white paper

Ferrum **ERCO**

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Content:

What makes ERCO special

First of all ERCO is in many ways similar to OOR, but because it has a built in DAC, some design aspects needed a different approach. We decided on the IC based headphone amplifier, however it is not some off the shelf solution. ERCO has a composite topology amplifier, which means it has two IC amplifiers in one feedback loop. One of them acts as a buffer with its own feedback loop. This is a fast power op-amp which can deliver more than 700 mA. The second amplifier has this previously described buffer in its own feedback loop, which allows it to be an op-amp with lower output current, however, it lowers distortion significantly, because the buffer shows much higher impedance on the output of the second amplifier. This whole composite amplifier is externally compensated in the same manner as OOR's two-pole compensation scheme. Open loop bandwidth is around 20 kHz (-3 dB), which makes distortion almost flat in whole audio spectrum.

Secondly, the internal power supply is a technological variation of the one in OOR. It has low noise switching regulators with double stage input and output filtering. There are separate power rails for both channels for improved channel separation. As OOR, ERCO has two DC power inputs. One classic 2.5mm/5.5mm DC jack plug and the second 4 pin WEIPU plug, the same as in HYPSOS. For the second option we have our dedicated cable – FPL (Ferrum Power Link) with 4 pin WEIPU connectors on boths sides. When a normal cable is used 4TSD function in HYPSOS measures the voltage directly on the cable output, but with FPL voltage is measured on the motherboard of ERCO. This allows HYPSOS to stabilize the voltage even further in the power path.

Thirdly, the entire signal path is fully balanced and there are no transformers and inductors in it. Volume regulation and gain circuitry is fully balanced even though analog input is only single ended (RCA), because the input amplifier is converting the single ended signal to balanced. Outputs of the ESS9028PRO DAC are differential and there is no change to single ended down the signal path. Therefore, as in OOR, in ERCO we are using quad ALPS RK27 potentiometer for volume control. To accommodate for single ended output the signal is converted from balanced mode to single ended only at the single ended outputs.

THE ANALOG PART

Analog input stage

The analog input stage of ERCO (an internal preamplifier) adjusts gain and volume. It is made from carefully picked, fast op-amps with special external compensation, which act similarly as two-pole compensation.

Output stage

The output power amplifier is based on IC, however it is not a typical configuration, but a composite amplifier. There are 4 of those amplifiers, 2 for each channel, which are needed for balanced output. This amp is DC coupled and yes, there is DC servo, which has -3 db cutoff frequency at about 0.1 Hz.

Internal power stage

The power supply of the analog stage is based on the same concepts as the one in OOR. This time it has +/-15 V and the power rails are separated for the left and right channel. However, apart from an analog side ERCO has a digital part. This means ERCO needs proper separation between those sides and the whole power scheme is much more sophisticated than it is in OOR. First of all, the ES9028PRO DAC has its analog side supplied by LDO from ESS, which is optimized for low noise analog sections of the DAC. Secondly the power supply is separated from main digital power rail for improved stability of generated frequency for the clock oscillators.

Grounding and the PCB design

ERCO has one, six-layer board. ERCO's PCB has two layers just for ground planes. There are two grounds in ERCO: signal ground and power supply ground. Those grounds and power rails are separated by common mode choke for further attenuation of common mode EMI from switching converters and from the input power supply.

Output impedance

On the headphone output the impedance at 1 kHz is <0.3 Ohm regardless of the load. On the preamp output: RCA 22 Ohm, XLR 44 Ohm.

Output power

ERCO has internal current limiting (without foldback). Therefore, steady state and transient power, until the distortion from current limiting or dropout occurs, is the same. For 50 Ohm: single ended 1.7 W, balanced 6.1 W. For 300 Ohm: single ended 300 mW, balanced 1.2 W.

THE DIGITAL PART

ARM rules them all

Heart of the digital part of ERCO is a hi-performance ARM microcontroller from ST Microelectronics®. It is responsible of everything starting from simple controlling analog part through USB transmission and ending on signal processing.

Audio Engine and Audio Path

While designing the software architecture of ERCO we created a library internally called Audio Path. It is our internal framework made to easily connect different audio processing blocks. That gives us ability to connect different technologies, ideas and functions in one DSP system. It is not only about features we have put into ERCO, but also about future extensions like digital filters. Audio Path gives us the ability to connect all processing blocks, but it still has to be done. Creating, connecting, managing inputs and formats are done in a component we called Audio Engine. That is the main thing inside the ERCO software which allows you to listen to music. Audio Engine prepares all connections inside Audio Path for every input and every format independently, so there are only processing blocks necessary for signal processing in each moment.

MQA Full Decoder Embedded

As an MQA certified device, ERCO has implemented MQA Full Decoder. It has been built into the ARM microcontroller and gives us the possibility to optimally integrate it with the other audio processing we made inside. We used the MQA Decoder Library (provided by MQA Ltd.) to make the "MQA processing block" which perfectly fits our internal processing flow in "Audio Path".

Proprietary USB Device Library

After years of experience making audio equipment with USB, we decided to make our proprietary implementation of USB Device stack. It gives us the ability to make

all we want and connect with other components with first in class integration. Main function of USB in ERCO is transmitting audio, but it is also responsible for firmware update and integrates MQA with applications on the computer/ smartphone side. Furthermore it would be easily extended to do whatever we want.

Audio Class 2.0 supported

Using our USB Device Library, we implemented standard USB Audio Class in version 2.0. It is well supported on every modern operating system for computers and smartphones because of the built-in drivers. Additionally, we provide the driver for Microsoft Windows® to extend capabilities i.e. add support for ASIO and Native DSD playback. Audio Data Transmission over USB is asynchronous. It means that data is delivered to the DAC in the rhythm of its internal ultra-low jitter clock generator. There is no clock recovery because there is no clock to recover in this architecture. The whole system is clocked by the internal clock inside ERCO, and computer or smartphone are responsible only for delivering data into it. This means that there is no jitter on USB transmission and no quality loss of sound because of it.

DSD in all formats

ERCO supports DSD in all formats up to 12.288 MHz. It works with base frequencies of 44.1 kHz as well as 48 kHz. That is true also for DSD over PCM (DoP). All of that is done thanks to the great integration between all our software components. DoP decoder is put into Audio Path. When DSD is detected the whole PCM processing path is bypassed and the signal goes directly to the DAC. In case of Native DSD signal (USB only) there is no processing at all, so our Audio Path doesn't contain any processing blocks.

Putting the Analog in Digital Design with Smart Control

The digital part of ERCO is very complex, but it is responsible only for processing signal from the digital inputs. Still a lot of operations are done in analog manner. Included are volume control, gain/attenuation adjustment for headphone output, line input and line output level adjustment, output enabling, volume bypassing and selection between analog and digital inputs. Most of these operations are controlled in a smart way, because they are controlled by the microprocessor.

Analog signal goes through only a few analog blocks i.e., input buffer or DAC output stage, input selector (analog/digital), gain/attenuation circuit, volume potentiometer and output/headphone amplifier. There are also a few relays to bypass volume and enable each output. Let's call them all "analog path". On the other side there are only 3 knobs on frontpanel (Volume, input selector and headphone gain/attenuation) and bypass switch on rear panel. In addition, there is detection of jacks plug-in. All that information we can call "control signals". MCU gathers all control signals and processes it to configure whole analog path. It gives us new layer inside ERCO which makes it smarter and easier to use.

Industrial Design

The design elements of ERCO follow those of HYPSOS and OOR. The backlit Ferrum logo is embedded in lacquered corten steel, so it doesn't leave stains. ERCO can be stacked on top of HYPSOS without any risk of overheating. All the knobs for switches and volume control are our custom design. We wanted them to be as user-friendly as possible. We checked many different prototypes of volume knob (diameter, depth) and gain switches, to achieve optimum size, shape and visual cohesion. Under the PCB board, where output power amplifiers are situated, there is an aluminum block for dissipating heat to the chassis. Many colleagues in the HEM team were cooperating on the casework. There are many parameters, that need to be optimized, as visual factors, usability, availability of components and manufacturing factors. All those parameters are not always consistent with each other, therefore gathering ideas and discussing pros and cons of them is crucial for achieving best results.

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