HYBRID MICROPHONE PREAMPLIFIER WITH VARIABLE SELECTION OF AMPLIFIER TECHNOLOGY

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Abstract: This paper deals with the design of a studio level hybrid microphone pre-amplifier using a vacuum tube and semiconductor technology. The pre-amplifier circuit also contains an analog VU meter, 48 V phantom power supply, variable high pass filter, phase inverter switch and adjustable stage input impedance. This paper also deals with the design of a multi-voltage power supply unit and microprocessor controller unit ensuring completely automatic amplifier functions. The end of the paper is dedicated to a characteristics measurement determining its parameters.

Keywords: Vacuum tube, phantom power, microphone, microprocessor, operational amplifier, preamplifier, triode, heating

1 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. The key to this phenomenon is a relatively high harmonic distortion causing an increment of even and odd harmonic frequencies if using the vacuum tube as an amplifier. On the other hand semiconductor based amplifiers have an advantage of easier circuit wiring requirements and also very low harmonic distortion making its sound more precise and cold. This article deals with the design of the hybrid microphone pre-amplifier using both technologies letting the user smoothly select a suitable ratio between solid-state and vacuum tube. For a greater user experience the pre-amplifier is equipped with many useful features as a 48 V phantom power supply to operate condenser microphones, input and output analog VU meter, variable high pass filter, phase inverter and adjustable input impedance.

2 INPUT PROCESSING CHAIN

A pre-processed signal from a source (dynamic or condenser microphone, low level line signal, etc.) is led into input part of the pre-amplifier. The purpose of this part (Figure 1) is to process a raw input signal to forthcoming processing and also to adapt its input parameters for the best performance. It consists of a 2^{nd} order LCR high pass filter, -20 dB attenuation pad, adjustable input impedance in 4 steps (600 Ω, 1.4 kΩ, 2.4 kΩ, 6.8 kΩ) and phase inverter swapping the polarity of the input signal. The next 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 pair of resistors (6.81 kΩ) according to a norm DIN 45596 [1].

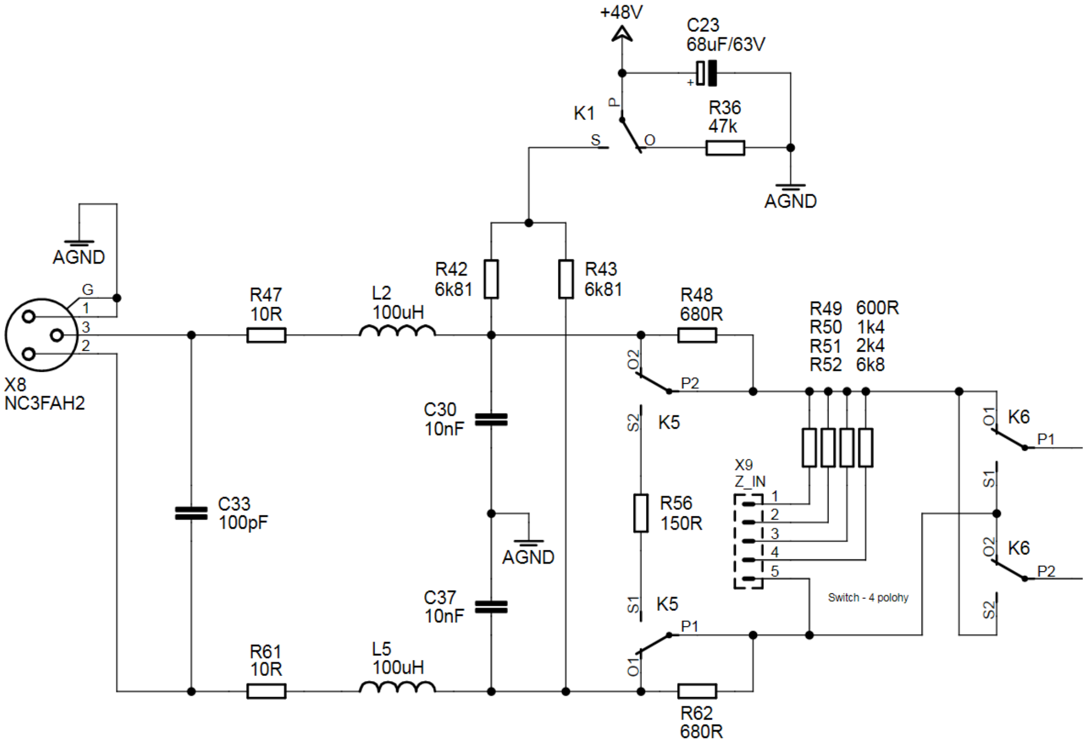

Figure 1: Pre-amplifier input (part 1)

Then the audio signal leads into a second part (Figure 2) which contains an AC coupling capacitors removing a DC component of the signal, ESD protection circuit protecting an integrated circuit INA217 and reducing voltage spikes caused by phantom power supply when activated. At this point the partially processed audio signal leads into the 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 [2] converts the symmetrical input signal into unsymmetrical and then amplifies it in a range of 6 dB to 40 dB. A final frequency adjustment is made by 1st order RC high pass filter which is adjustable in 4 steps (10 Hz, 75 Hz, 100 Hz and 150 Hz).

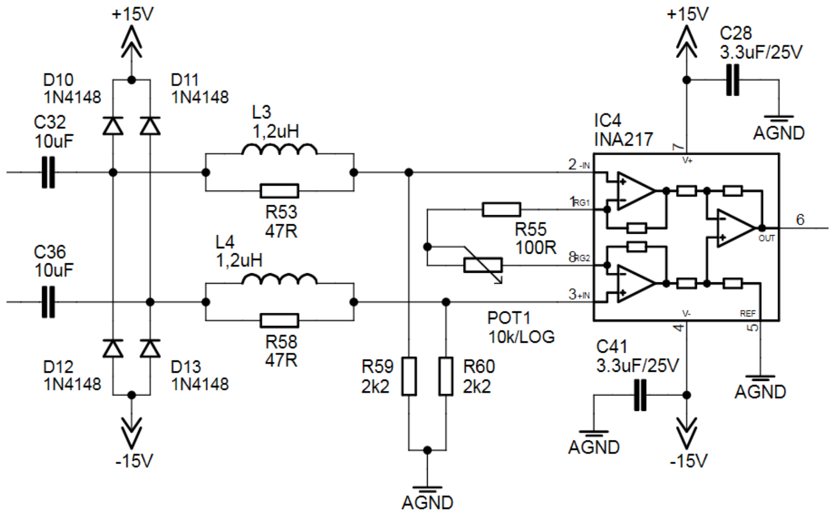

Figure 2: Pre-amplifier input (part 2)

3 VACUUM TUBE STAGE

Vacuum tube stage (Figure 3) is based on a double triode ECC82 (otherwise marked as the 12AU7) working as a cathode follower in first stage and then in a final stage as a common cathode amplifier using an output audio transformer Lundahl LL1660 (10 mA version) [3].

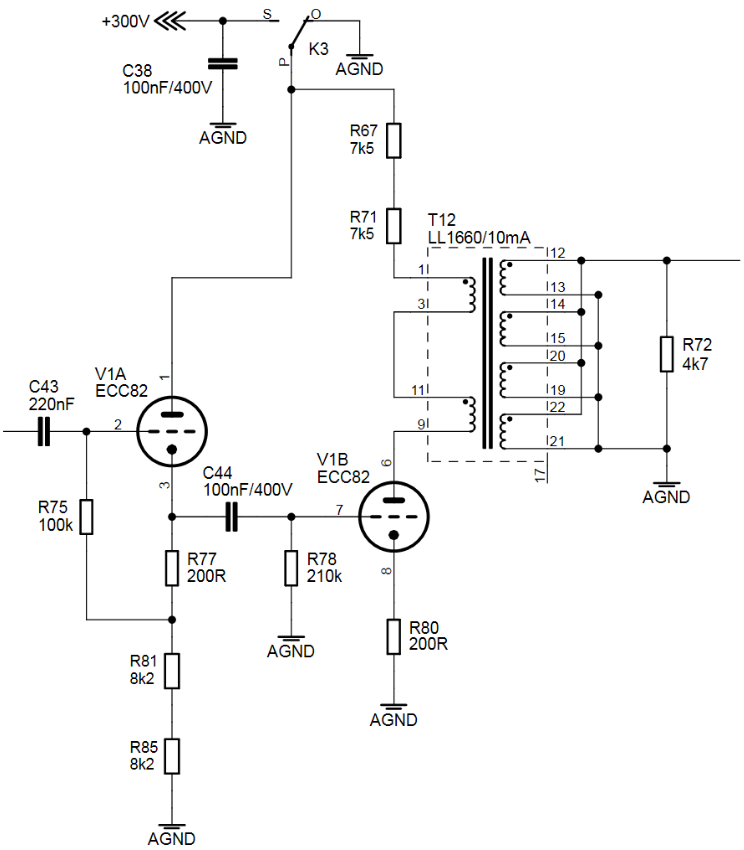

Figure 3: Vacuum tube stage

The cathode follower at the first stage is supposed to separate incoming audio signal from a rest of the circuit. A formula (shown below) defines the calculation method determining a voltage gain of the first stage.

$$A_V = \frac{\mu \cdot R_K}{r_a + R_K \cdot (\mu + 1)} \quad (1)$$

Using the ECC82 vacuum tube [4] the voltage gain equals 0.345. The second and final common cathode stage has the voltage gain equal to -11.33 and a result is solved using the formula below.

$$A_V = \frac{-\mu \cdot R_A}{r_a + R_A + R_K \cdot (\mu + 1)} \quad (2)$$

The whole tube stage is powered by stabilized 300 V power supply (Figure 4) based on a TL431 precise programmable reference [5] and power MOSFET IRFBG30. The maximum output current that can be delivered to a load is internally limited to 194.4 mA with only 7 V drop-out voltage.

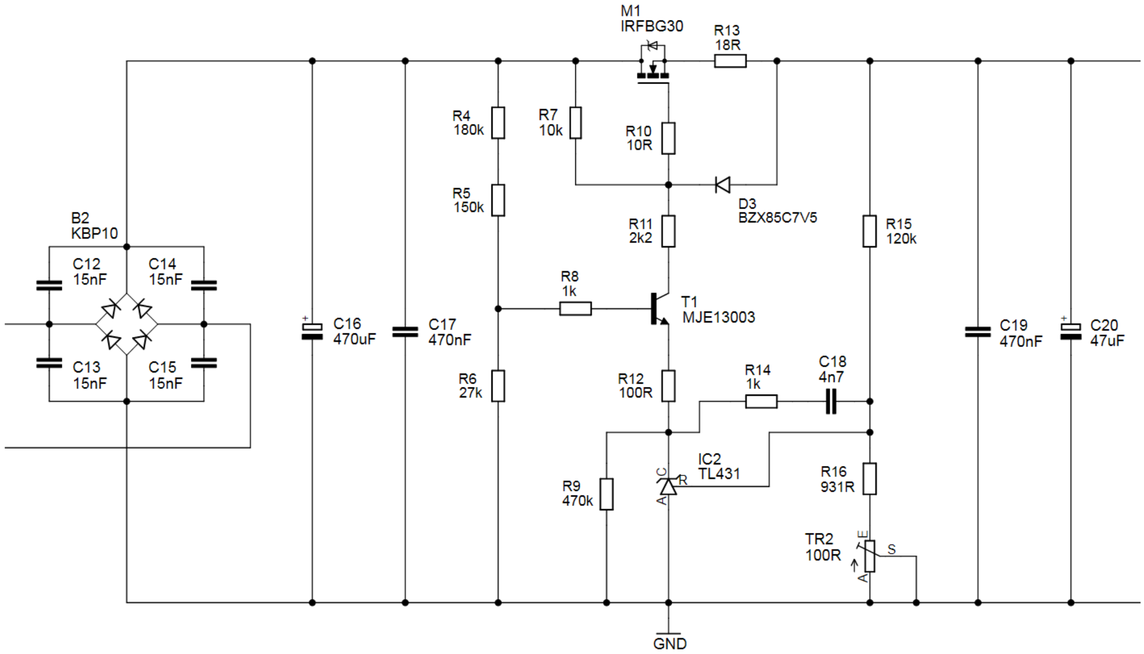

Figure 4: Vacuum stage power supply

4 MICROCONTROLLER

The pre-amplifier is equipped with an 8-bit microcontroller ATtiny24A with 2 kB of Flash memory [6] by Atmel Corporation, for simplification purposes. Its job is to automate a power-up and power-down sequence and handling all user functions.

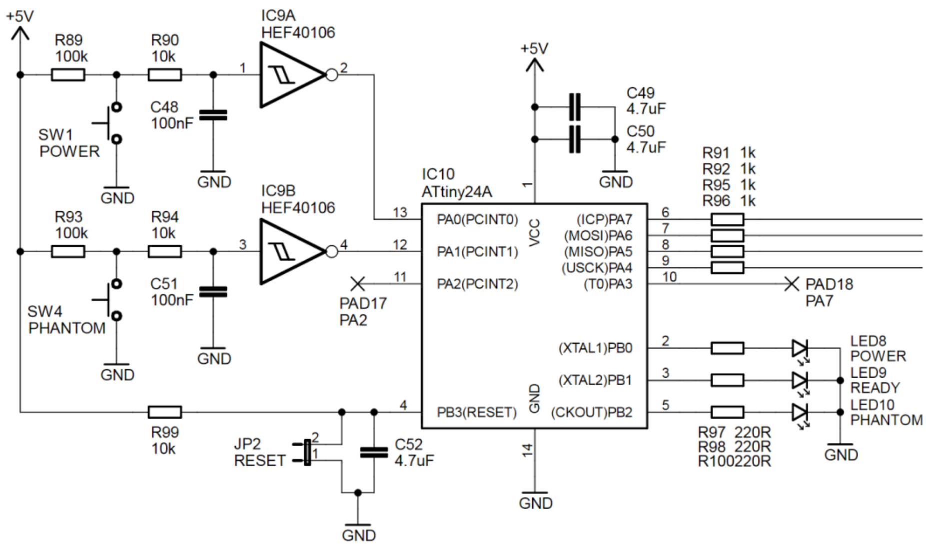

Figure 5: Microcontroller unit circuit

The user interface consists of 2 user buttons (power button, illuminated phantom power button) and 3 status LEDs (power state, ready, phantom power indication). The power-up sequence takes 62 seconds to fully operational state (most of the time takes a heating of the vacuum tube) and 7 seconds to power-off. Also the phantom power button has a safe protection (it has to be pressed longer than 2 seconds) so it cannot be switched on unintendedly.

5 CHARACTERISTIC MEASUREMENT

An audio analyser Apx525 by Audio Precision was used for measuring 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}.

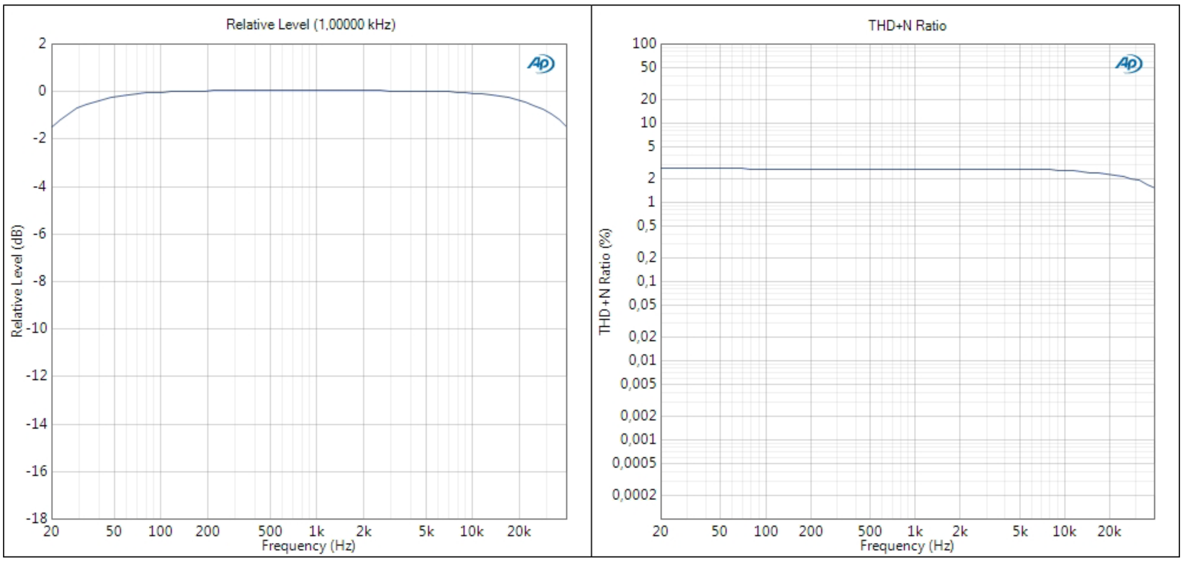

Figure 6: Illustration of measurement results

6 CONCLUSION

This article shows a partial circuit design solution of the hybrid microphone pre-amplifier. Final product contains the vacuum tube and semiconductor stage with smooth summation amplifier at the end and also all the designed features. The series of measurements was taken to provide final 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 2^{nd} harmonics). If the semiconductor technology is used the frequency response is within the range of 25 Hz to 31.5 kHz with total distortion less than 0.02 %

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