbalanced current input. This can be selected via the rotary switch on the rear panel.

The minimal path input circumvents the input buffer and directly sends the signal into the voltage amplifier section. Although the input impedance is low, there is the possibility of achieving an even higher purity in sound so long as the source has enough driving capability. The current input is to receive the signal sent via current transmission mode from the dm8 preamplifier, which will become available in near future.

I can guess the circuit construction, judging from the information that the voltage amplification circuit utilises a "current mirror and asymmetrical single-stage amplification structure" and that the "front and rear stages are balanced current transmission".

The output stage uses N-channel and P-channel FETs. However, as the circuit construction is not designed for "complementary turn-off," the construction of the N-channel Class A single circuit is likely combined with a P-channel current drain circuit which turns on only when the large output power is required. This is similar to the Aleph 0 amplifier of Pass Laboratories.

This circuit is based on my analogous inference from the existing circuit examples. As it seems that techniques of microwave circuitry is introduced, this circuit could be unknown to the audio industry. I am very interested in the actual circuitry.

To obtain low impedance and countermeasure radiant noise, the printed circuit board is a 6-layer board with thick copper foil. The input amplifier board has many high sonic quality parts like Vichey's metal foil resistor, Rodenstein's metal film resistor, and WIMA's polypropylene capacitors.

Furthermore, as there is no measurement equipment on the market that can measure super low distortion rates of 0.2ppm, an in-house-made super low distortion oscillator, a high accuracy band reject filter for eliminating fundamental frequency, and an SSR's spectrum analyser are used to measure distortion. On the input amplifier board, there is a D-sub 9-pin terminal for connecting measurement equipment.

Summary

It was said a long time ago that "circuit technology for amplifiers has reached the perfected stage". However, as I saw the dm68, I was made to re-consider that there are still many things we can do to amplifiers. HALCRO is a hot new brand that blows a refreshing breeze into the stereotyped amplifier industry, and I am very interested in the future activities of this brand.

Bibliography

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Co-operation

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