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STUDIO GRADE HYBRID MICROPHONE PREAMPLIFIER FOR PROFESSIONAL USE

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Anotace:
Tato práce se zabývá návrhem cenově dostupného mikrofonního předzesilovače pro použití v nahrávacích studiích. Hybridní zesilovač pro svou funkci využívá současně polovodičovou i elektronkovou technologii s možností plynulé změny zesilovacího poměru mezi jednotlivými typy aktivních prvků. Jsou popsány hlavní části zesilovače, funkce jednotlivých bloků jsou otestovány provedením zkušebních měření na vývojovém prototypu (harmonického zkreslení, frekvenční a fázové charakteristiky).

Annotation:
This work is focused on designing a commercially available studio-grade tool that might be used as an equivalent alternative for common choices in professional recording studios. The main aim is to use both semiconductor and vacuum tube technology simultaneously letting the recording technician smoothly select a suitable ratio between the solid-state and vacuum tube. In this paper, a several main parts are shown including test measurements of total harmonic distortion, frequency and phase response for each amplifier technology.

INTRODUCTION

Almost each recent electronic device is based on the semiconductor technology. The benefits are indisputable – low price, high efficiency, small dimensions and high-density integration. However, there is a significant part of the market where the vacuum tube technology is preferred over the semiconductors. The music industry is exactly the one where equipment based on the vacuum tubes is the most preferred because of its soft and warm sound which is naturally more pleasant to the human ear.

Using the semiconductor-based amplifier, a very low THD+N ratio, small phase shift and precise amplification of the original signal can be achieved. Also, the circuit wiring requirements, power consumption and the supply voltage are much less demanding compared to the vacuum tube circuits. On the other hand, in this specific type of usage – vocals or musical instrument recording, the vacuum tubes offer a warm sound coloration caused by a relatively high harmonic distortion (mainly increment of even harmonics), which might be useful if any sound enhancements are needed, for example, brightening up an original sound of musicals instruments.

For this reason, the hybrid microphone preamplifier actively uses both technologies, so the recording technician is able to select a suitable ratio between these two types of amplifiers from one to another [1].

To be suitable as a studio-grade tool that might be used as an equivalent alternative for common choices in professional recording studios, this device has to offer most advanced features that are common in this product category

- OLED screen for navigation in a control menu (allowing user to manage advanced settings),
- symmetrical inputs and outputs using XLR connectors,
- 40 dB input gain,
- digitally driven input level LED indication with RMS/Peak mode,
- 48 V phantom power,
- adjustable input impedance (600 Ω, 1.4 kΩ, 2.4 kΩ, 6.8 kΩ steps),
- variable high pass filter (10/75/100/150 Hz),
- phase inverter and 20 dB attenuation pad,
- analog output VU meter,
- optional AES3 (AES/EBU) output [2].

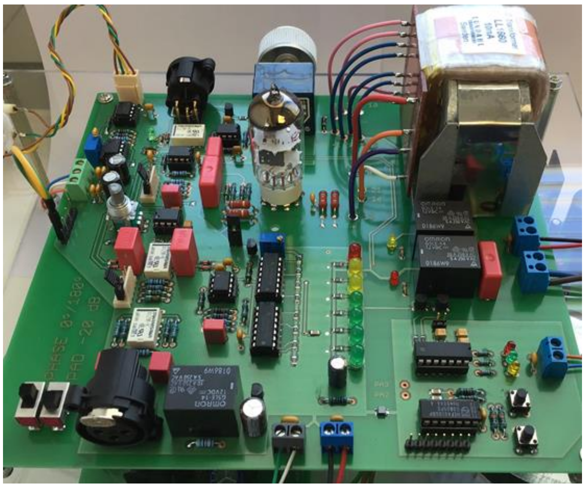

Fig. 1: Original development board

DESIGN

The preamplifier device consists of several parts (only a few blocks will be shown). First, the input processing block that contains a 2nd order LCR high pass filter, 20 dB attenuation pad, adjustable input impedance and phase inverter is shown in Fig. 2 and Fig. 3. Another important feature is the 48 V phantom power supply allowing to use the condenser microphones. This process is controlled by microprocessor which simply connects or disconnects both positive (+) and negative (-) wires to the phantom power supply. These signal wires and the power supply are separated from each other by a pair of resistors (6.81 kΩ) according to norm DIN 45596 [3]. Then the incoming input signal is processed and transformed by opamp INA217 (IC4). This precise low-noise (1.3 nV/√Hz at 1 kHz), low-distortion (THD+N 0.004% at 1 kHz), monolithic operational amplifier [4] converts the symmetrical input signal into unsymmetrical and then amplifies it within a range of 6 dB to 40 dB. A final frequency adjustment is done by 1st order RC high pass filter which is adjustable in 4 steps (10 Hz, 75 Hz, 100 Hz and 150 Hz). Then the audio signal continues into another processing block – semiconductor and vacuum tube stages (Fig. 4).

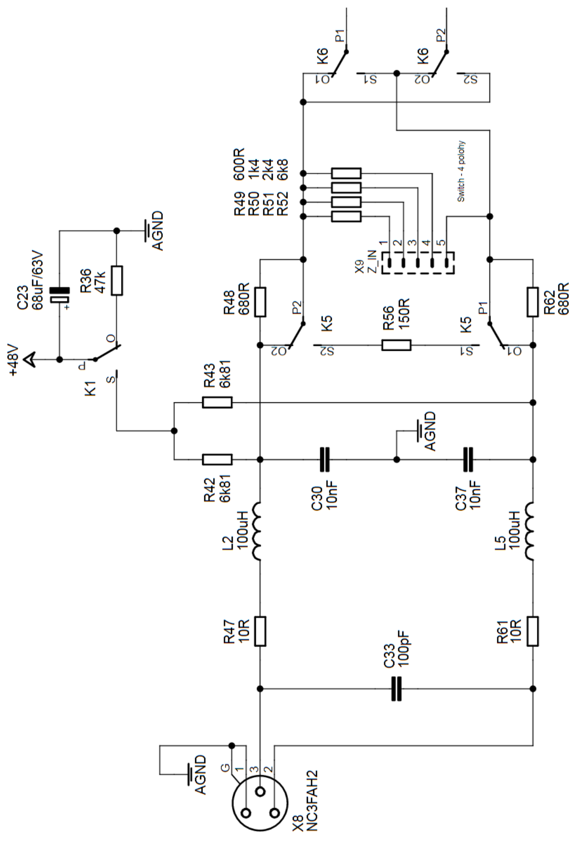

Fig. 2: Pre-amplifier input block (part 1)

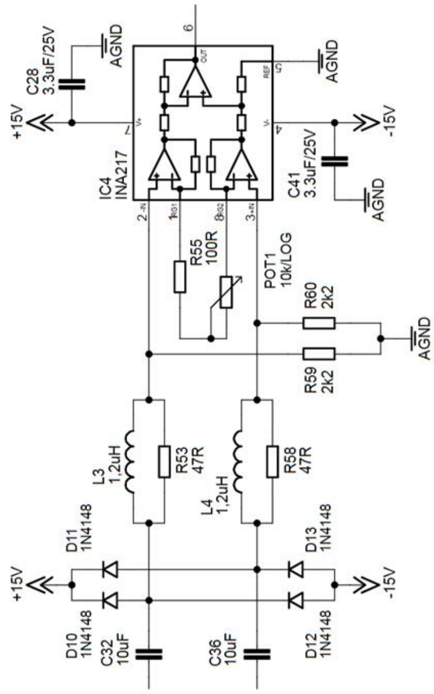

Fig. 3: Pre-amplifier input block (part 2)

Vacuum tube stage amplifier (Fig. 4) is based on a double triode ECC82 (otherwise marked as the 12AU7). The first stage is used as a buffer between an input processing block and the final amplifying stage, so the final stage does not cause loss of gain or increased distortion. A formula (1) shown below defines the calculation method determining a voltage gain of the first stage. Using the ECC82 vacuum tube the voltage gain equals 0.345.

$$A_{\mathrm{V}} = \frac{\mu \cdot R_{\mathrm{K}}}{r_{\mathrm{a}} + R_{\mathrm{K}} \cdot (\mu + 1)} \tag{1}$$

The final stage is based on the common-cathode wiring using an output audio transformer Lundahl LL1660 (10 mA version) [5]. The voltage gain in this case equals -11.33, this result can be achieved using the formula (2) below.

$$A_{\mathrm{V}} = \frac{-\mu \cdot R_{\mathrm{A}}}{r_{\mathrm{a}} + R_{\mathrm{A}} + R_{\mathrm{K}} \cdot (\mu + 1)} \tag{2}$$

The preamplifier is controlled by 8-bit AVR RISC-based microcontroller ATmega324PA by Atmel (original version was driven by ATtiny24a). Its purpose is handling all user functions, for example, front panel buttons and rotary encoder for navigation in a control menu that is shown on OLED screen (allowing user to manage advanced settings and saving these as presets), evaluation of an input signal level using an integrated ADC and also handling a power-up and power-down sequence (vacuum tube heating time, switching on and off a high voltage anode power supply).

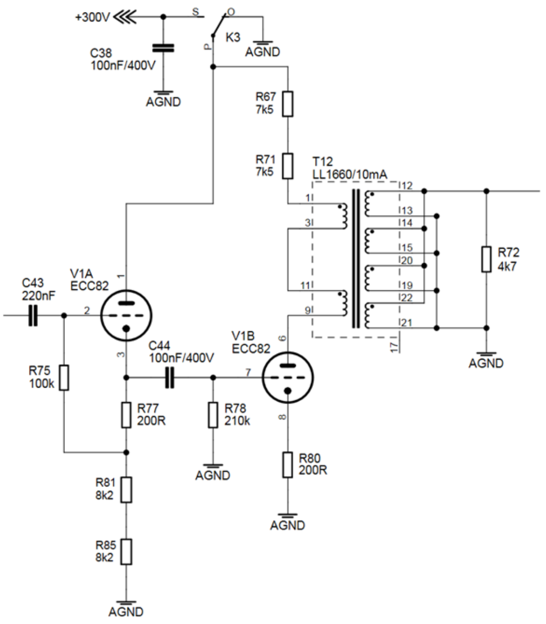

Fig. 4: Vacuum tube stage

The advanced user settings – heating time, Master Clock selection (AES3 sample rate), digital output preferences etc. are stored in the MCU Flash memory as individual presets so they might be recalled while using the device. Power is provided by a linear multi-voltage power supply with stable low-noise outputs (5 V, 12 V, ±15 V, 48 V, 300 V) including over-current protection and soft-start function. The whole preamplifier casing is designed as a 19-inch 2U rack mount unit that meets norm ČSN – Mechanical construction of an electrical devices [6].

MEASUREMENT

The audio analyzer Apx525 by Audio Precision [7] was used to measure a frequency and phase response and harmonic distortion. A measurement bandwidth of 20 Hz to 40 kHz was applied using a sine wave signal with amplitude of 1 V_{RMS}.

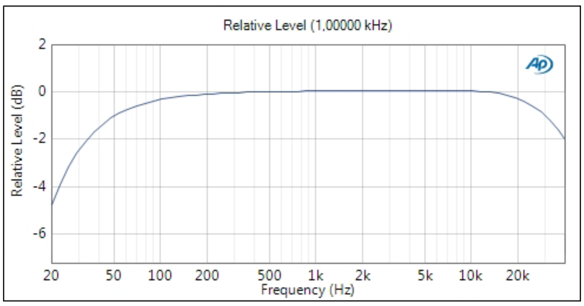

Fig. 5: Frequency Response of Vacuum tube stage

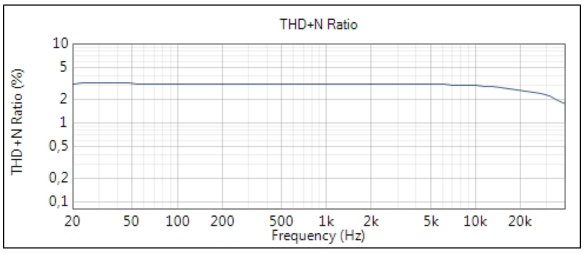

Fig. 6: THD+N Analysis of Vacuum tube stage

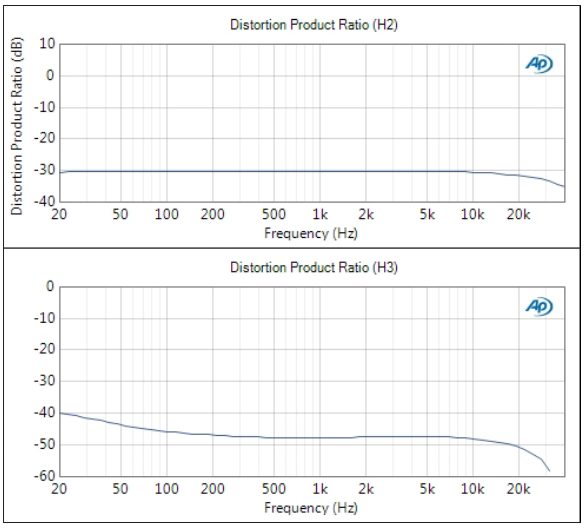

Fig. 7: 2nd and 3rd Harmonics Distortion Ratio of Vacuum Tube Stage

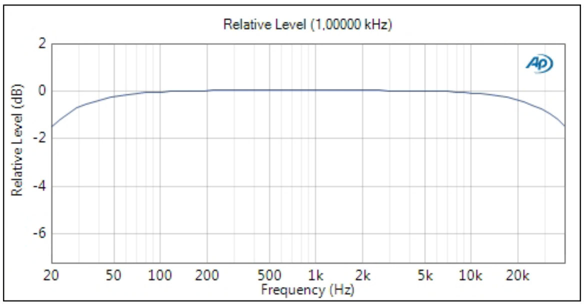

Fig. 8: Frequency Response of Semiconductor Stage

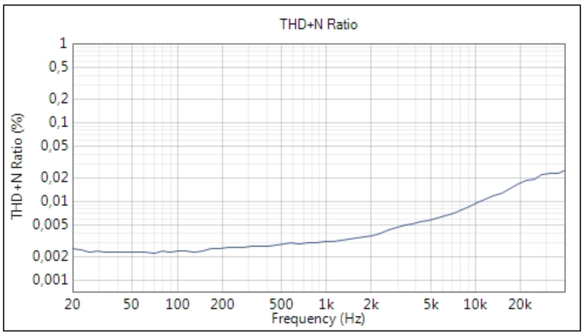

Fig. 9: THD+N Analysis of Semiconductor Stage

CONCLUSION

This paper represents a partial circuit design solution of the hybrid microphone pre-amplifier. The final device which is currently being developed contains both the vacuum tube and semiconductor stages along with all the other necessary functional blocks (MCU control unit, power supplies, AES/EBU digital audio output etc.). The series of measurements was taken to provide the results. The pre-amplifier overall maximum gain is approximately 53 dB, the frequency response if the vacuum tube stage is used is within the range of 50 Hz to 30 kHz (-1 dB) with maximum distortion of 3 % – mostly 2nd and partly 3rd harmonics (Fig. 7). If the pre-amplifier is switched to semiconductor technology, the frequency response is within the range of 25 Hz to 31.5 kHz with total distortion less than 0.02 %. The phase response is within the range of +40° at 20 Hz to -40° at 40 kHz using the semiconductor stage only, in case of using the vacuum tube stage the phase response is within +120° at 20 Hz to -100° at 40 kHz.

The AES3 (AES/EBU) for transferring the digital audio data is currently being developed. It is supposed to be implemented as a software-controlled feature allowing transmitting data rates up to 192 kHz using a DIT4192 digital audio transmitter, PCM4220 216 kHz Delta-Sigma ADC with PCM output and PLL1707 PLL Multi-Clock generator. So far, the Master Clock selection is being developed considering another hardware and software implementation – digital output selection that would allow switching between multiple digital audio interfaces as AES3 using 110 Ω twisted-pair cabling with XLR connectors, S/PDIF unbalanced connection or optical fiber with F05/TOSLINK connector.

ACKNOWLEDGEMENT

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