ARCHIVES OF ACOUSTICS
33, 4 (Supplement), 135–140 (2008)

TESTING THE SOUND QUALITY OF ACOUSTIC VACUUM TUBE AMPLIFIER

Stanisław MALECZEK

Wrocław University of Technology
Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland

Military Institute of Engineer Technology
Obornicka 136, 50-961, Wrocław, Poland
e-mail: maleczek@witi.wroc.pl

(*received June 15, 2008; accepted November 3, 2008*)

The study presents analysis of basic electrical parameters and sound quality of two acoustic amplifiers: an acoustic vacuum tube amplifier and a transistor amplifier. Computer-aided measurement methods have been used through the tests. For the measurement of basic electrical parameters, specialized computer stands and a computer psychoacoustic model have been used. Additionally, audio monitoring has been carried out. The paper is an attempt of answering the question: why tube amplifiers, despite worse electric parameters sound much better than transistor amplifiers do.

Keywords: acoustic vacuum tube amplifier, psychoacoustic model, sound quality.

1. Introduction

The quality of the sound from acoustic amplifiers is strictly connected with their electric parameters: passband, dynamics and with the level of nonlinear distortions. Thanks to proper technological solutions, it is possible to assure relatively low linear distortions, optimal bandwidth and good dynamics, and the resultant high sound quality [3]. Subjective methods comprise audio monitoring [8] and are applied at the end of the measurement cycle, whereas the results of objective measurements fulfil a number of complex criteria. High complexity of the subjective tests means that they are usually quite expensive. The alternative solution is a psychoacoustic model, which assures high objectivity of the measurement method, total repeatability of the results; short time of tests and low costs. Psychoacoustic model is typically applied on sound signal tests which were subjected to loss compression. On the other hand, the tests of sound samples obtained form electro acoustic devices operating on a no loss data compression basis is an interesting possibility of utilizing psychoacoustic models and it can allow a more credible audio electronics which is not based solely on electrical parameters.

2. The description of the amplifiers

2.1. DENON PMA-250SE

Each channel of the amplifier consists of four independent blocks: input stage, the task of which is initial signal amplification and the adjustment of the amplifier to the signal source impendence; correction stage which is to properly form frequency characteristics of the amplifier and driver stage, which amplifies the signal to a proper level, and the power stage, which ensures that proper input power is supplied to the loudspeaker sets.

2.2. PP EL34 vacuum-tube amplifier

PP EL34 amplifier was designer as a typical system with push-pull [2, 7] power stage [13] and differential driver stage with a current source. It was based on E188CC voltage triodes and EL34 power pentodes [4]. Local and general negative feed-back has been employed in order to improve the parameters. Construction of the amplifier involved its optimization with regard to low non-linear distortions [11]. The values and the description of the elements of the diagram below are shown in paper [10].

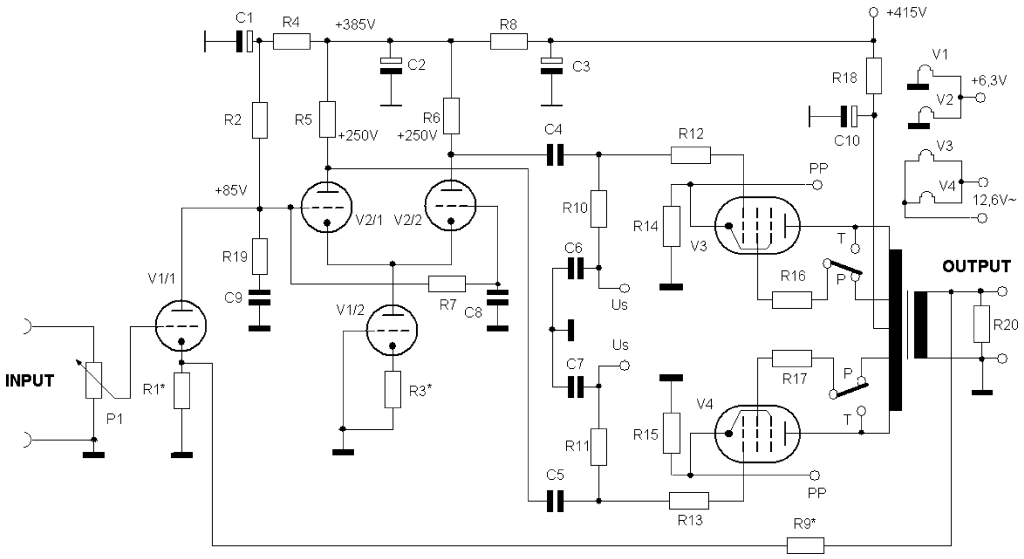

Fig. 1. Amplifier schematic diagram.

3. Tests using audio precision system

The measurements of amplifiers' parameters were conducted using "System Two" specialist equipment. During the measurements, the amplifiers were loaded with pattern resistor and their control depended on the signals coming from the system. The visible

effects in the form of diagrams and tables were shown on the computer screen. The measurements were carried out in few stages which allowed for the changes introduced and the following electric parameters were measured:

- sinusoidal output power,
- transmission characteristics,
- harmonic level,
- THD – non-linear distortion and noise.

3.1. Comparison of electrical parameters [9]

The comparison has been conducted between the two amplifiers, as far as the frequency transmission characteristics, non-linear distortions and harmonics content analysis are concerned. The obtained measurement results are presented below.

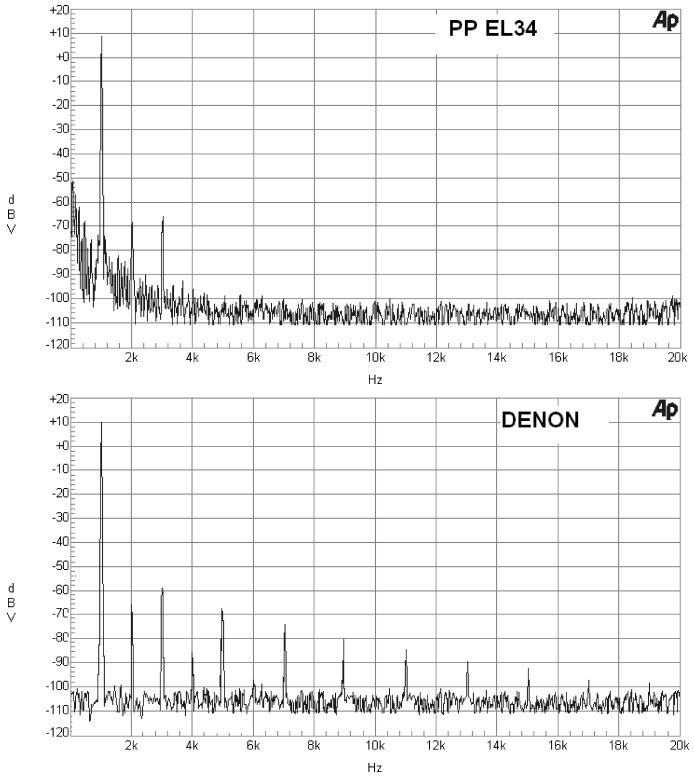

Fig. 2. PP EL34 and DENON (1W, 1kHz) harmonics content.

For DENON amplifier:

- transmission band equals 10 Hz – 20 kHz with the drop under 1 dB;
- output power equals 50 W with distortion less than 0.05%;
- THD non-linear distortion and noise less than 0.045 % for 1 W output power.

For PP EL34 amplifier:

- transmission band equals 10 Hz–90 kHz with the drop under 1 dB;
- output power equals 35 W with distortion less than 0.2%;
- THD non-linear distortion and noise less than 0.15% for 1 W output power.

The value of Transient Intermodulation Distortions has a significant impact on the sound quality of the amplifiers and will be the subject of further study.

4. Sound material preparation

Recording of sound samples has been done for CD player (pattern signal) and for both amplifiers (right channels only) and average output power 1 W (tested signal). During the session, three sound tracks were being recorded at the same time. The obtained sets of three sound track sequence from the session were initial material for the preparation of the proper music samples. The recording analysis having been done, the number of musical composition fragments was limited to 10. Each sample was given a number. As recommended [8] each sound sample was ca. 20 s long. Two pairs of samples in "wav" were formed from each three sound samples. The pairs were tested using audio monitoring and also psychoacoustic model.

5. Psychoacoustic model tests

The tests were conducted using PQMS (Perceptual Measurement Quality System) software which was developed as part of doctoral thesis on the quality of mp3-compressed signals [6]. PAQM (Perceptual Audio Quality Measure Algorithm) was selected [1, 5] with bark scale and standard settings. Before commencing to the measure-

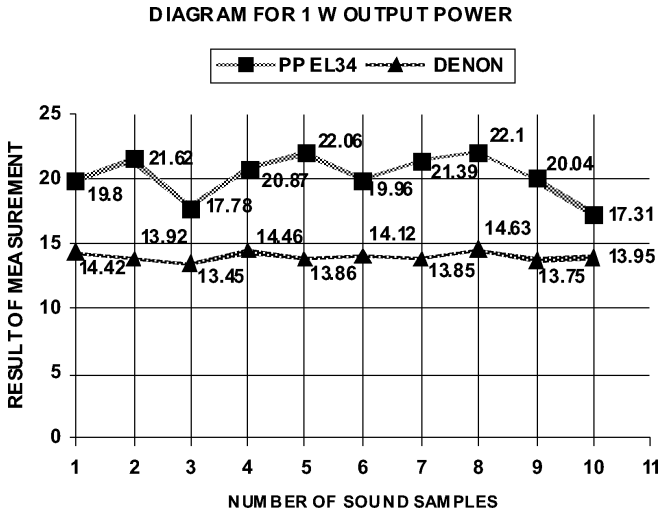

Fig. 3. Psychoacoustic model test results of sound samples.

ments proper, identical samples were tested using the abovementioned model and the result obtained was -95.72 for identical samples, and $+1.23$ for complete different samples.

The test results of sound sample tests were presented on the diagram below. In order to illustrate the results better, absolute value of the test result was used. In case of all kinds of music better results were obtained for vacuum tube amplifier.

6. Audio monitoring

In compliance with the requirements concerning this sort of tests [8], audio monitoring was conducted in a studio with a group of 36 listeners present.

The same sound samples were used for audio monitoring tests, as were verified with psychoacoustic model. They were recorded on a CD and reproduced on a audio system. The listeners were asked to answer the question: is the difference between the model sample and the tested sample audible? The test results, including all samples, regardless the kind of music, is presented on a diagram showing percentage of answers stating that there is no significant difference between the signals. In this case, the vacuum tube amplifier once again proved superior and received a better note.

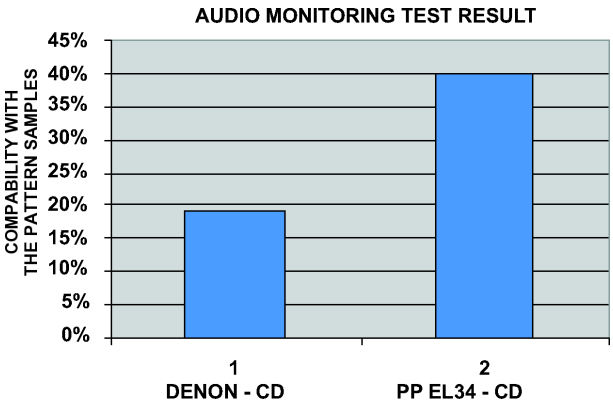

Fig. 4. Audio monitoring test result of sound samples.

7. Test result review

Having evaluated the obtained results in accordance with the standard [12], it can be stated that DENON amplifier characterized by slightly better electrical parameters requirement-wise and it should provide better sound quality. In order to verify this assumption, measurements using psychoacoustic model and audio monitoring were conducted. Contrary to the assumption, it is the vacuum tube amplifier which provided better sound quality for all kinds of music. The above situation could have been caused by the fact that vacuum tube amplifier is characterised by wider frequency characteristics and low harmonic content in the output signal. In the output signal for 1 W

DENON amplifier has rich harmonics spectrum, particularly the odd ones. And so, for 13th harmonic the signal level is still -90 dB, while the vacuum tube amplifier of the same power has only 3rd harmonic. Second harmonics are comparable (at the level of -67 dB), while 3rd harmonic is lower in the vacuum tube amplifier by about 6 dB. Delays generated by complex transistor amplifiers and negative feedback, much deeper than the one in case of the vacuum tube amplifiers, may scientifically contribute to this fact.

8. Summary

On the basis of test results it can be stated that the evaluation of sound quality of electroacoustic equipment basing solely on their electrical parameters is not entirely reliable. What is necessary, is the introduction of changes to the way the electric parameters are measured and the need to conduct audio monitoring tests. Nowadays there exists an even more favourable solution – the use of psychoacoustic model with properly optimized parameter settings of the selected measurement protocol. Such an approach to electroacoustic equipment testing guaranteed total objectivity of the measurement method which takes into account the specificity of human hearing.

References

[1] BEERENDS J.G., STEMERDINK J.A., *A Perceptual Audio Quality Measure Based on a Psychoacoustic Sound Representation (PAQM)*, J. Audio Eng. Soc., **40**, 12, 963–978 (1992).

[2] FESZCZUK M., *Electroacoustic amplifiers* [in Polish], WKiŁ, Warszawa 1986.

[3] GEISLER J., *Technical aspects of musical recordings* [in Polish], WKiŁ, Warszawa 1979.

[4] HENNEL J., *Electron tubes* [in Polish], WNT, Warszawa 1973.

[5] KOZŁOWSKI P.Z., DOBRUCKI A.B., *Perceptual Models Based Evaluation Of Speech And Audio Signals*, OSA 2007.

[6] KOZŁOWSKI P.Z., *Method of objective evaluation of sound signal quality utilising lossy compression* [in Polish], D.Sc. Thesis, Wrocław 2005.

[7] LANGFORD–SMITH F., ASTON R.H., *The design of high fidelity amplifier*, Radiotronics, No. 128.

[8] ŁĘTOWSKI T., *Aural evaluation of electroacoustic devices* [in Polish], COBRRiT 1976.

[9] MALECZEK ST., *Comparative analysis of sound quality of vacuum-tube amplifiers and transistor amplifiers using computer measurement methods* [in Polish], KOWBAN Szklarska Poręba, 2007.

[10] MALECZEK ST., *Acoustic vacuum-tube amplifier* [in Polish], Elektronika Praktyczna nr 4/2008.

[11] MALECZEK ST., *Optimisation of the total harmonic distortions of the acoustic vacuum tube push-pull amplifier*, 12th International Symposium on Sound and Vision Engineering and Mastering, Gdańsk 2007.

[12] PN-T-06256-06:1993, *Electroacoustic high fidelity equipment and systems* [in Polish]: *Urządzenia i systemy elektroakustyczne wysokiej jakości odtwarzania*.

[13] WILLIAMSON D.T.N., *Amplifiers and superlatives* Wireless Word, September 1952.