

## Current Feedback Amplifier using simplified input stage from APEX AX17

The amplifier circuit is shown in fig. 1

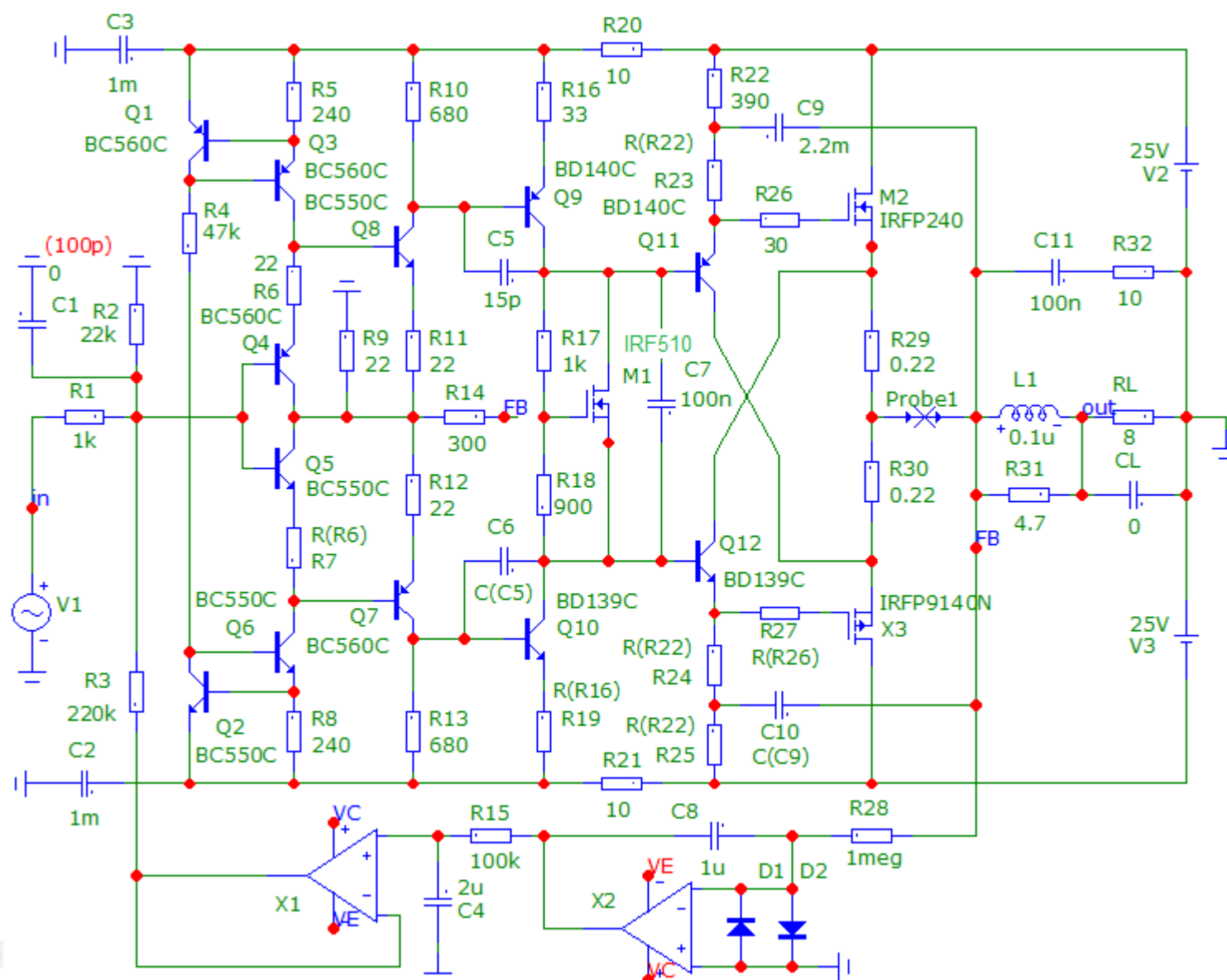


fig. 1

The amplifier is a direct current amplifier with current feedback and servo control system. The idea of the input stage is borrowed from the APEX AX17 amplifier. The output stage is made on field-effect transistors. The driver transistors operate in sliding-powered mode. The emitter circuits of the pre-output transistors are powered by resistors with a voltage boost, which essentially provides the GST mode for their emitter current, which also helps to reduce the distortion they introduce. Temperature stabilization is provided by a voltage multiplier on the FET. The quiescent current is set by selecting a resistor R18 (you can turn on a constant resistor of 750 ohms and a trimmer of 220 ohms).

The Bode diagram is shown in Fig. 2

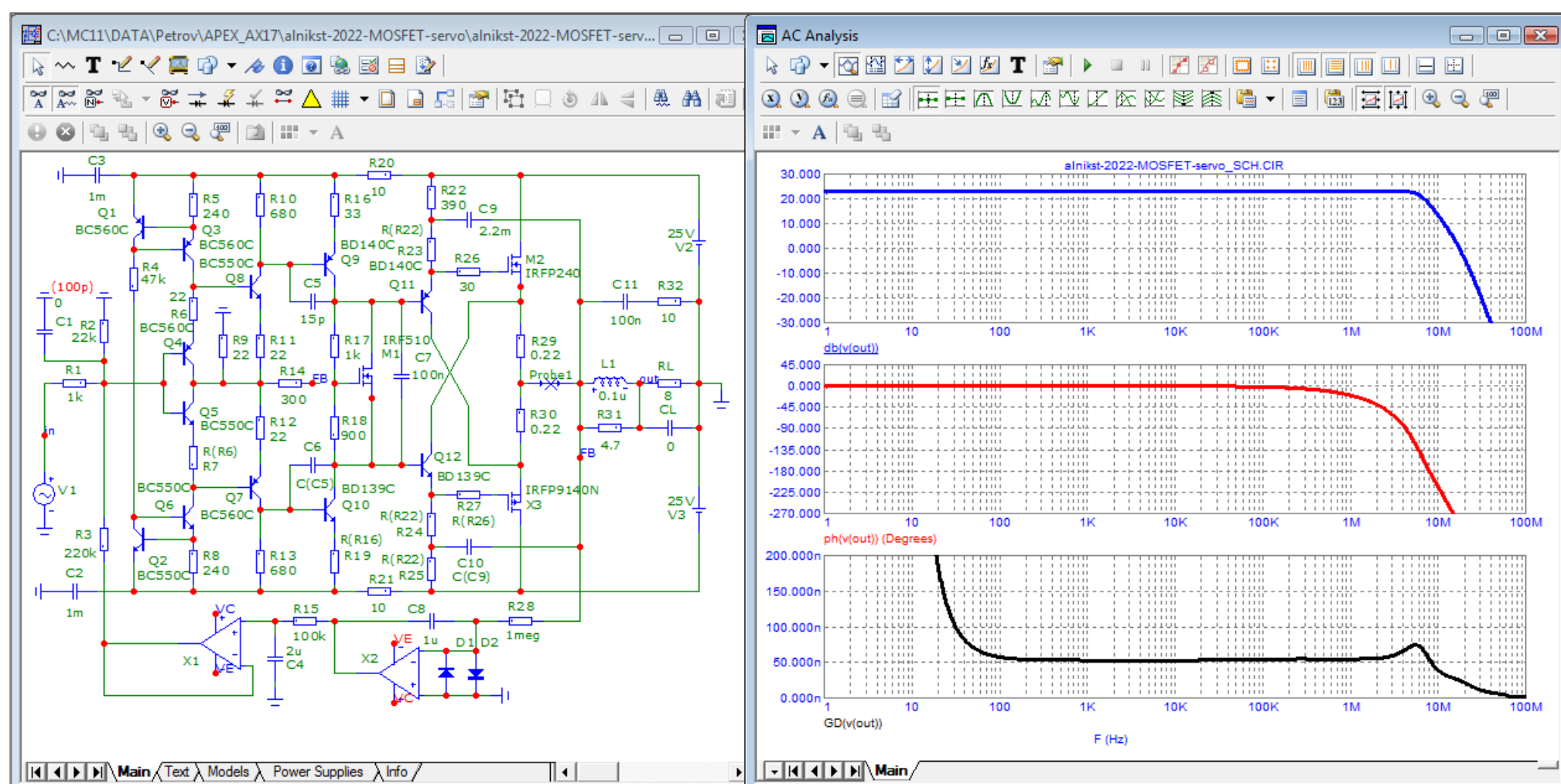


fig. 2

An important parameter of an amplifier with feedback is the signal propagation delay time (tPD - time Propagation Delay), which is responsible for high-speed distortion. Velocity distortion is something other than the loss of micro-level information of audio material.

To ensure stable operation of the amplifier, margins are important both in phase (at least 30 degrees) and in gain (at least 3 dB). The loop gain graph is shown in fig. 3

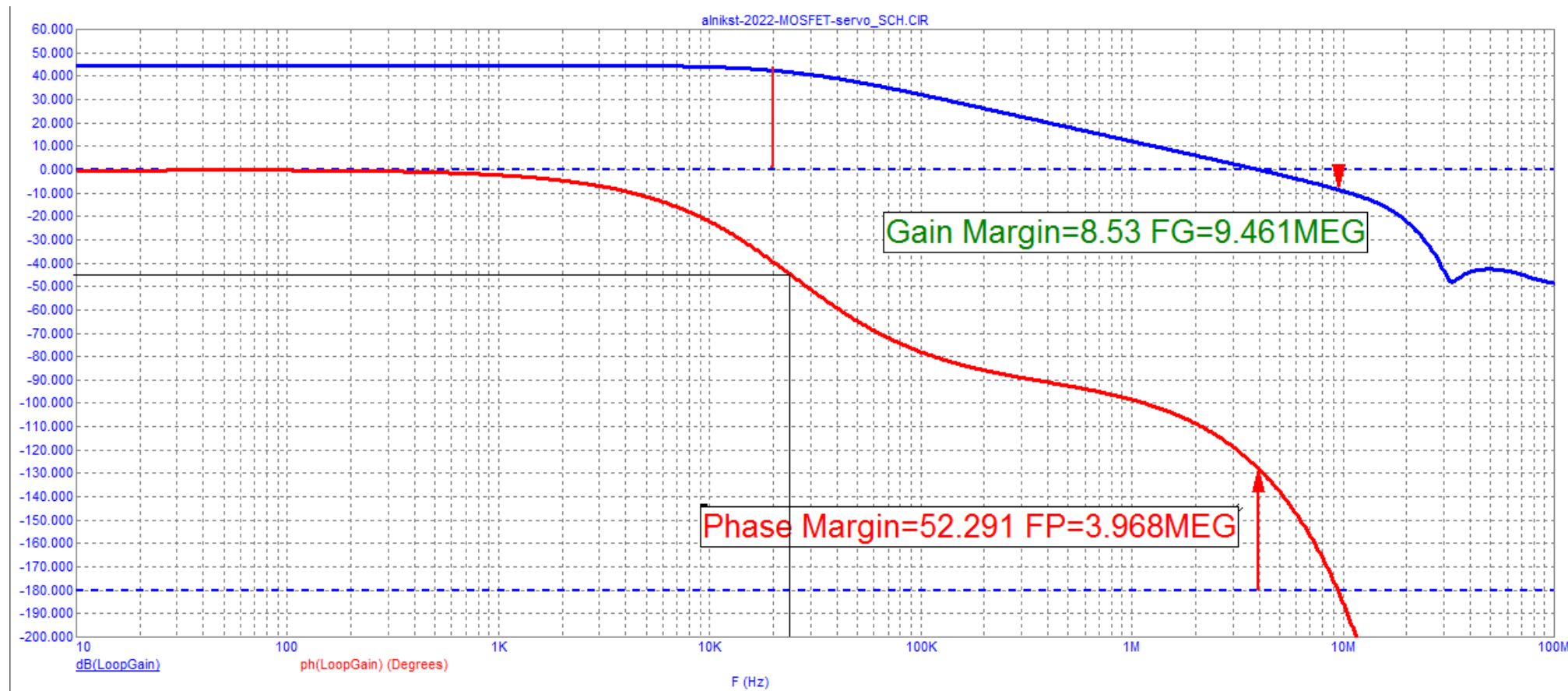


fig. 3

Loop gain exceeds 40 dB across the entire audio band. The frequency of the first pole is above 20 kHz, which ensures a constant output impedance throughout the entire audio band.

The stability of operation on a reactive load is ensured by the use of a purely symbolic inductance (0.1  $\mu$ H - 3 turns of 1 mm wire on a mandrel with a diameter of 9 mm) at the output of the amplifier. This inductance has a small piece of wire. Therefore, a place for the inductance on the board can be provided, and if it is not reserved, then it can always be soldered on the output connectors or simply put on a small ferrite ring.

According to the popular developer Nelson Pass, the spectrum of the first watt is of great importance. Another well-known developer, John Curl, pays a lot of attention to odd harmonics from the 7th and up. Let's measure the spectrum of the first Watt at the upper frequency of the audio range, fig. 4

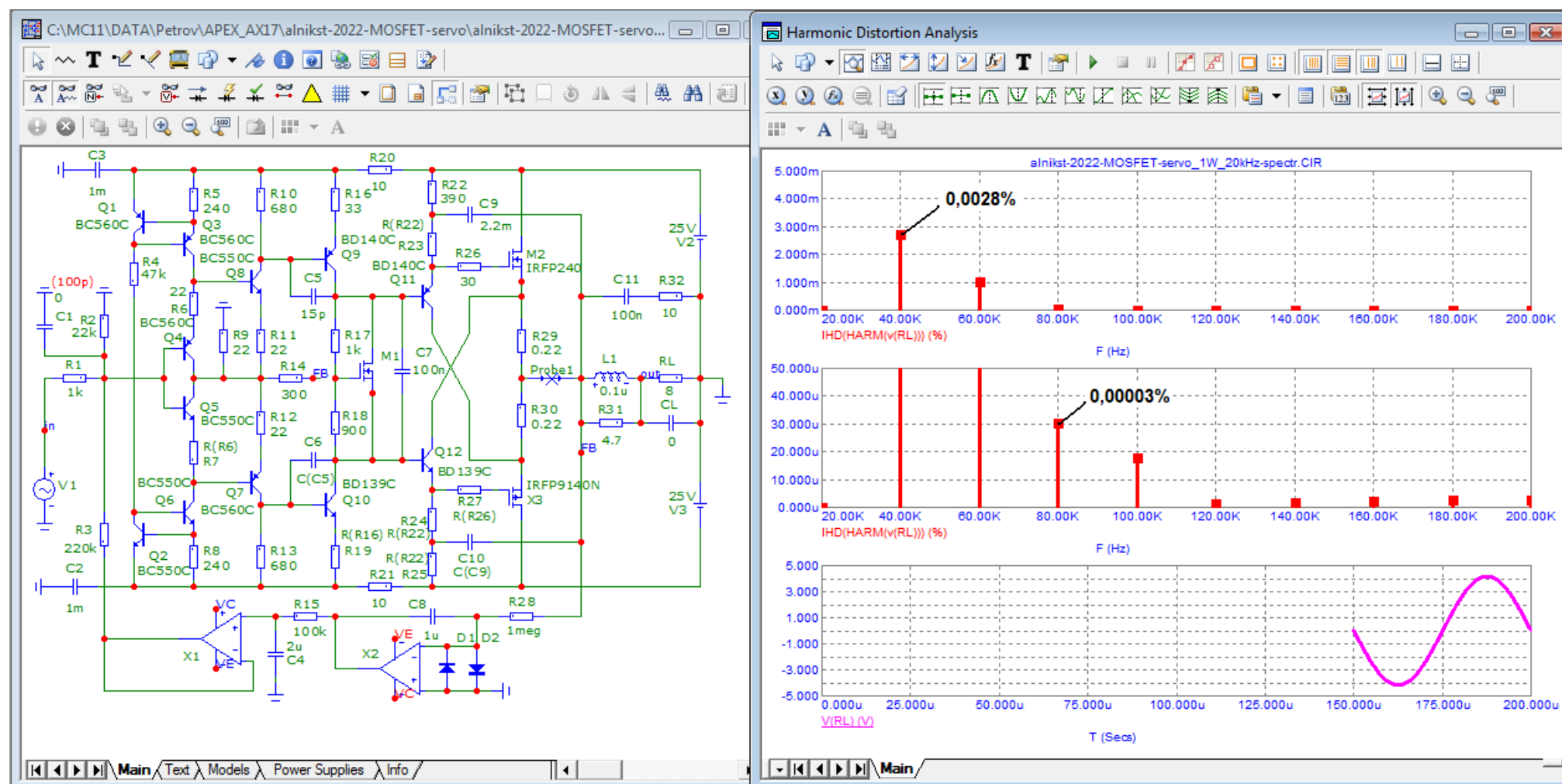


fig. 4

As we see in the spectrum of the output signal, in fact, the 2nd and 3rd harmonics are negligible, the harmonics of a higher order are negligible (the spectrum is typical for reference tube amplifiers).

Let us measure the distortion spectrum at a power close to clipping, Fig. 5

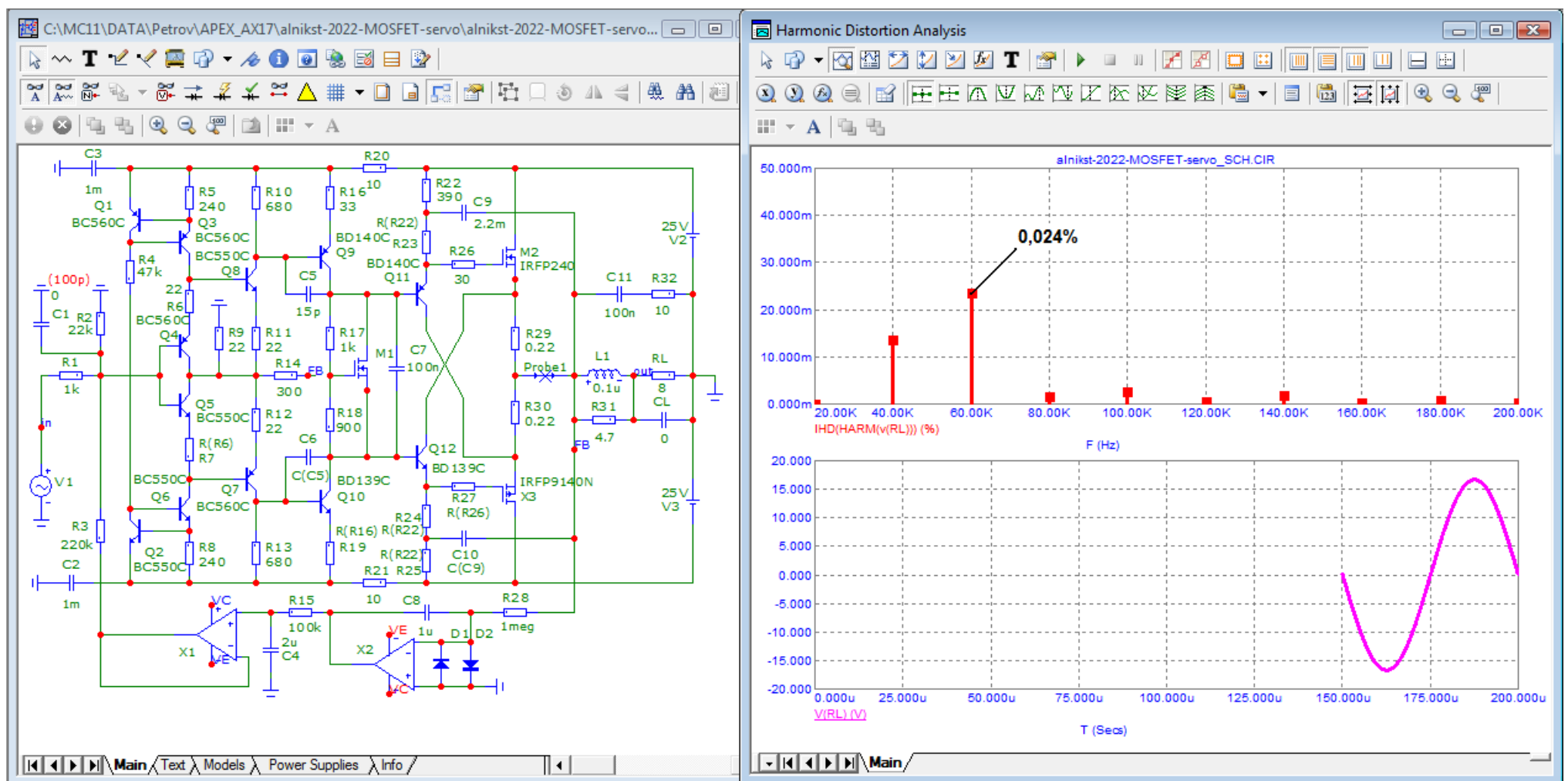


fig. 5

As you can see, at an output power close to the maximum, the spectrum is extremely short (limited by the first two harmonics)

And finally, tests for high-speed distortion in Fig. 6 and 7. The distortion measurement was performed by a compensation method using an ideal delay line for a normalized input signal.

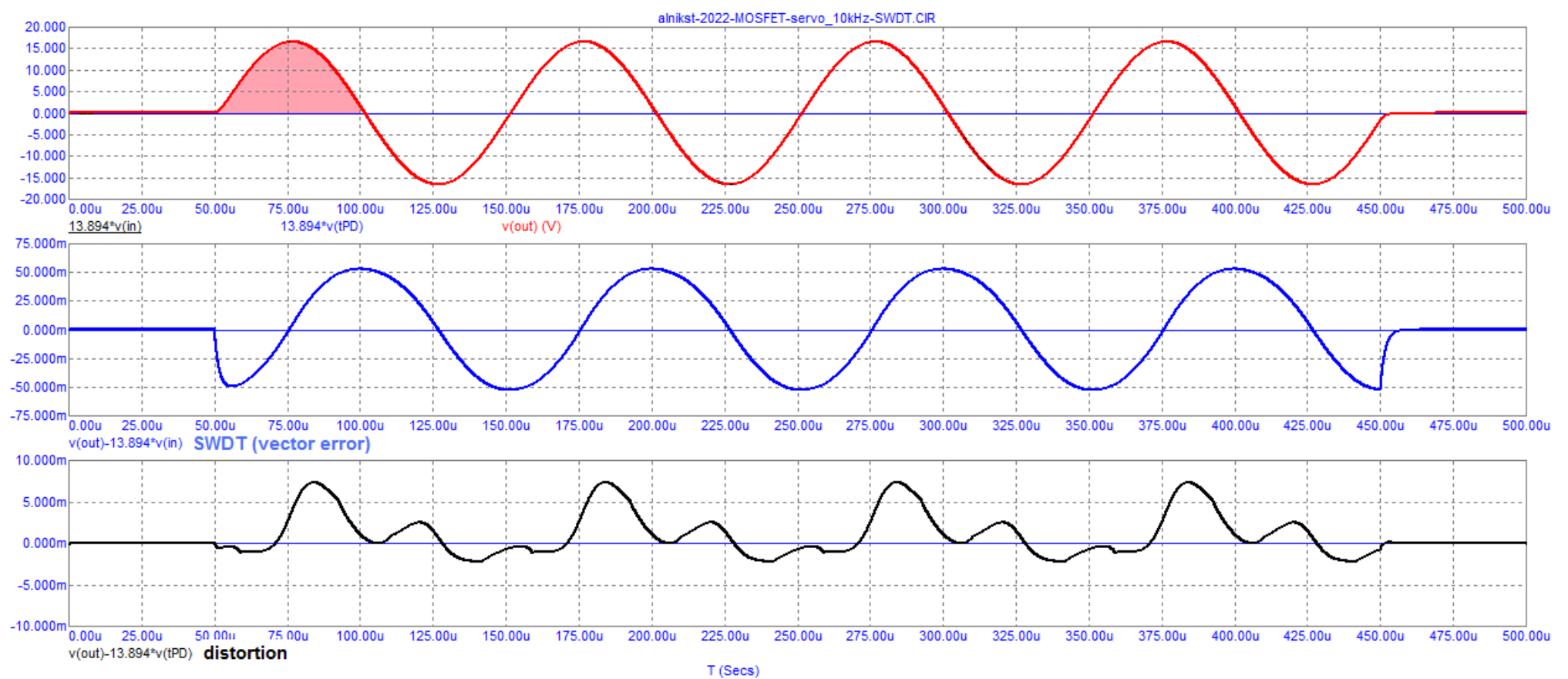


fig. 6

The test shows that neither at the beginning nor at the end of the burst there are any additional distortions in the form of high-speed distortions. This is primarily due to the small value of  $t_{PD} = 50$  ns!



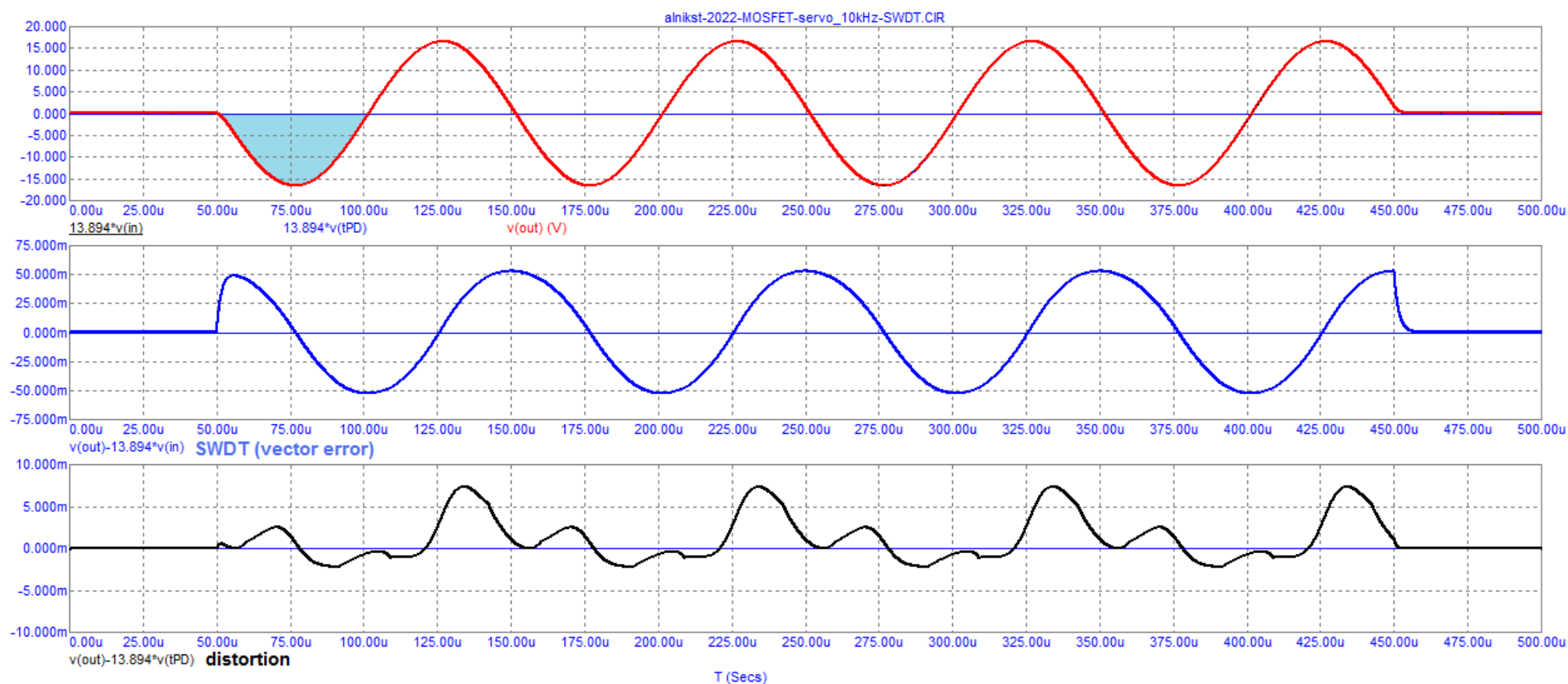


fig. 7

The vast majority of amplifiers, in addition to high-speed distortion, also introduce an additional shift in the distortion products (the appearance of a constant component depending on the polarity of the first half-cycle in the burst). In this amplifier, there is no constant component in the distortion products. When passing through zero, there are no explicit switching (crossover) distortions.

Let's check the dynamic capabilities of the amplifier. To do this, let's check its operation on a rectangular signal with a frequency of 20 kHz, Fig. 8

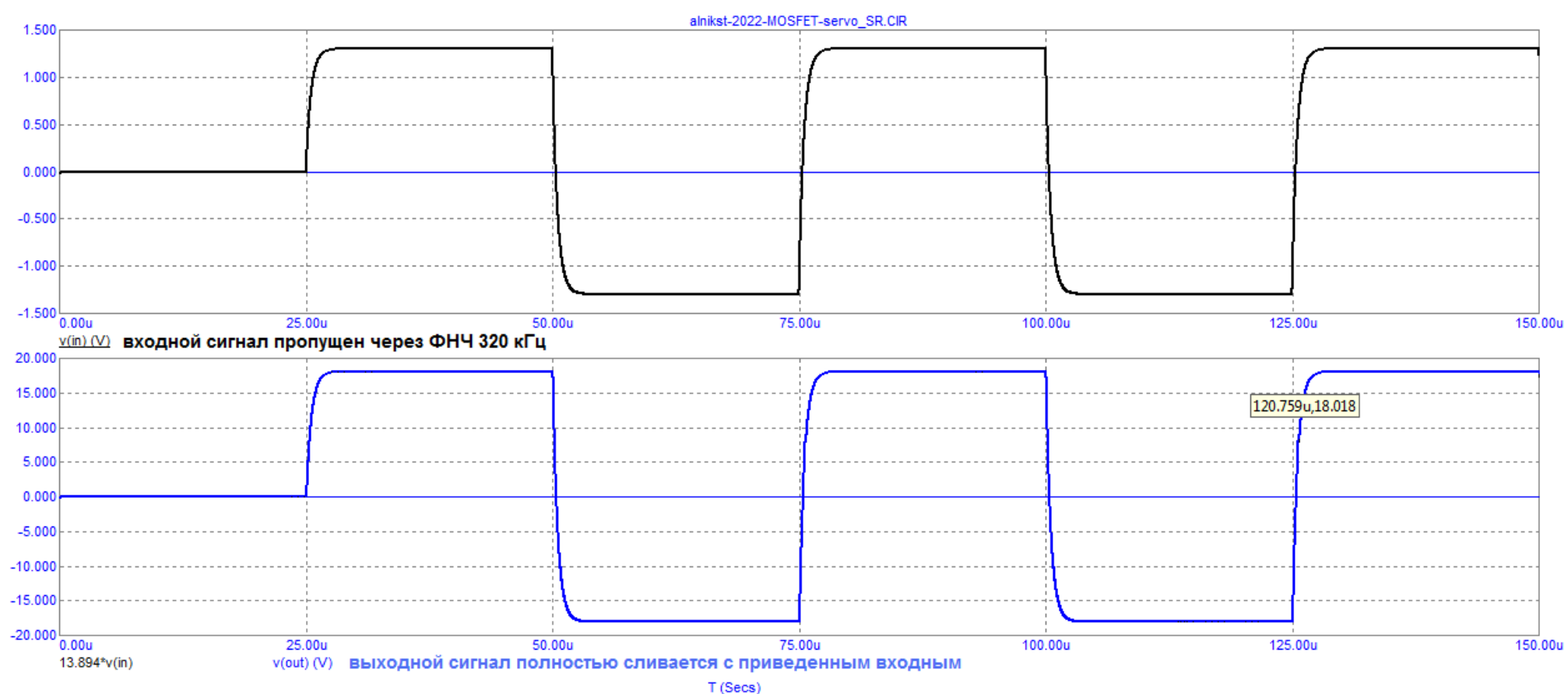


fig. 8

The input signal before being fed to the input of the amplifier is processed by a low-pass filter with a cutoff frequency of 320 kHz, there is no input capacitance  $C1 = 100$  pF. To normalize the input signal (bring it to the output level), the voltage gain  $K_u = 13.894$  was used.

As you can see, the output signal completely repeats the input signal reduced to the output (both signals merge).

The next dynamic ability test is the 400 kHz high frequency test, fig. 9

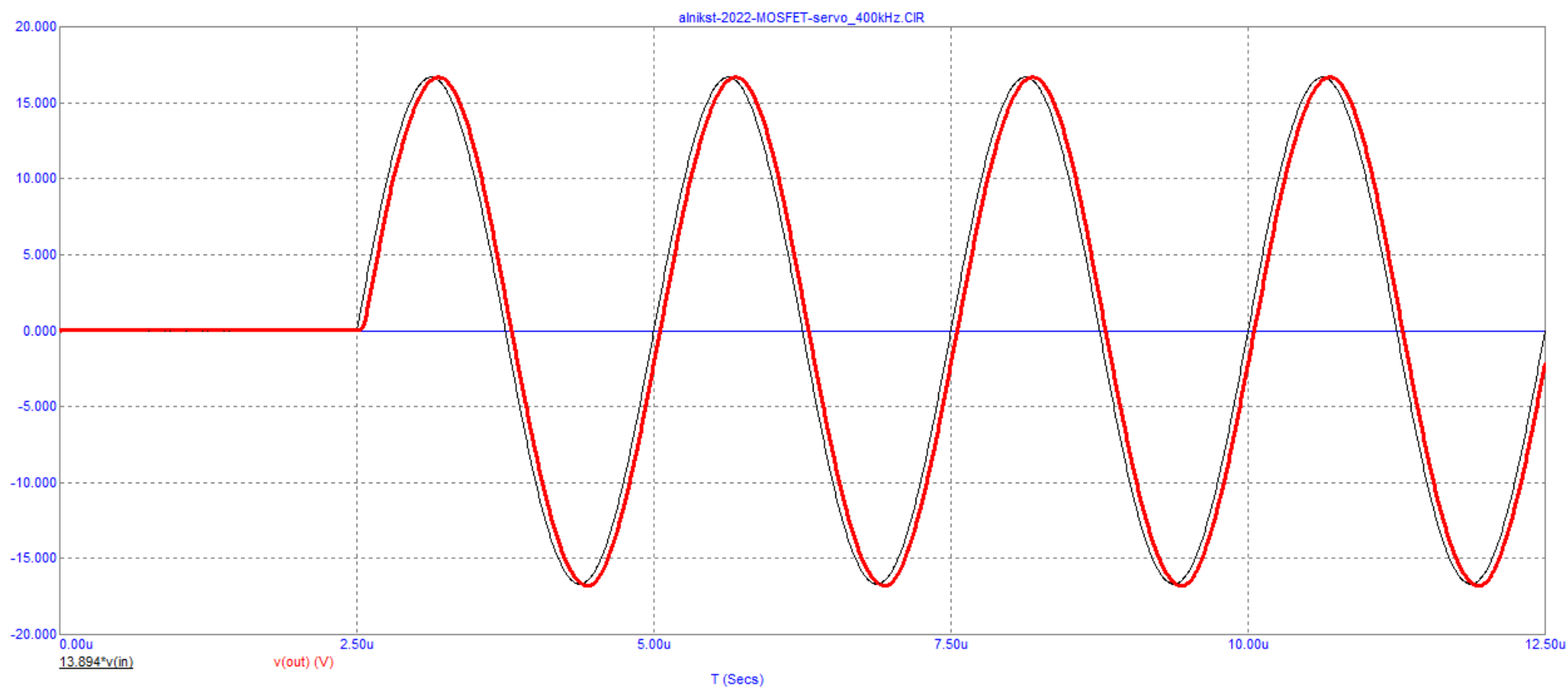


fig. 9

As the test shows, here the output signal is without visible distortion. At the beginning of the period, there are no transients of an oscillatory nature, the output signal repeats the input signal with a delay of 50 ns.

The next test is checking operation in the LF region on a rectangular signal with a frequency of 20 Hz, fig. 10

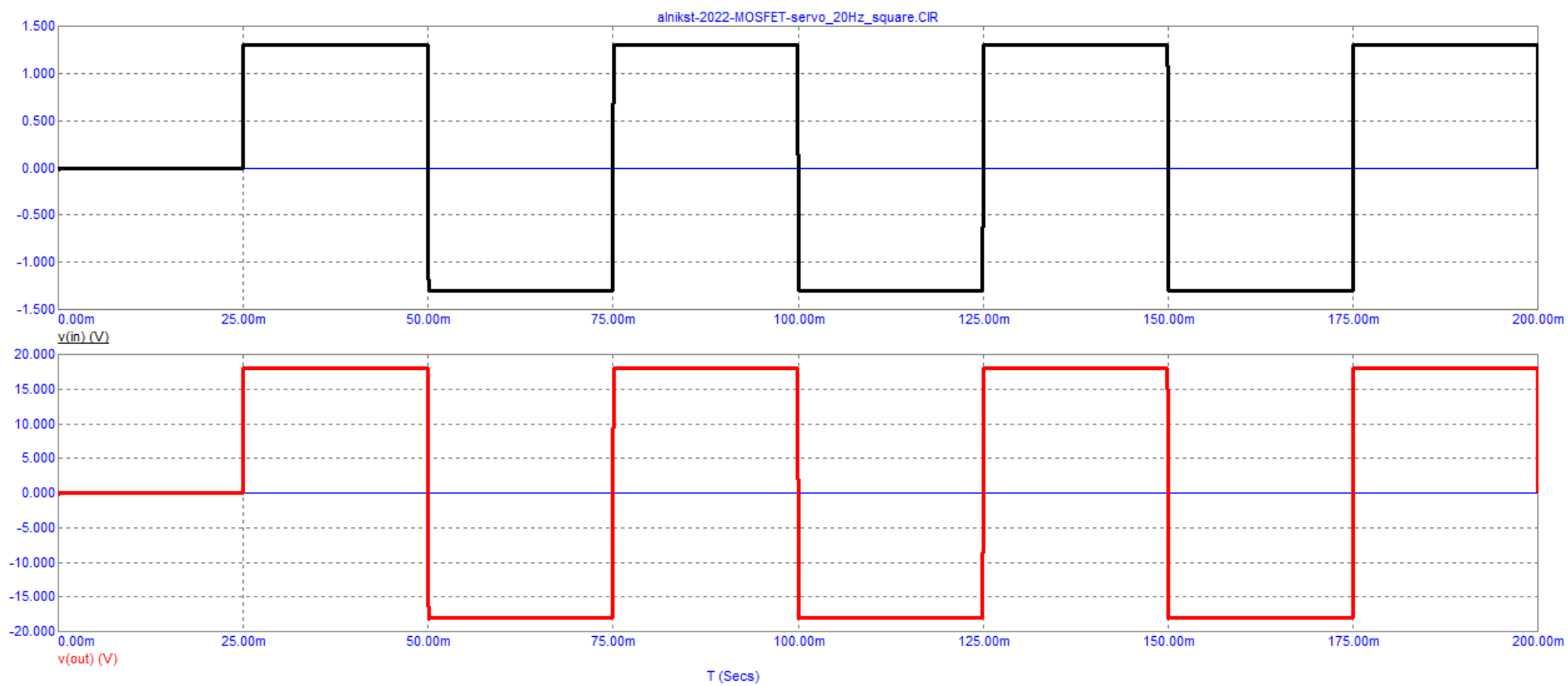


fig 10

The square-wave signal is also amplified without distortion - there are no signs of the slope of the signal shelves.

Additionally, we will check the operation on bursts of 20 Hz with alternating polarity of the first half-cycle, fig. 11

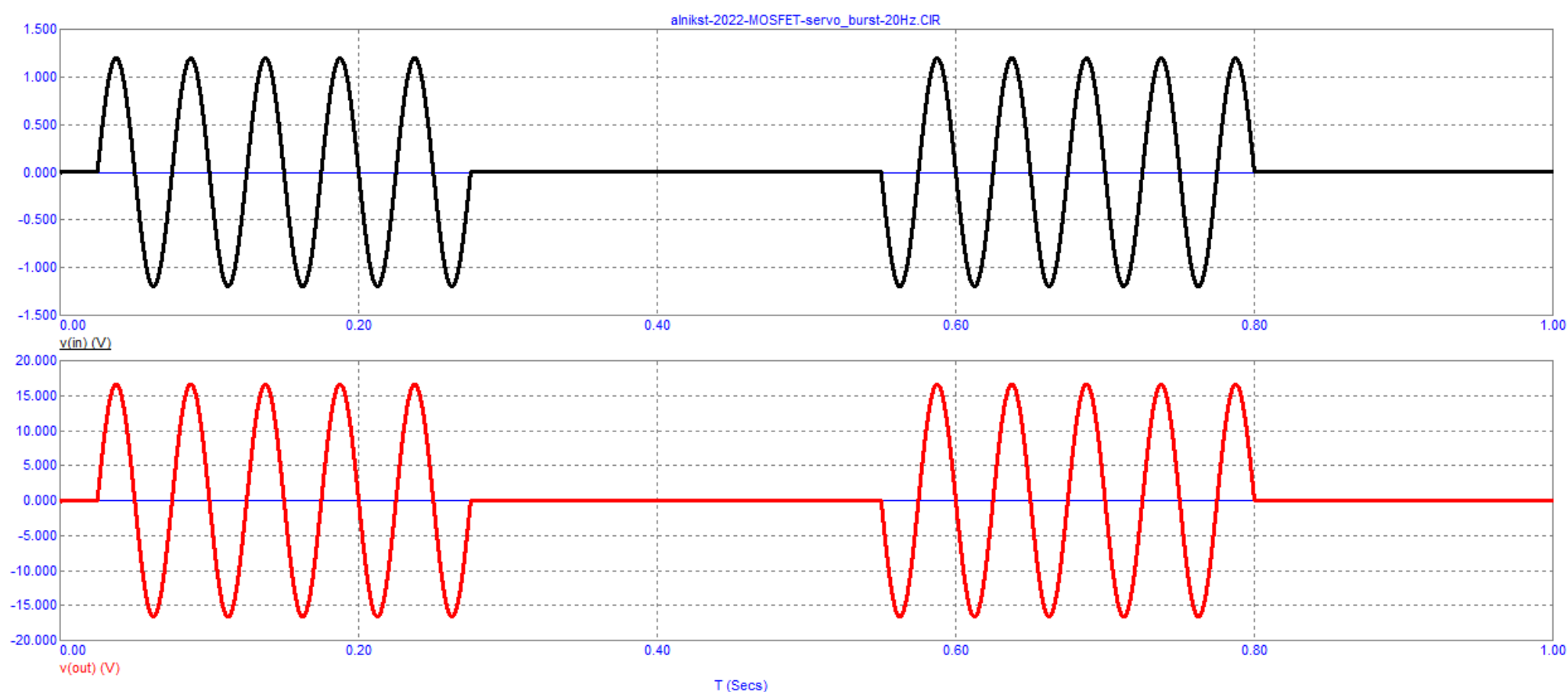


fig. 11

Due to the fact that the UPT amplifier, as well as due to the correct operation of the servo control system, the first half-waves of the bursts do not “crumple”, at the end of the bursts there is no constant component that occurs in the vast majority of amplifiers.

The IMI test for correlation with sound quality ranks second from the bottom after the Total Harmonic Distortion (THD) test. Just in case, let's carry it out at frequencies of 19 and 20 kHz, fig. 12

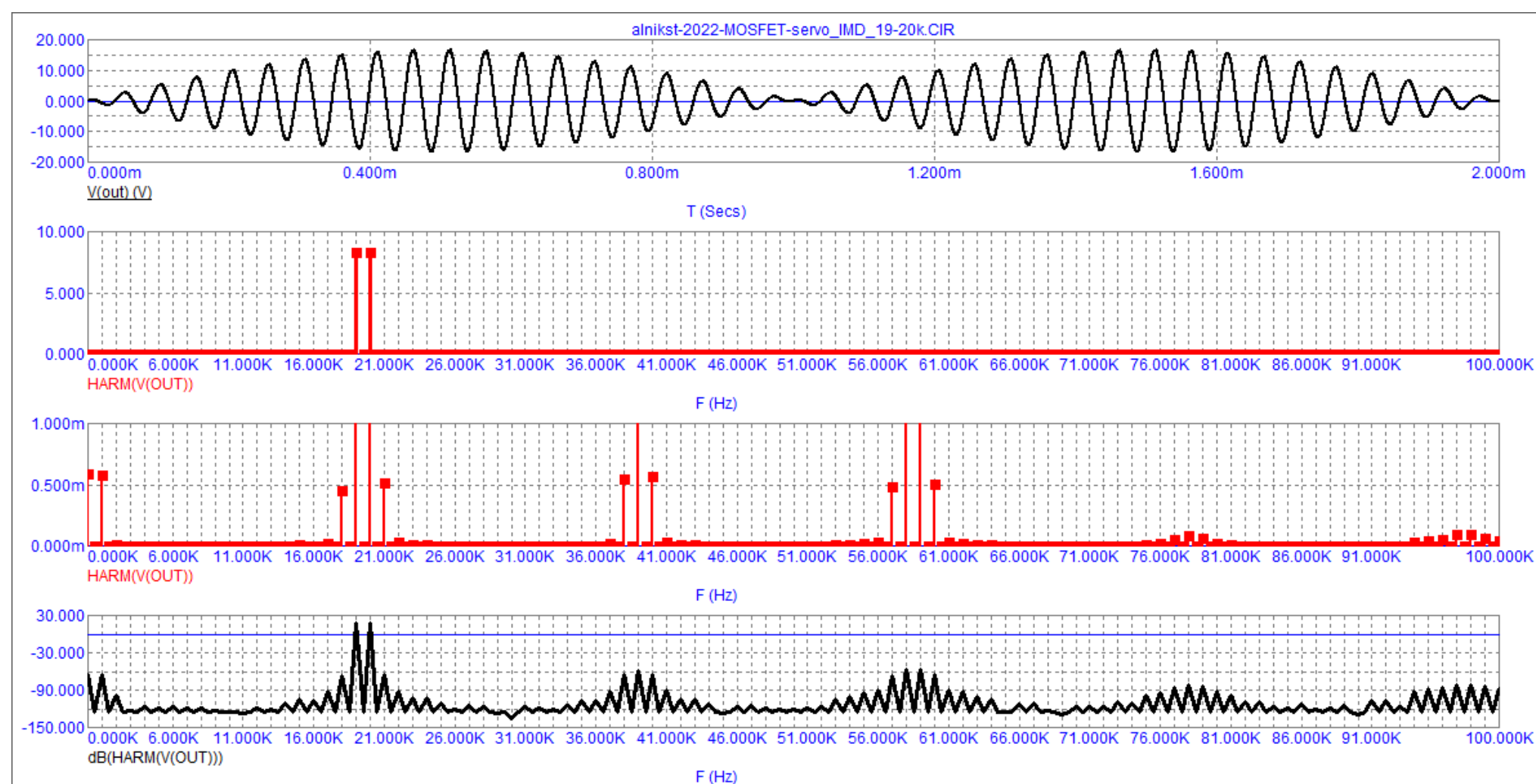


fig. 12

The test shows that in the audio band, especially in the region of the greatest hearing sensitivity, the highest products of the IMI are at the level of -120 dB (in most good amplifiers they are at the level of -90 dB at best).

In order to simplify the model of the power supply circuit, the op-amp (15 V zener diodes and 820 ohm resistors with 47 microfarad filter capacitors) are not shown.

And finally, let's see the operating modes of the output transistors for current at a frequency of 10 kHz, Fig. 13

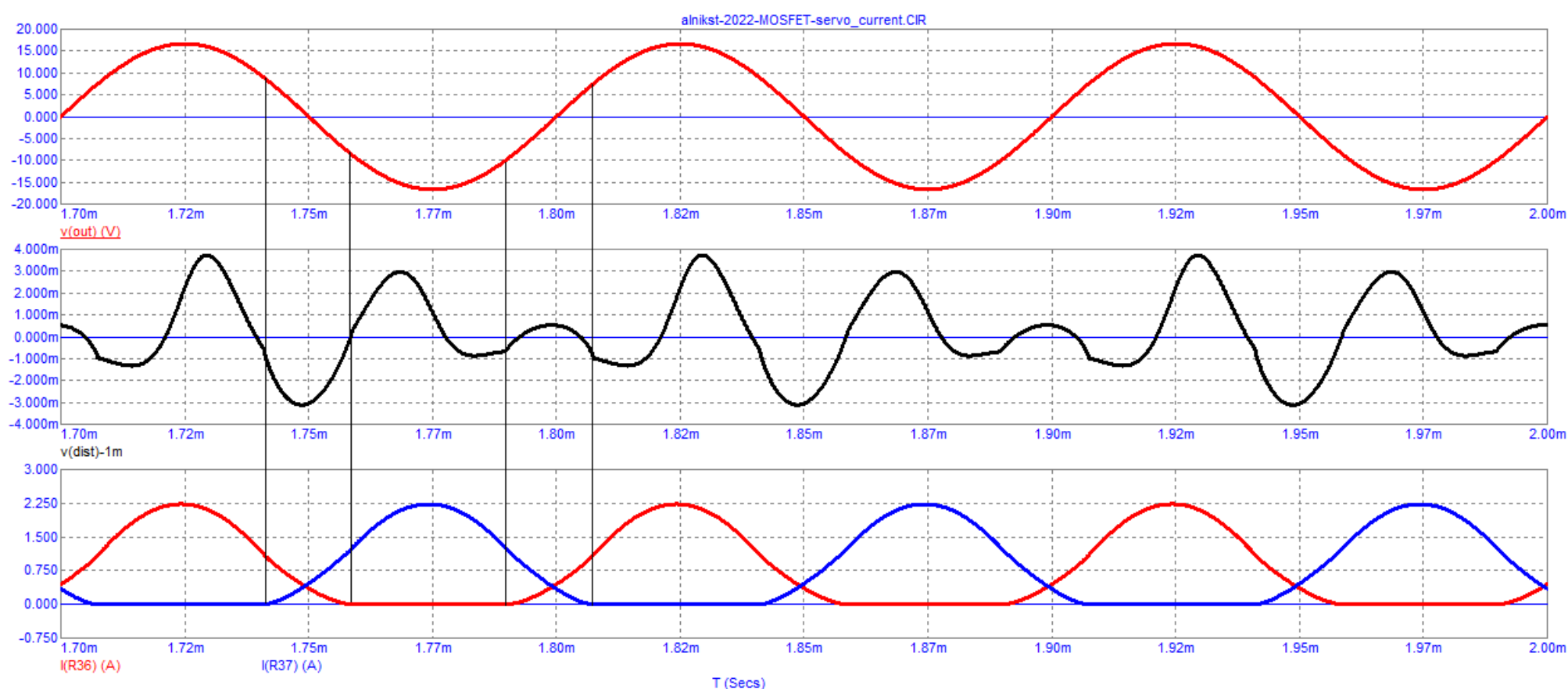


fig. 13

According to the current graphs of the output transistors taken on the current sensors in the drains (R36, R37), the class A mode is maintained up to almost 10 V peak output voltage. Thus, the amplifier operates in class A up to about 6 watts into an 8 ohm load (which is more than enough for comfortable listening on highly sensitive acoustics).

At the moments when the shoulders are completely turned off, small kinks occur in the distortion products. Let's call these breaks switching distortions. In any case, these distortions are much less than in economy class A (Super-A) amplifiers, and even more so in class AB amplifiers with insufficient speed to deal with them. Most often they look like needles or bursts, and in some cases they are oscillatory.

Distortion is usually measured using professional instruments (Audioprecision and similar) in steady state, i.e. at the end of transients. The developers of the Micro-Cap program met the wishes of, apparently, theorists and introduced the Periodic Steady State mode, which finishes measurements at the end of transients. The minimum number of periods for calculation on THD is limited to 4. However, if you use special techniques, you can measure the spectrum and behavior of THD depending on the frequency, even if you are limited to two periods in test bursts, which we will do in Fig. 14.

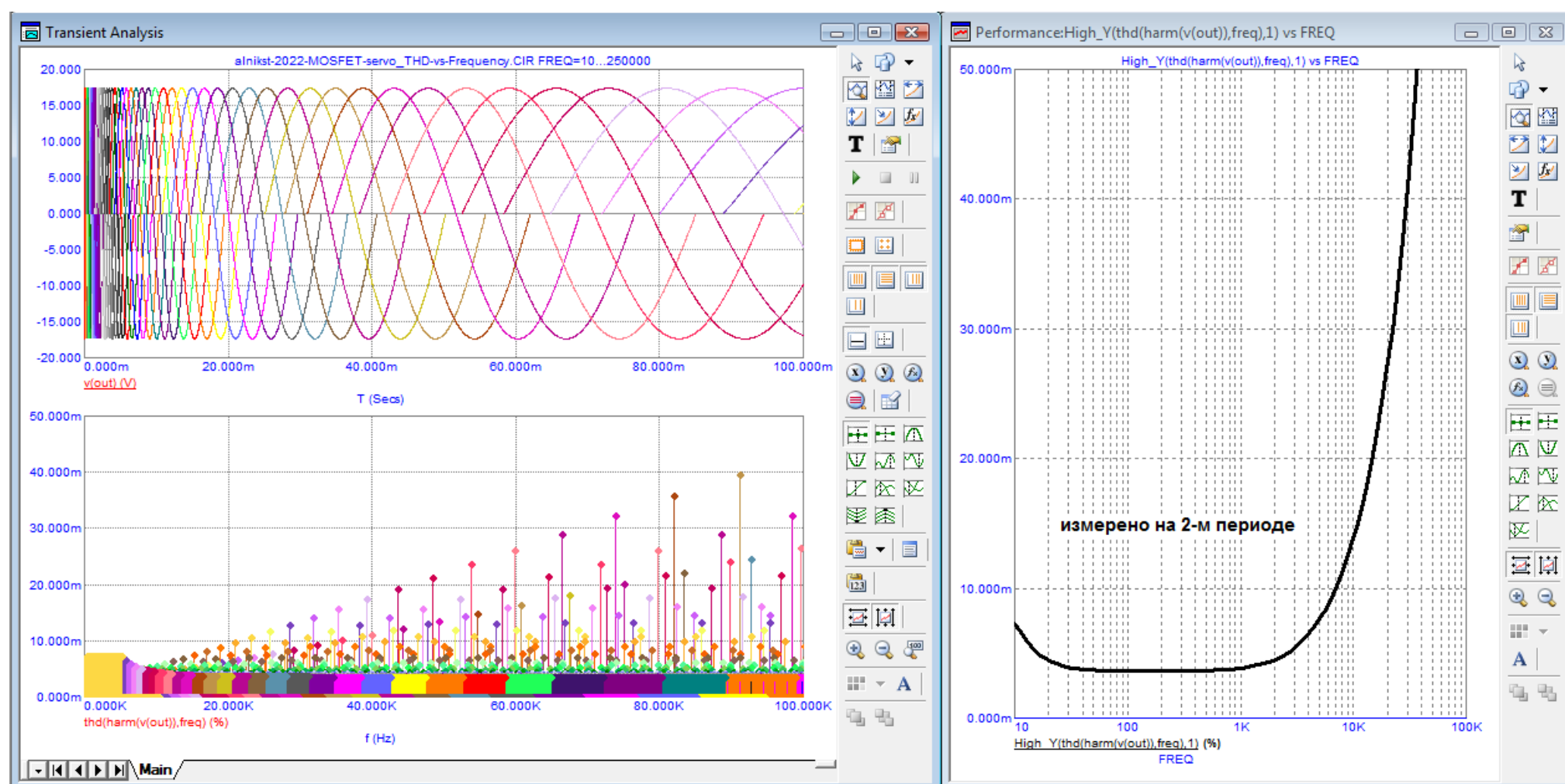


fig. 14

Due to the fact that the DC amplifier has a low signal delay time, even in the 2nd period, the spectral components from transients at low frequencies do not penetrate into the audio range.

To see how the driver transistors work, let's measure their currents and the power dissipated by them in dynamics, fig. 15

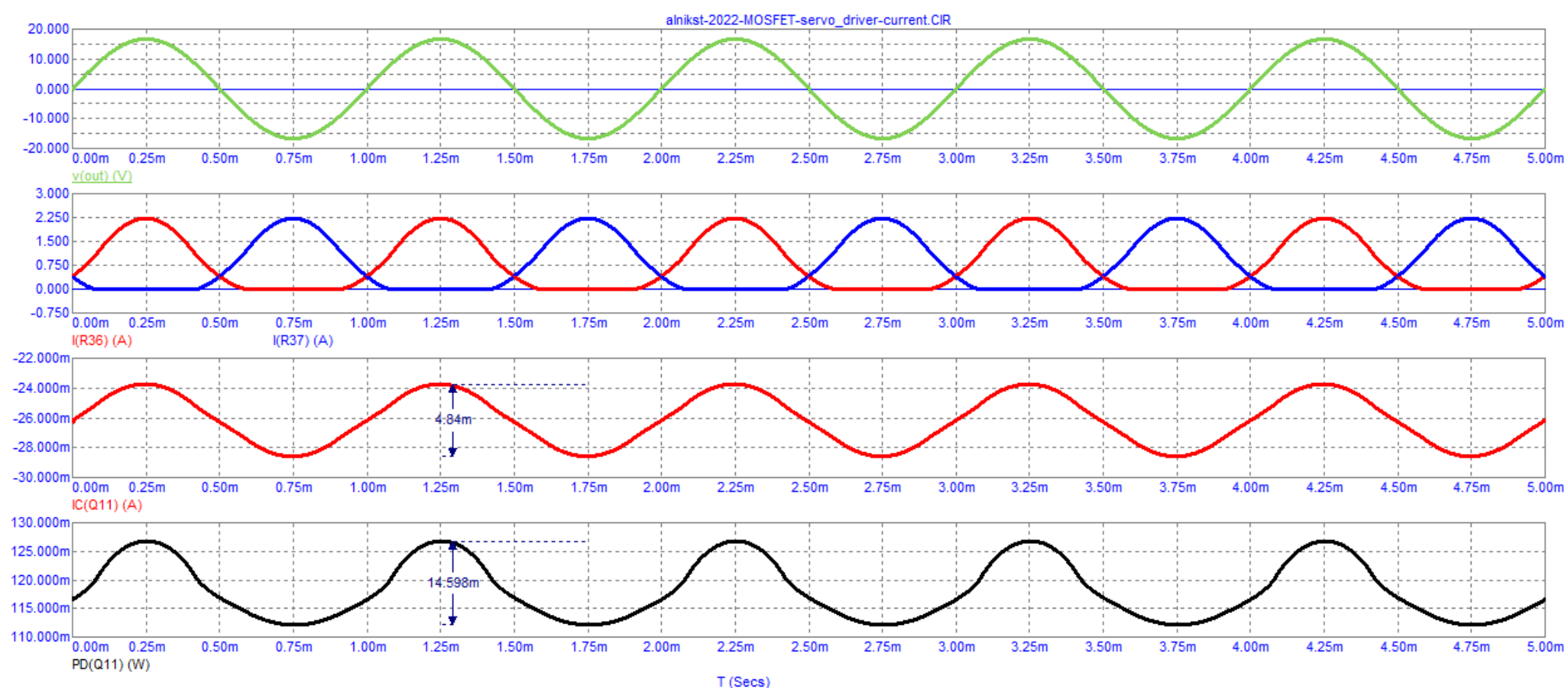


fig. 15

It can be seen from the test that the average power released on the driver transistors is 120 mW, and its fluctuations do not exceed 15 mW, which will help minimize the thermal distortions introduced by them. The average collector current is approximately 26 mA, and its fluctuations do not exceed 5 mA, while the transistors operate in class A.

Best regards

Petr