

«There are only advantages and no disadvantages to applying stratospheric amounts of negative feedback in an amplifier. The only hard part is figuring out how to do it.

Improving loop gain improves TIM. There is no horse trading between “ordinary” distortion and TIM

Open-loop bandwidth is no measure of how fast an amplifier is. Gain-bandwidth product is Slew Rate is a bad predictor of audio performance »

### The F-word

Bruno Putzeys

To begin with, there are composite amplifiers with a stratospheric Loop-Gain whose nonlinear distortions are less than the distortions of the best generators and it is a big problem to measure the level of their distortion.

However, as you know, the last word belongs to the auditory examination, and when they start listening to music with the help of such amplifiers, it suddenly turns out that on separate fragments of music some instruments and performers' voices sound unrecognizable.

Using the example of a composite amplifier on two op amps, I showed how easy it is to obtain high loop gain at a frequency of 20 kHz, but at the same time, the slew rate of the output voltage, contrary to Bruno's statements, only decreased, and the speed distortions increased.

Instead of abstract reasoning, consider the results of testing the same voltage amplifier, Fig. 1 with four various types of correction.

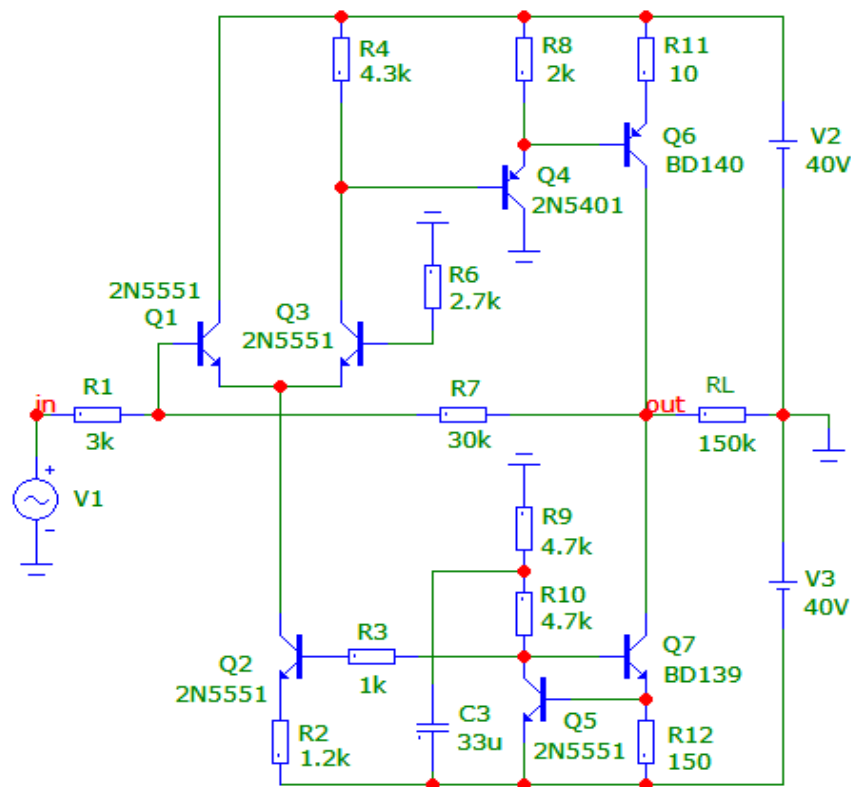


Fig. 1

Figure 1 shows the simplest voltage amplifier with a differential input. Let's analyze four correction options: 1 - JLH-1972; 2 - Cdom (Miller); 3 - 2-pole; 4 – TMC. The test results are summarized in table

	VAS_JLH	VAS_Miller	VAS_2-pole	VAS_TMC
GBW, MHz	20	6,4	5,9	13
FPBW, kHz	800	30	70	70
SR, V/us	150	5,6	13	13
20 kHz, Loop Gain, dB	63	38	68	45
20 kHz, THD, %	<0,001	0,04	0,0014	0,004

The total power bandwidth (FPBW) was measured by decreasing the oscillator frequency until the distortion visible to the naked eye disappeared in the output signal.

The slew rate of the output voltage is related to the FPBW by the well-known formula (but not to the GBW):

$$SR = 2\pi f V_p \text{ (V/us)}$$

где  $f$  – full power frequency in MHz:

$V_p$  – peak value of the output undistorted voltage in Volts

First, let's see how John Linsley Hood corrected it back in 1972, Fig. 2

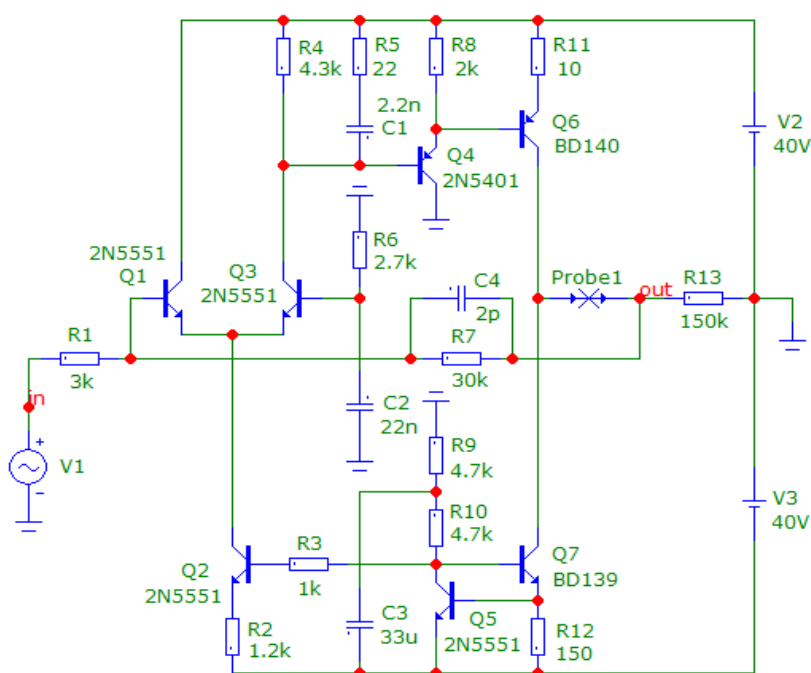


Fig. 2

Let's remove the Bode diagram, fig. 3

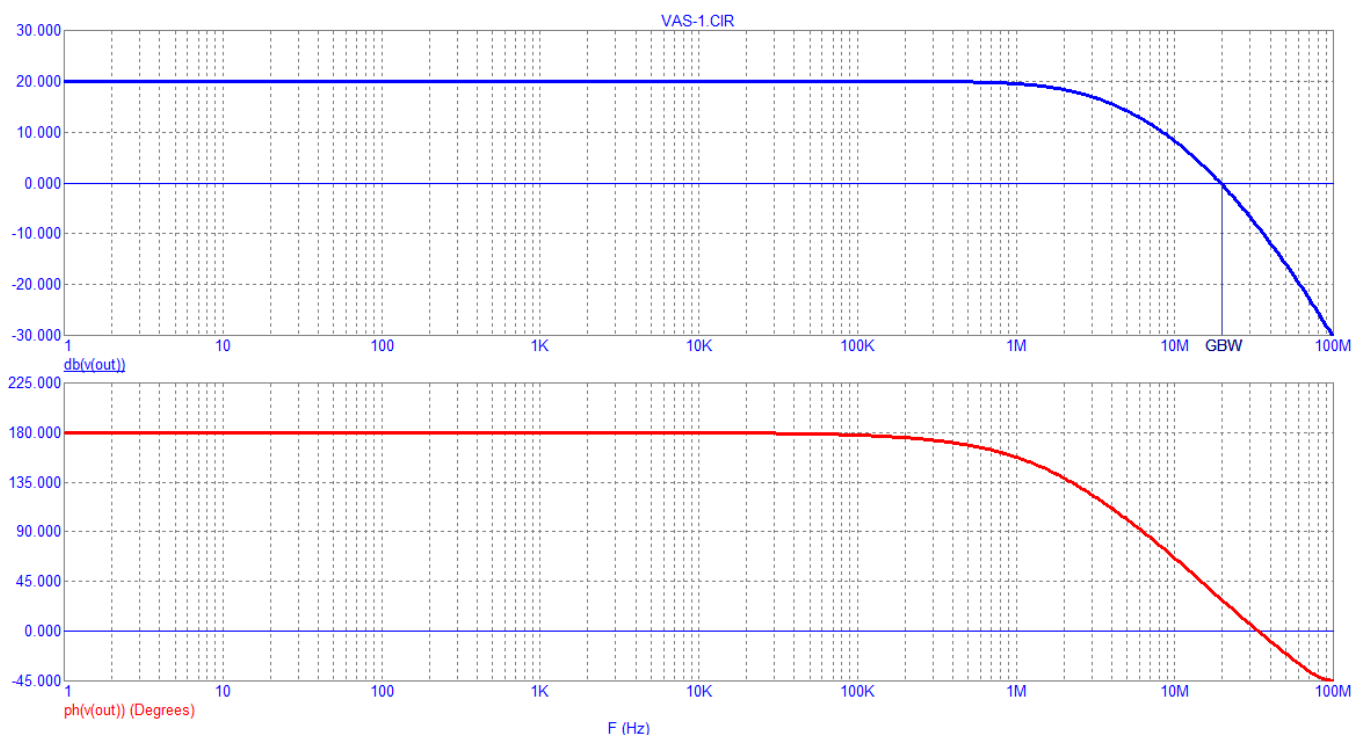


Fig. 3

The task of correct correction is to obtain a compromise between loop gain and stability margins,

Fig. 4

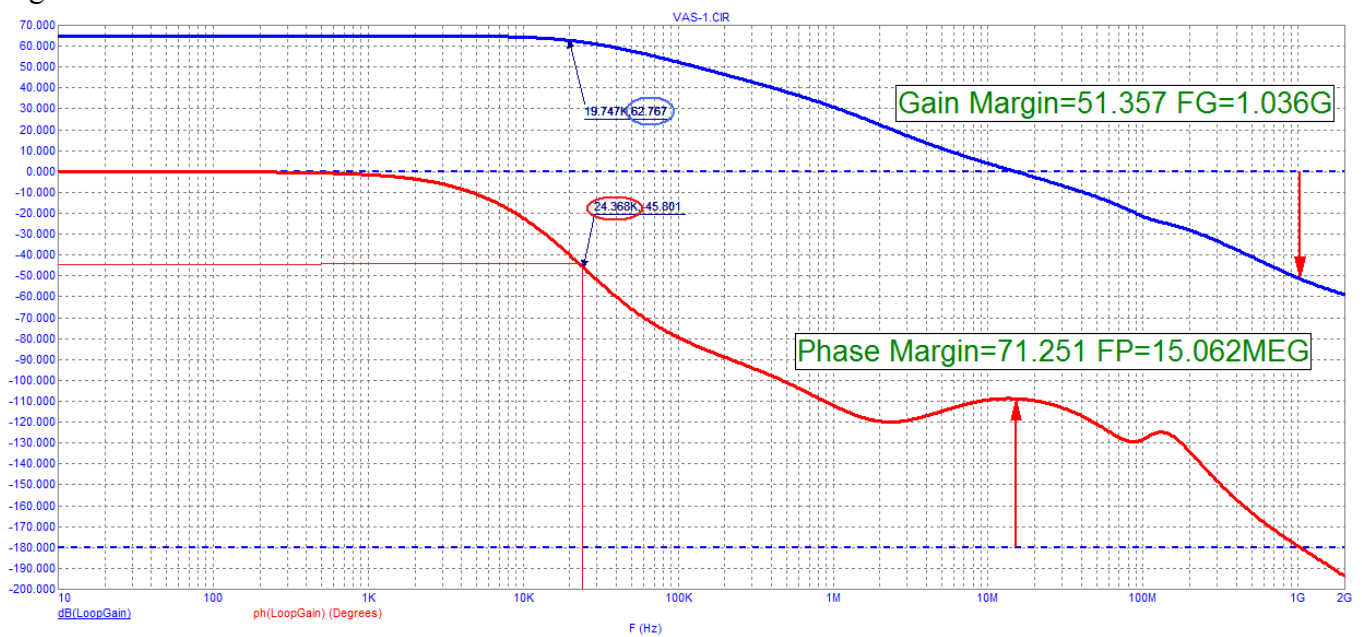


Fig. 4

Nonlinear distortion spectrum at a frequency of 20 kHz in a steady state, Fig. 5

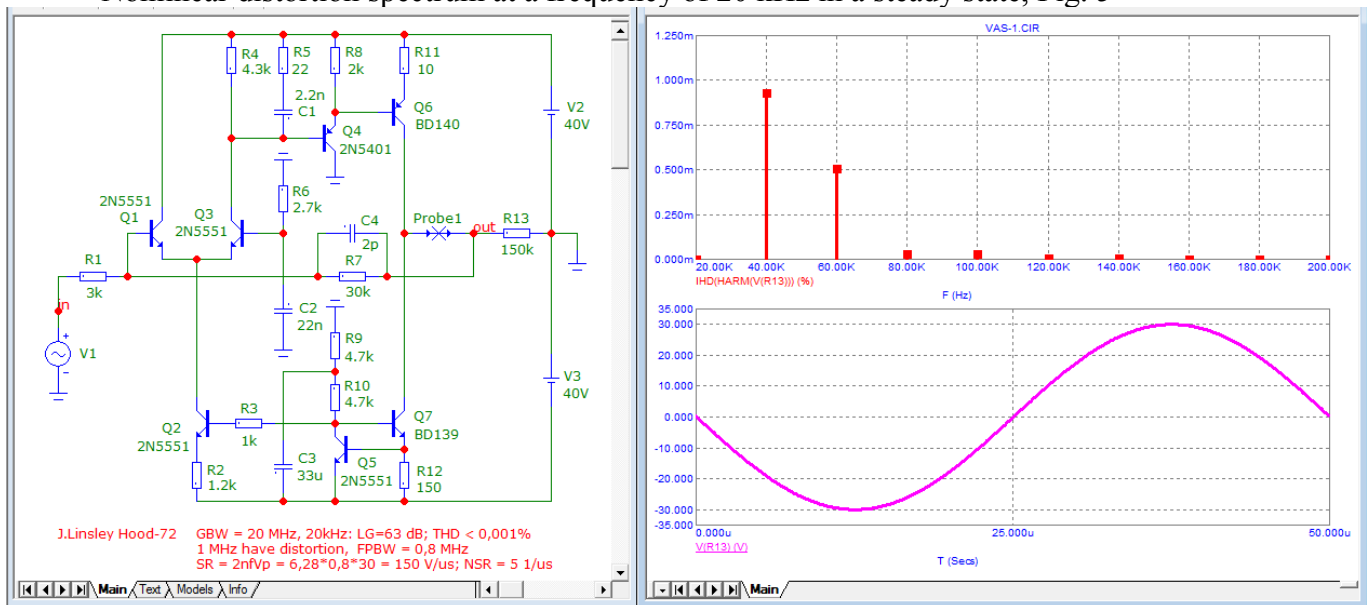


Fig. 5

The program itself determines the end of the distortion of transient processes and only after their end makes measurements.

Let's see how the amplifier amplifies the signal at the upper frequency of the FPBW, Fig. 6

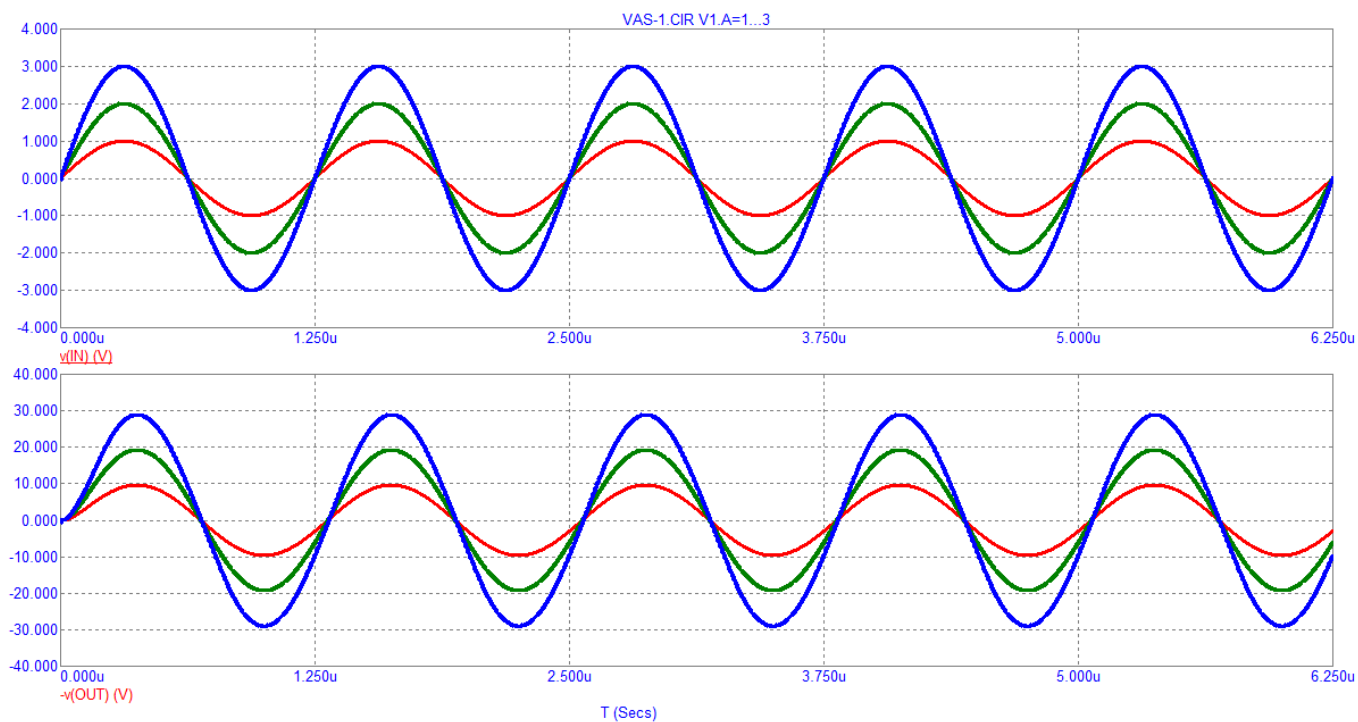


Fig. 6

Well, now let's see how the scheme with Miller's correction would look like (a favorite correction of some authors, I will not indicate so as not to be offended), Fig. 7.

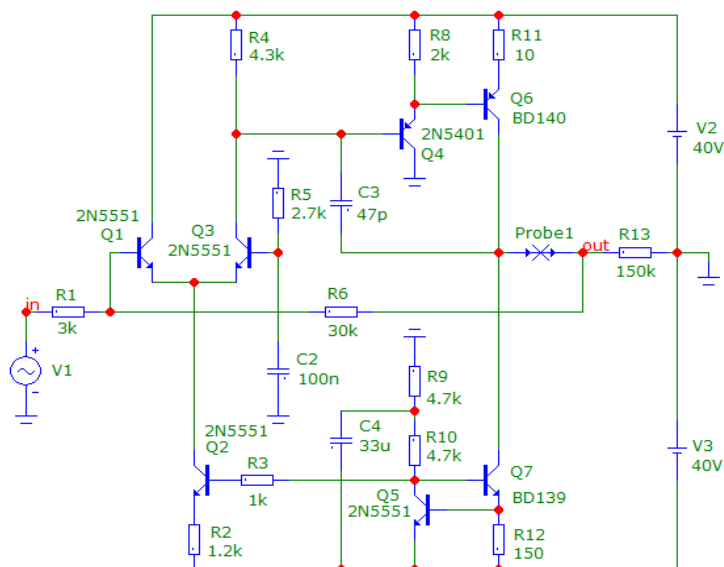


Fig. 7

Let's remove the Bode diagram and the loop gain graph, Fig. 8, fig. 9

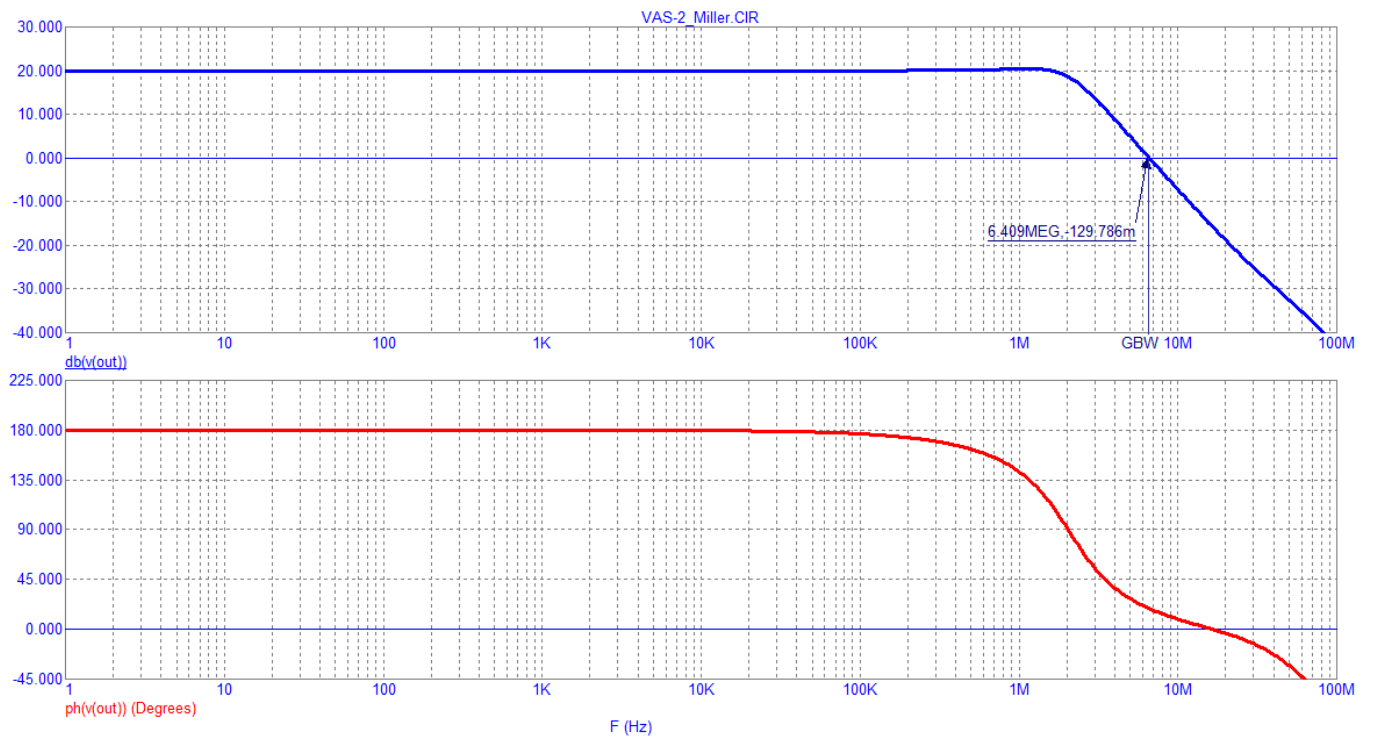


Fig. 8

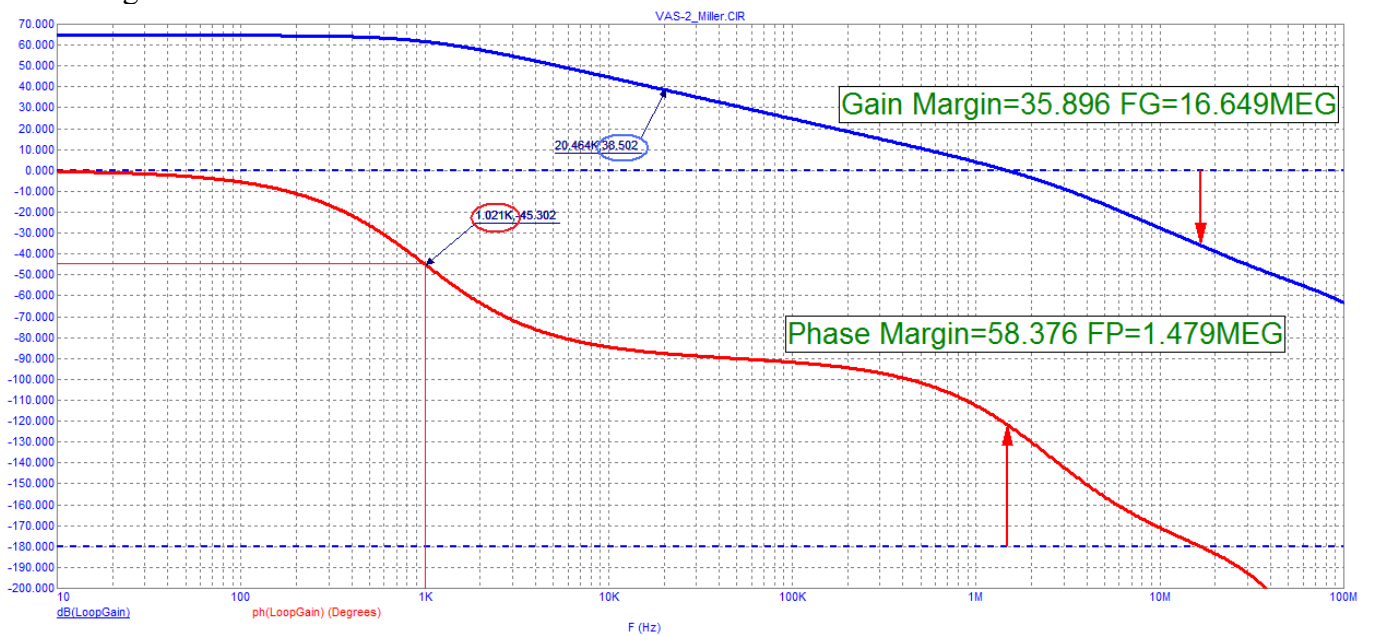


Fig. 9

The level of nonlinear distortion at a frequency of 20 kHz, Fig. 10

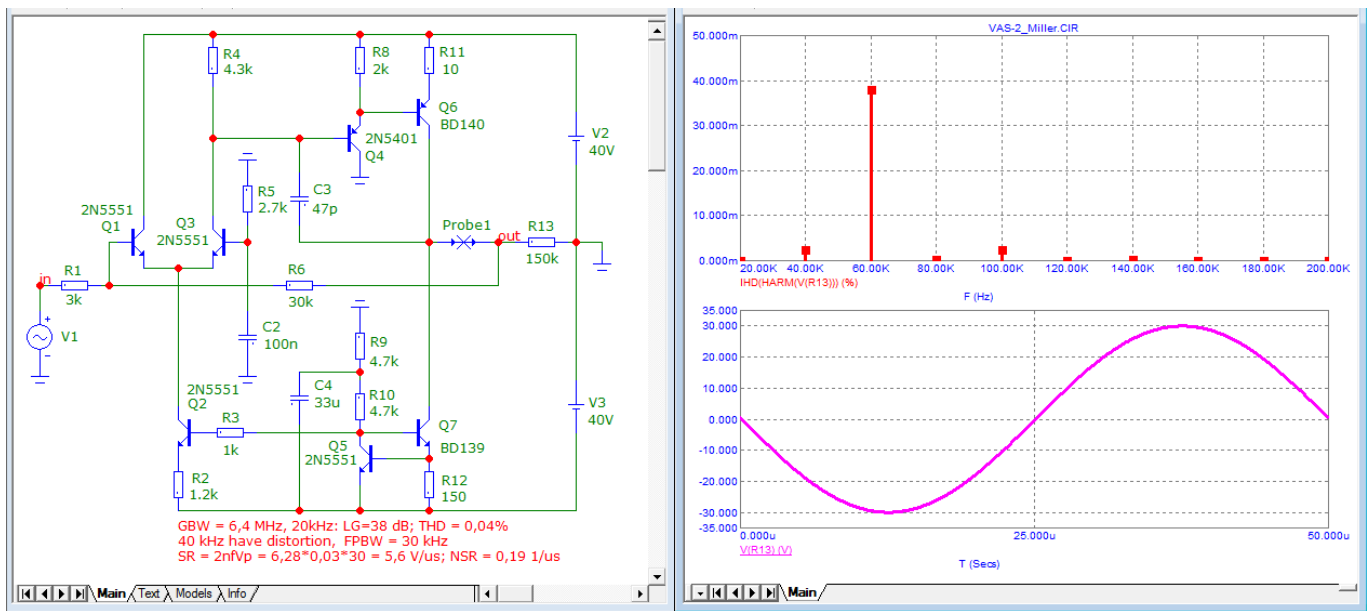


Fig. 10

Amplification of a 40 kHz signal is shown in Fig. 11

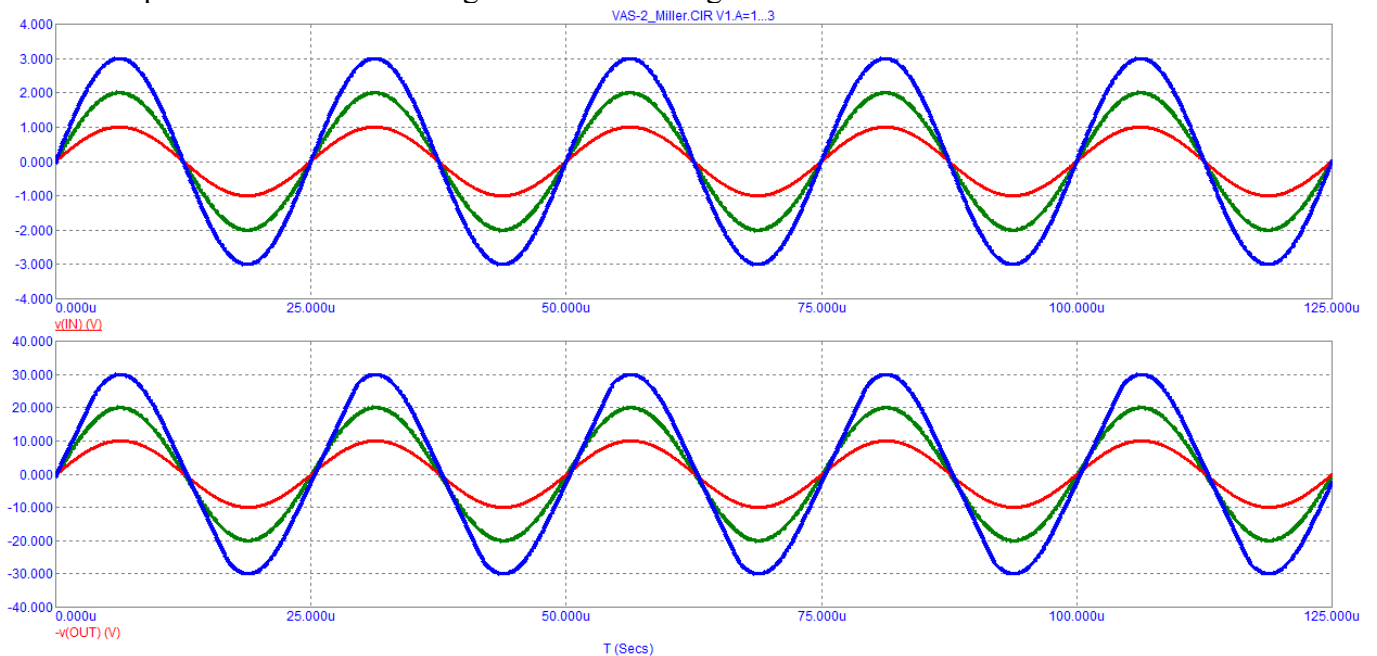


Fig. 11

Figure 11 shows that already at a frequency of 40 kHz, TIM distortions begin.

In the next version, a 2-pole correction is used, Fig. 12

Great hopes were pinned on this type of correction, since it allows you to increase the loop gain at higher frequencies in the audio range and thereby reduce the level of nonlinear distortion. For example, Douglas Self in his books also describes the operation of this type of correction and, despite the resulting reduction in distortion at higher frequencies, recommends its use with great caution, despite the seemingly obvious advantages.

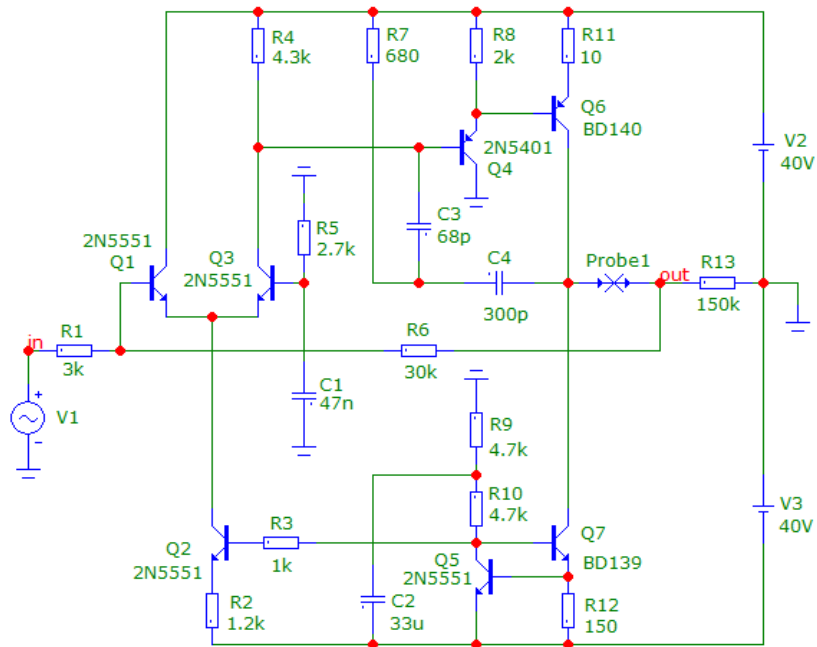


Fig. 12

Let's run similar tests

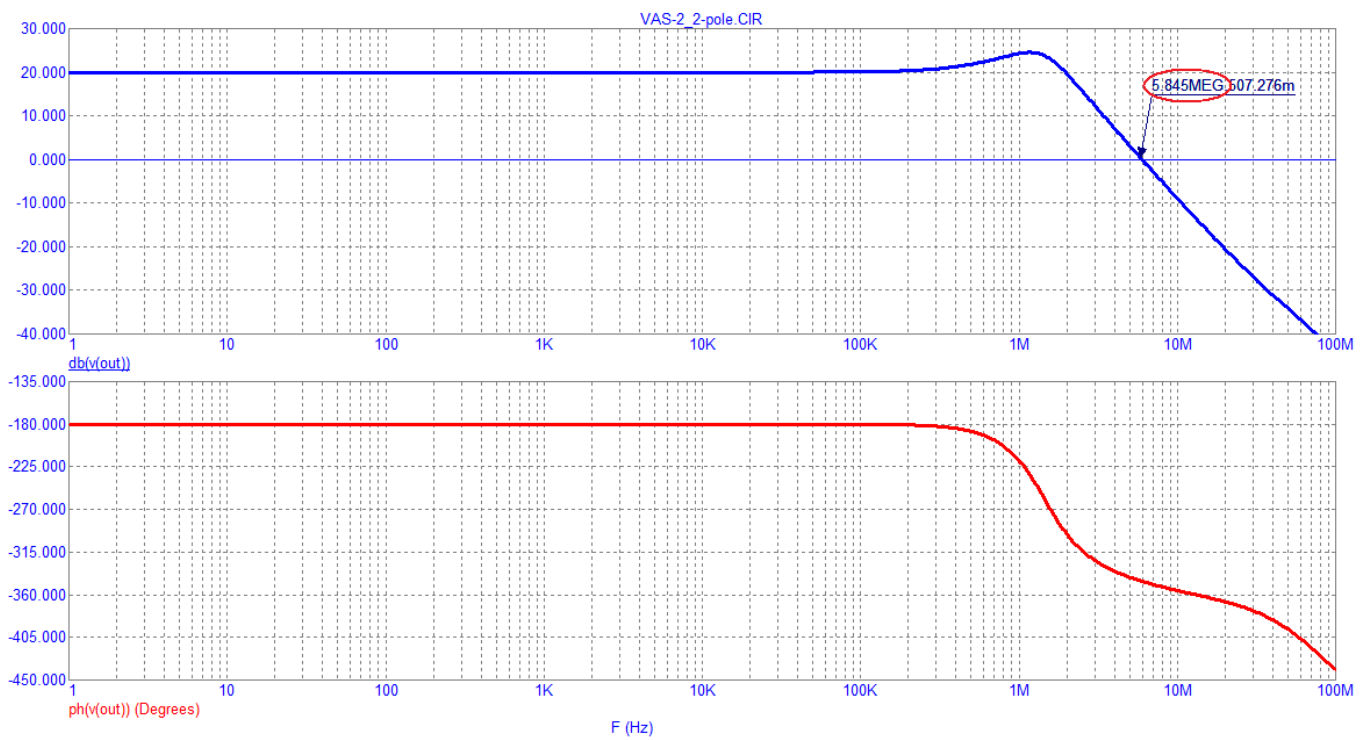


Fig. 13

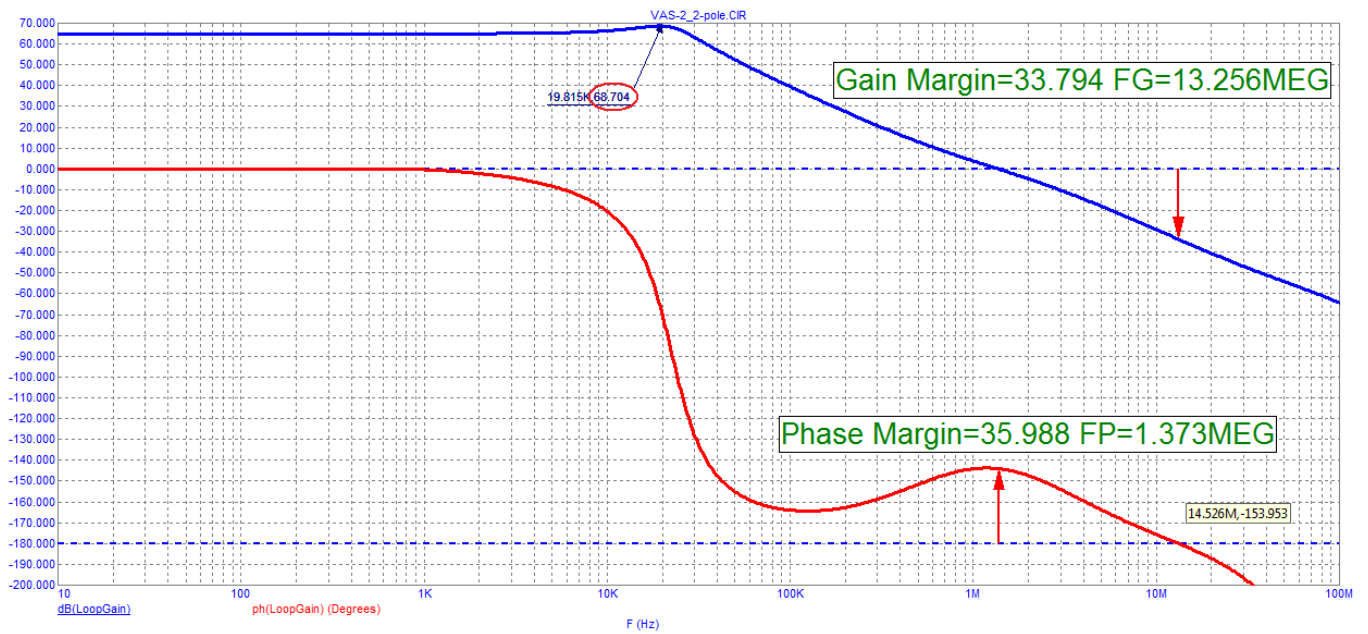


Fig. 14

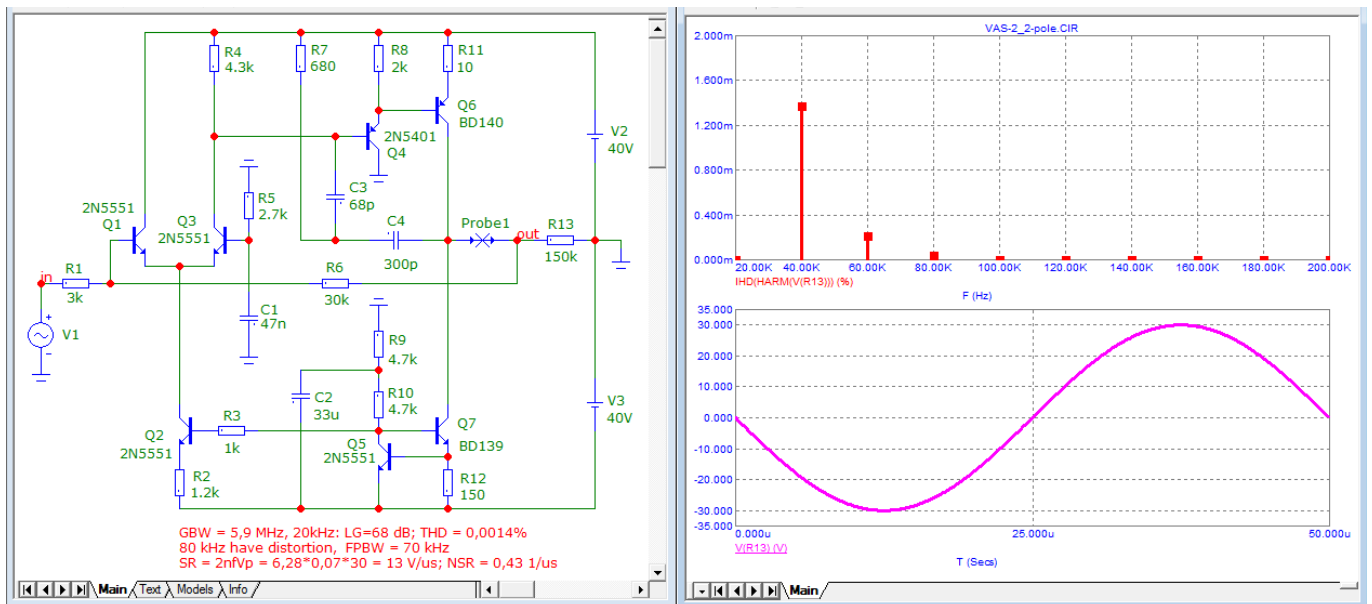


Fig. 15

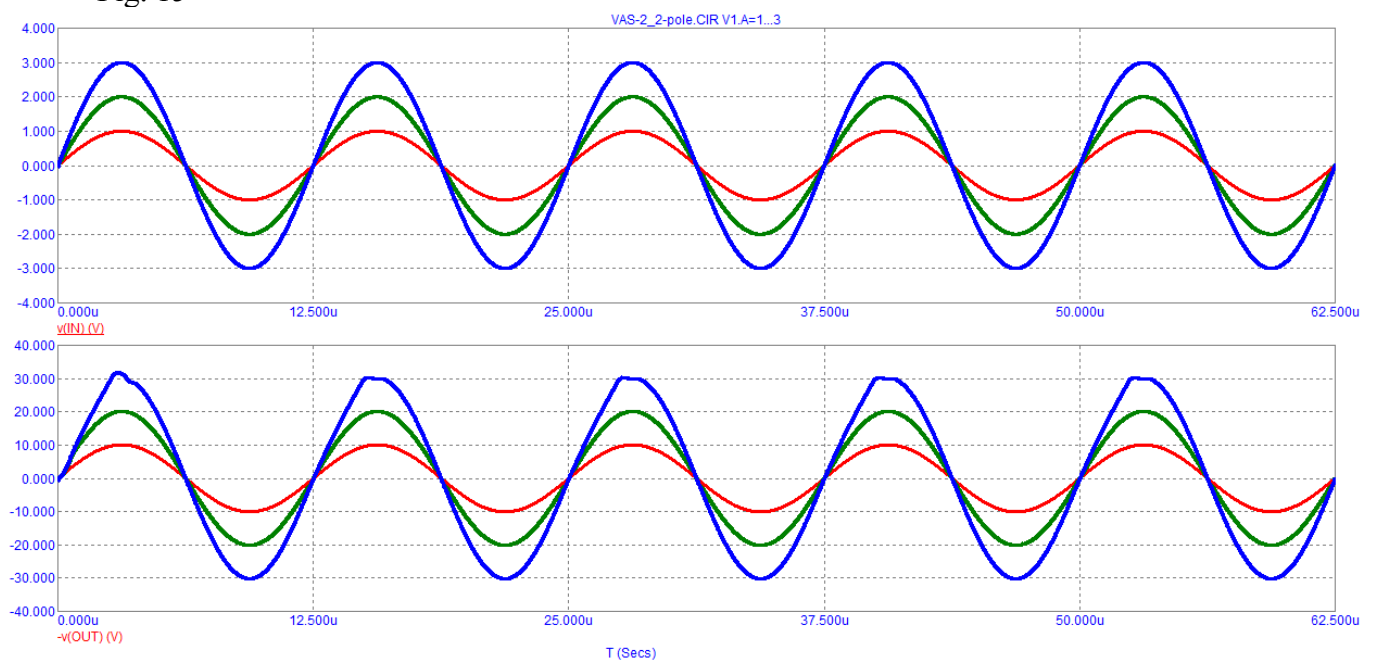


Fig. 16



Figure 16 shows that distortions appear already at a frequency of 80 kHz.

The next type of correction is the modification of the 2-pole correction, the so-called TMC, Fig. 17 and the results of its testing ...

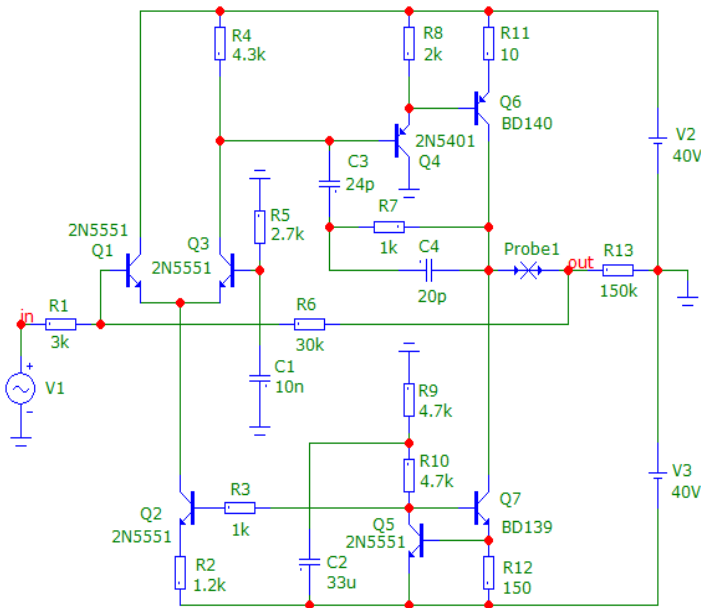


Fig. 17

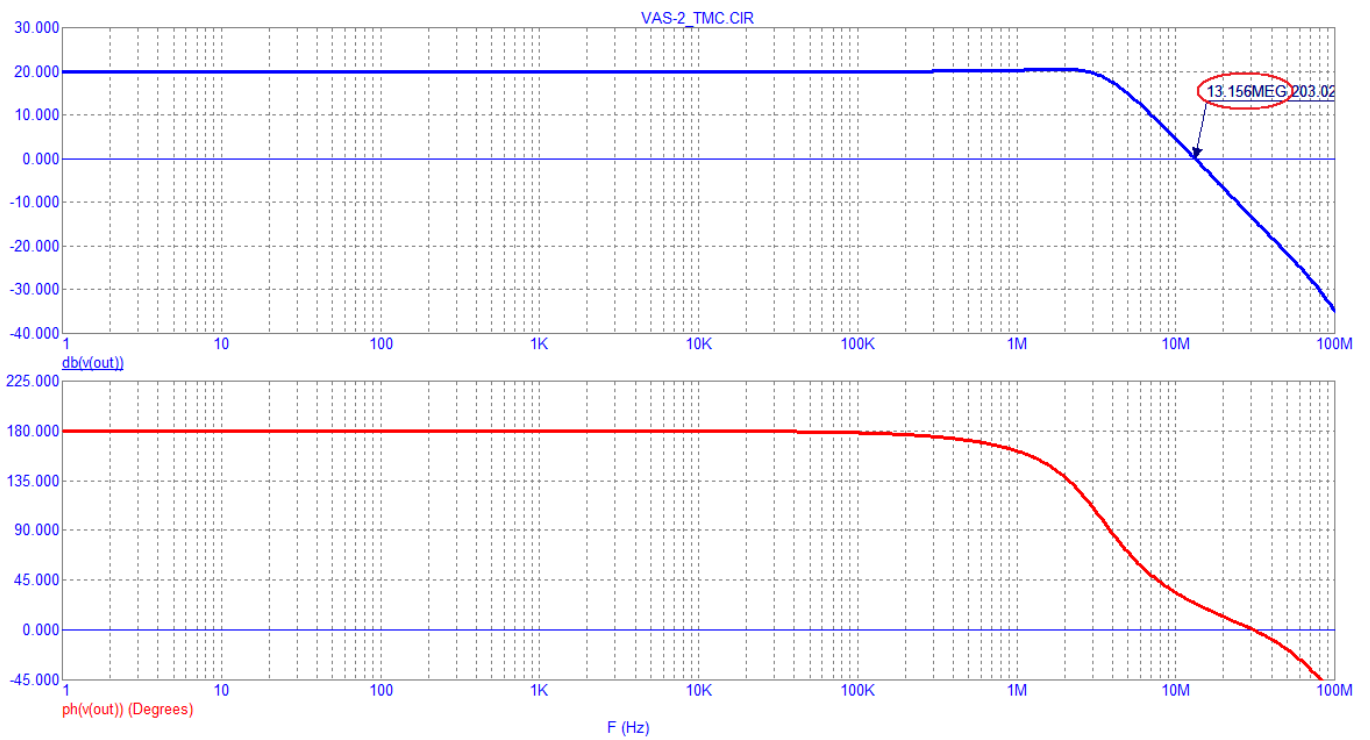


Fig.18

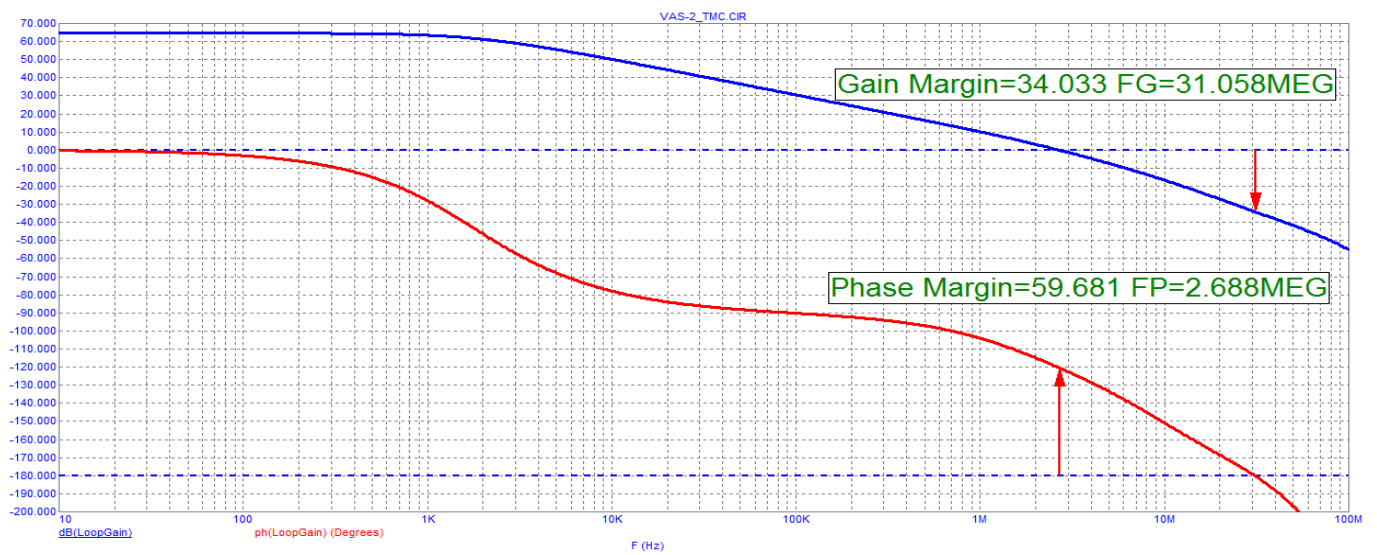


Fig. 19

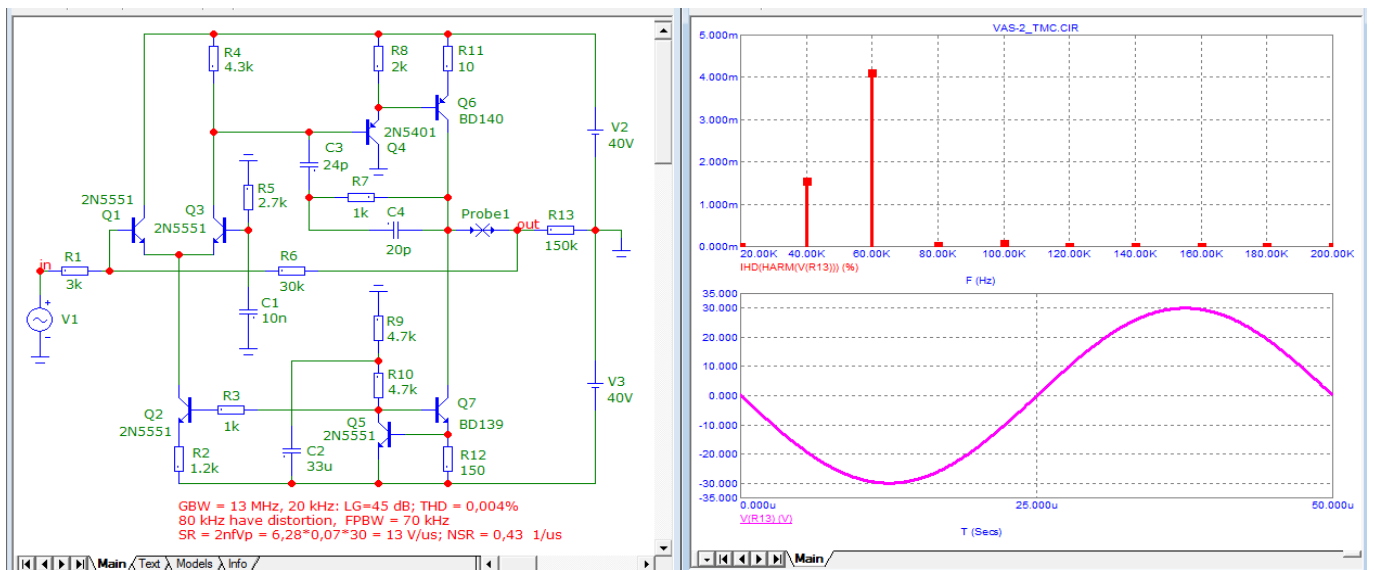


Fig. 20

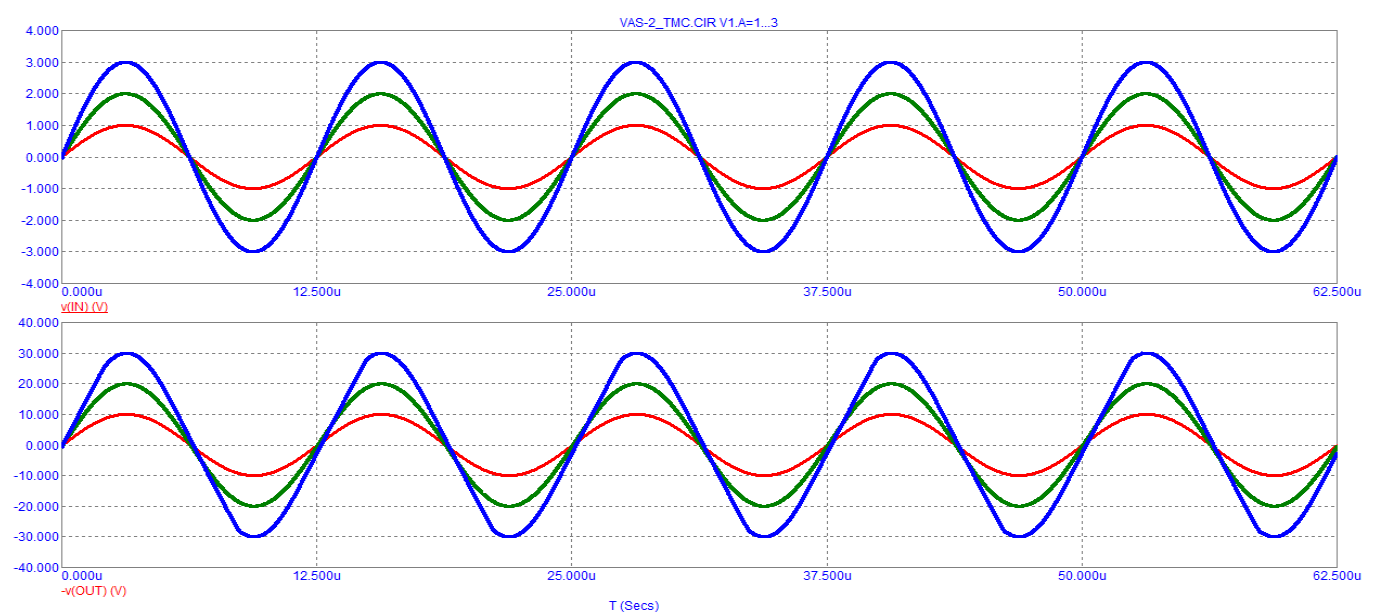


Fig. 21 (amplification of a signal with a frequency of 80 kHz)

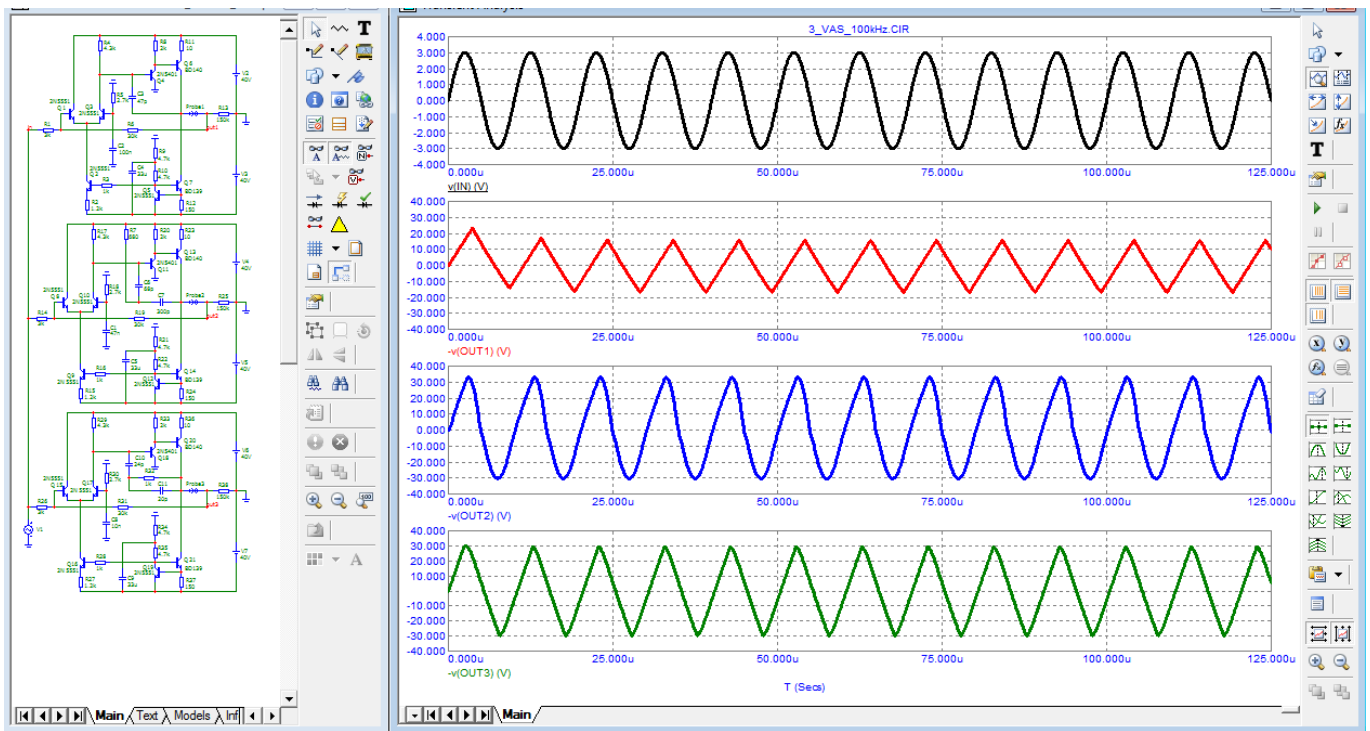


Fig. 22

Figure 22 shows the result of testing three corrections at 100 kHz. All three are subject to TIM distortion. An amplifier with 2-pole correction is not helped even by a loop gain at 100 kHz equal to 40 dB

The table shows that despite the fact that at a frequency of 20 kHz the amplifier with 2-pole correction has a loop gain of 5 dB (almost 2 times) higher, nevertheless, its distortion is 1.5 times higher than in an amplifier with JLH correction. That also contradicts Bruno's statement.

An analysis of four correction versions of the same amplifier was carried out

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