Letter to the editor

Aat Vroegop writes:

Dear editor,

I appreciate and applaud Frank Blöhbaum for his inventive tube/semiconductor circuits.
I am of course referring to the article “Multiplied Transconductance Amplifiers” in Volume 6 of Linear Audio.
However, one thing puzzles me. The capacitor in parallel to the current sources range in value from 22000uF to 47000uF, which would imply an extremely low impedance at that node.
Is there an error in the capacitor values or am I overlooking something?

Aat N. Vroegop
Delft, The Netherlands

Frank Blöhbaum replies:

Dear Aat,

I understand that, being mindful of cathode capacitor values of standard textbook single-ended amps – typical 100µF - this overwhelming large capacitor inside my MTA structure looks wrong. But, there is no error. The reason is that the MTA works quite different from a ‘standard SE amp’. First, the open-loop gain is very large. The circuit in Fig. 17 (L|A Vol6) has an open-loop gain of more than 12000 from signal input to anode of power tetrode – at 1kHz. This open-loop gain will be limited to much lower values, if the anode load drops down or if the cathode impedance rises. The open-loop gain is limited basically by this equation:

$V_u = Z_a / Z_k$ [1]

where
Z_a – impedance at the anode (or anode load) and

Z_k – impedance at the cathode (basically the capacitor parallel to the current source).

At the low end of the frequency range the value of Z_a is determined by the primary inductance of the output transformer. For the example of Fig. 17 this value is given as:

$L_{primary} = 26H$ [2]

At 20Hz, Z_a equals:

$Z_{Lprimary(20Hz)} = Z_{a(20Hz)} = 2*Pi*20Hz*26H = 3267.3\ Ohm$ [3]

The impedance of the cathode capacitor:

$Z_{Ck(20Hz)} = Z_{k(20Hz)} = 1 / 2*Pi*20Hz*22mF = 0.3617\ Ohm$ [4]

Following [1] the open-loop gain equals to:

$V_{u\,(20Hz)} = Z_a / Z_k$ = 3267.3 / 0.3617 = 9033 times [5]

If we took a capacitor of 100µF the open-loop gain will drop a lot:

Calculation for C_k = 100uF:

$Z_{k\,(20Hz,\,100\mu F)}$ = 1 / 2*Pi*20Hz*100µF = 79.58 Ohm [6]

$V_{u\,(20Hz,\,100\mu F)} = Z_a / Z_k$ = 3267.3 / 79.58 = 41.06 times [7]

We still look at the anode of the power tetrode. Let's have a look at the secondary side of the output transformer. The impedance ratio is defined as:

Z_a / Z_{sek} = 4500 Ohm / 8 Ohm = 562.5

The square root of Z_a / Z_{sek} delivers the factor, by which the open-loop gain is divided at the secondary side of the output transformer:

n = SQRT(562.5) = 23.72 [8]

Therefore, the open-loop gain at the secondary side equals to:

$\mathbf{V_{u\,(sek,\,20Hz,\,22mF)}} = V_{u\,(pr)}$ / n = 9033 / 23.72 = **381** times [9]

$\mathbf{V_{u\,(sek,\,20Hz,\,100\mu F)}} = V_{u\,(pr)}$ / n = 41.06 / 23.72 = **1.73** times [10]

So the standard capacitor of 100µF will lower the open-loop (!) gain of the whole amplifier from input to the speaker to just 1.73 times or 4.76 dB – at 20Hz. (At 1 kHz the open-loop gain would be much higher of course).

Summary: the very large value of the electrolytic capacitor parallel to the current source is entirely necessary to keep the open-loop gain at the lower end of the frequency range large enough. The aim of the MTA is to get an amplifier having a very large open-loop gain over a large bandwidth – and to have a very large bandwidth of the feedback loop down to DC as well.

The measured closed loop gain of the amplifier of Fig. 17 (L|A Vol 6) is 7.816 times or 17.86 dB.

I made some additional measurements showing the very good performance of this MTA.

The good power bandwidth of the MTA of Fig. 17 is shown in **Fig. 1**. The rise of k5 at low frequencies is caused mainly by the influence of hum residuals at 100Hz and 200Hz, because the measurements were done using frequency steps at 20Hz (5 x 20Hz = 100Hz), 40Hz (5 x 40Hz = 200Hz), 120Hz, 333Hz, 666Hz, 1k, 2k, 4k, 6k, 8k, 10k. Despite of that k5 is very, very low. The rise of the distortion at 10 kHz is basically caused by the stray inductance of the output transformer which lowers the open-loop gain. The measurement bandwidth is 20 kHz; therefor there are no measurement values for spectral components above the 20kHz limit.

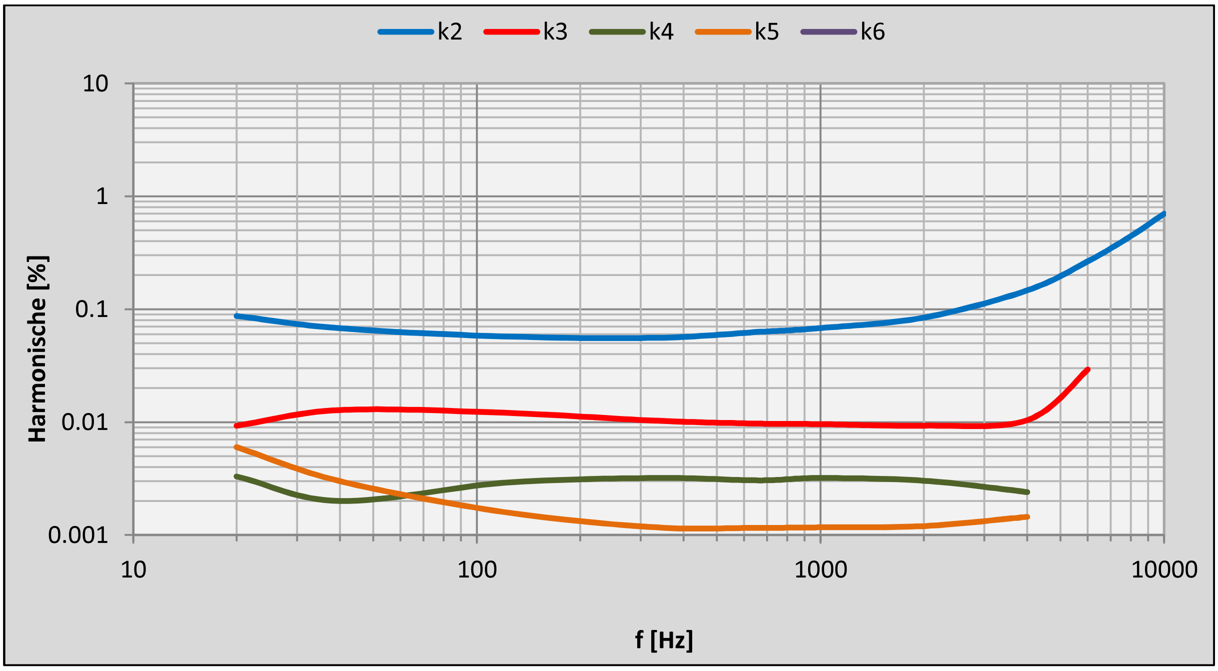

Fig. 1 – Distortion vs. freqency measured at 1Weff into 8 Ohm, MTA of Fig.17, L|A Vol 6, measured with Rohde&Schwarz UPL

The distortion vs. power is shown in **Fig. 2**. Isn`t it a nice amplifier, having a near perfect triode characteristic? K2 is dominating – on a very low level. And the sonic characteristic is kept along the whole power range – no cross-over of spectral components, very low k3, almost no k4. And k5 and k6 are below the measurement limit of 0.001%.

Please keep in mind, that this amplifier has a full power of approx. 2.8Weff only. That means, that the measured 2Weff show the power tetrode working under near full load.

The performance of this amplifier exceeds those famous DHT amps – without using such expensive tubes like the RE604, AD1 or 300B.

And, these measurements as well as the listening tests (MTA + horn system) show: don`t be afraid of using large electrolytic capacitors! Today these parts have a very good quality. As long as the electrolytic capacitor is working under steady polarized voltage across it the distortion caused by the ESR is negligible.

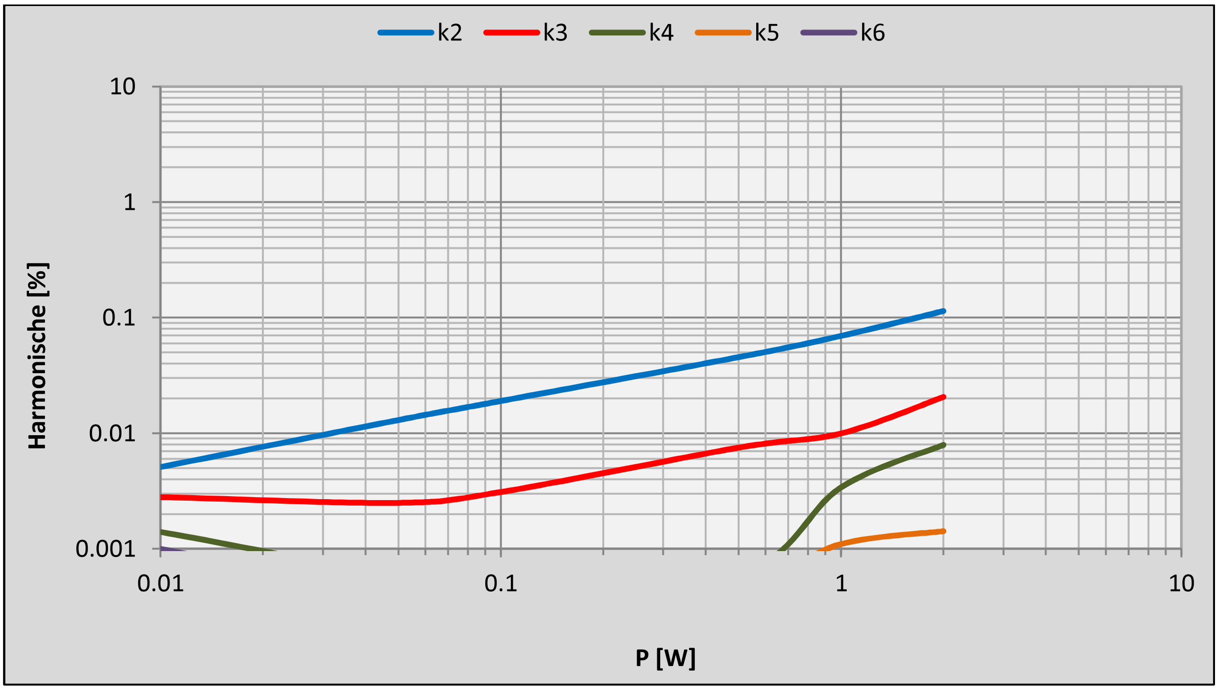

Fig. 2 – Distortion vs. Power measured at 1kHz into 8 Ohm, MTA of Fig.17, L|A Vol 6, measured with Rohde&Schwarz UPL