Extremums of the Average Output Dissipation of a Class AB Audio Amplifier

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Abstract – **Theoretical analysis of the output dissipation of an audio amplifier operating in class AB. Extremums (maximal and minimal values) of the average output dissipation of an output stage.**

Keywords – **Audio, amplifier, average dissipation, class AB, extremums.**

I. Introduction

The output stage is based on push-pull circuit with complementary power bipolar transistors, complementary power MOSFET's transistors or power vacuum tubes. Fig. 1 shows popular realization with complementary power MOSFET's transistors [1÷4].

The analysis is done at a constant sinusoidal signal or at smooth change of frequency and amplitude.

The theoretical analysis and the computer simulation are performed for an active load (rated impedance).

The average dissipation output can be obtained by integrating the instantaneous dissipation output.

In class AB and output level of $m = V_0/V_{ss} = 0 \div 1$ and $v = V_{Rt}/V_{ss}$, when integrating
from: $-\arcsin(v/m) \quad (t_0 = -\phi_{V_{Rt}} = -\arcsin(v/m))$
to $\pi + \arcsin(v/m) \quad (t_1 = \pi + \phi_{V_{Rt}} = \pi + \arcsin(v/m))$:

$$P_{d(AV)} = \frac{1}{2\pi}\int_{-\phi_{V_{Rt}}}^{\pi+\phi_{V_{Rt}}} P_{d(inst)} d\varpi t = 1 + \frac{2}{\pi} a\sin\left(\frac{v}{m}\right) + \frac{2}{\pi}\sqrt{m^2-v^2} - \frac{v}{\pi}\sqrt{m^2-v^2} - \frac{m^2}{\pi} a\sin\left(\frac{v}{m}\right) - \frac{m^2}{2} \tag{1}$$

In class B ($v = V_{Rt}/V_{SS} = 0$):

$$P_{d(AV)} = \frac{V_{ss}V_O}{\pi R_L} - \frac{V_O^2}{4R_L} = \frac{2}{\pi}m - \frac{1}{2}m^2 \;, \tag{2}$$

In class A and in class AB, but at $m = V_0/V_{ss} < v = V_{Rt}/V_{ss}$:

$$P_{d(AV)} = \frac{1}{2\pi}\int_0^{2\pi} P_{d(inst)} d\varpi t = 2v - m^2 \;, \tag{3}$$

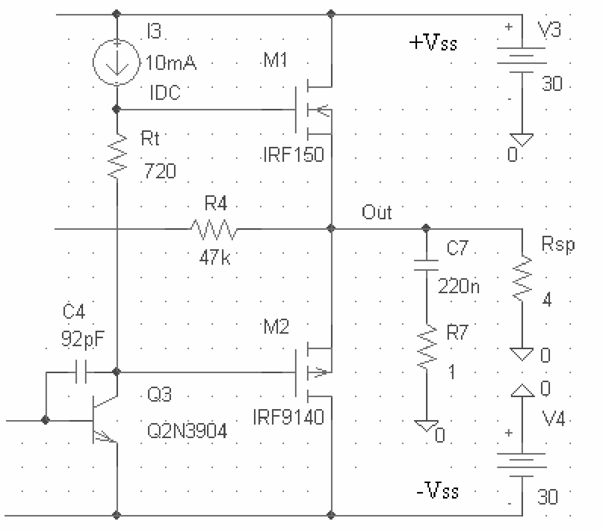

Fig. 1. Power-board (output stage) schematic diagram

II. Analysis of the Output Dissipated by the End Transistors at a Resistive Load

The first derivative of the expression for the average dissipation output in class B ($P_{d(AV)} = 2m/\pi - m^2/2$) is a straight line, trace 3 ($2/\pi - m$), which crosses the ordinate

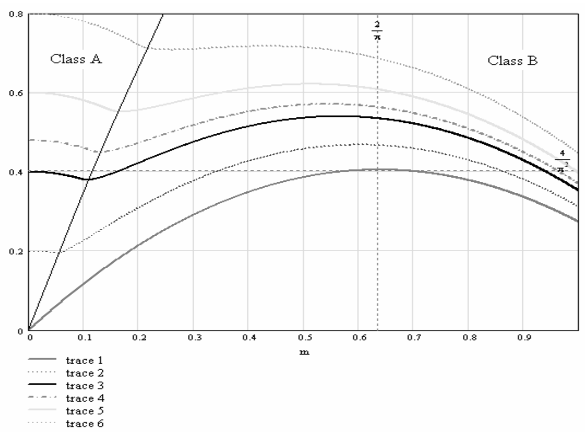

Fig. 2. Average dissipation output of both transistors M_1 and $M_2 P_{d(AV)}$ in class AB and B in case with a resistive load.
trace 1 – a curve of the average output dissipation of both transistors of the output stage working in class B.
trace 2÷6 – curves of the average output dissipation of both transistors of the output stage working AB.

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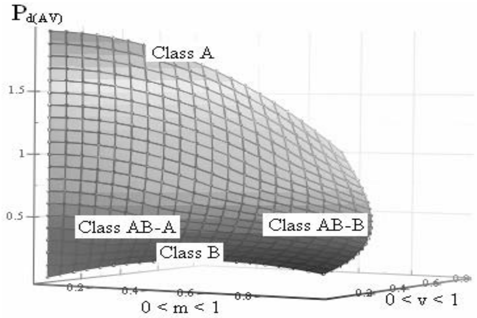

Fig. 3. 3 D - Average dissipation output in class A, AB and B

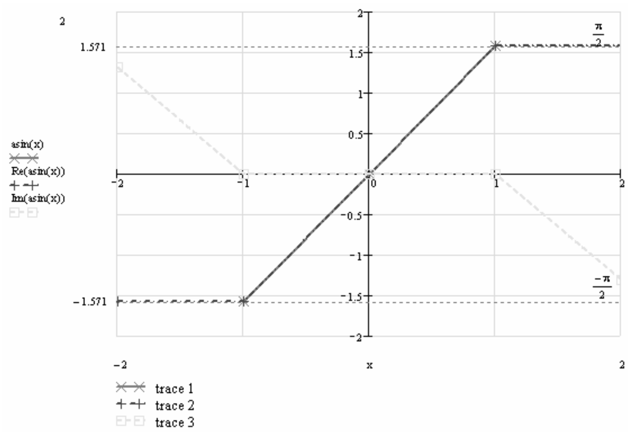

Fig. 4. Real and Imagine part of the mathematical function $\arcsin(x)$.
trace 1 – in this area $\arcsin(x)$ accepts real values only. This is a line determined by the points with co-ordinates $-1, -\pi/2$; $0, 0$ ($v = 0$ – class B) and $1, \pi/2$. This is the area of class AB, but at $m > v$ - the output stage operates with big signal, i.e. class B.
trace 2 – the real part of $Re[\arcsin(x)]$. Out of the area of trace 1 $Re[\arcsin(x)]$ accepts the value of $\pm\pi/2$ for $|\pm x| \geqslant 1$ correspondingly. This is the area of class AB, but at $m < v$ – the output stage operates with small signal, i.e. class A.
trace 3 – the imaginary part of $\arcsin(x)$.

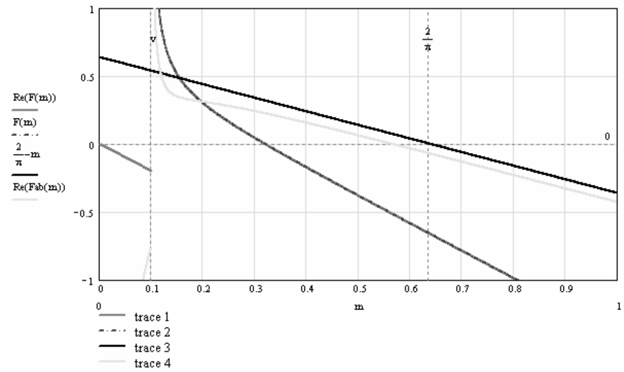

Fig. 5. Curves of the first derivative of the average power dissipation $P_{d(AV)}$ in class AB and B at a resistive load.

at $m = 2/\pi = 0.637$,– an extremum.

In class AB crosses the ordinates twice (two peaks) and is broken for the minimum.

III. Conclusions

Fig. 2 shows the extremums of the average power dissipation of the two push-pull arms of the output stage operating in class AB.

The average power dissipation in class AB there is maximum and minimum values depending on the level of the signal $m = 0 \div 1$, where the parameter is the bias voltage determining the working point of the end transistors.

The first minimum describes the curve which starts from the center of the co-ordinate system $0, 0$ ($v = 0$ - class B) and end at point $1, 1$ ($v = 1$ - class A).

This area characterize working amplifiers in class AB when they pass from class A to class B and conversely, where the parameters are the signal level (variable $m = 0 \div 1$) and the bias voltage determining the class of working (parameter $v = 0 \div 1$).

The two maximums for class AB correspond to the two areas of operation: area of class A (to the left of the ordinate) and area of class B (above the abscissa).

The first maximum with parameter $v = 0 \div 1$, describes a segment which coincides with the ordinate (area of operation in class A).

The second maximum, with parameter $v = 0 \div 1$, describes an arc (area of working in class B). The beginning of this curve you can see the maximum of the average dissipation output in class B, with co-ordinates $2/\pi, 4/\pi^2$. The end of the arc shows the extremum in class A$(0, 2)$.

The average dissipation output is minimum in this area at maximum output voltage (parameter $m = 1$,v).

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