Modification of the Hiragi class AB amplifier on lateral transistors

Figure 1 shows a diagram of a modification option for a Hiragi class AB amplifier

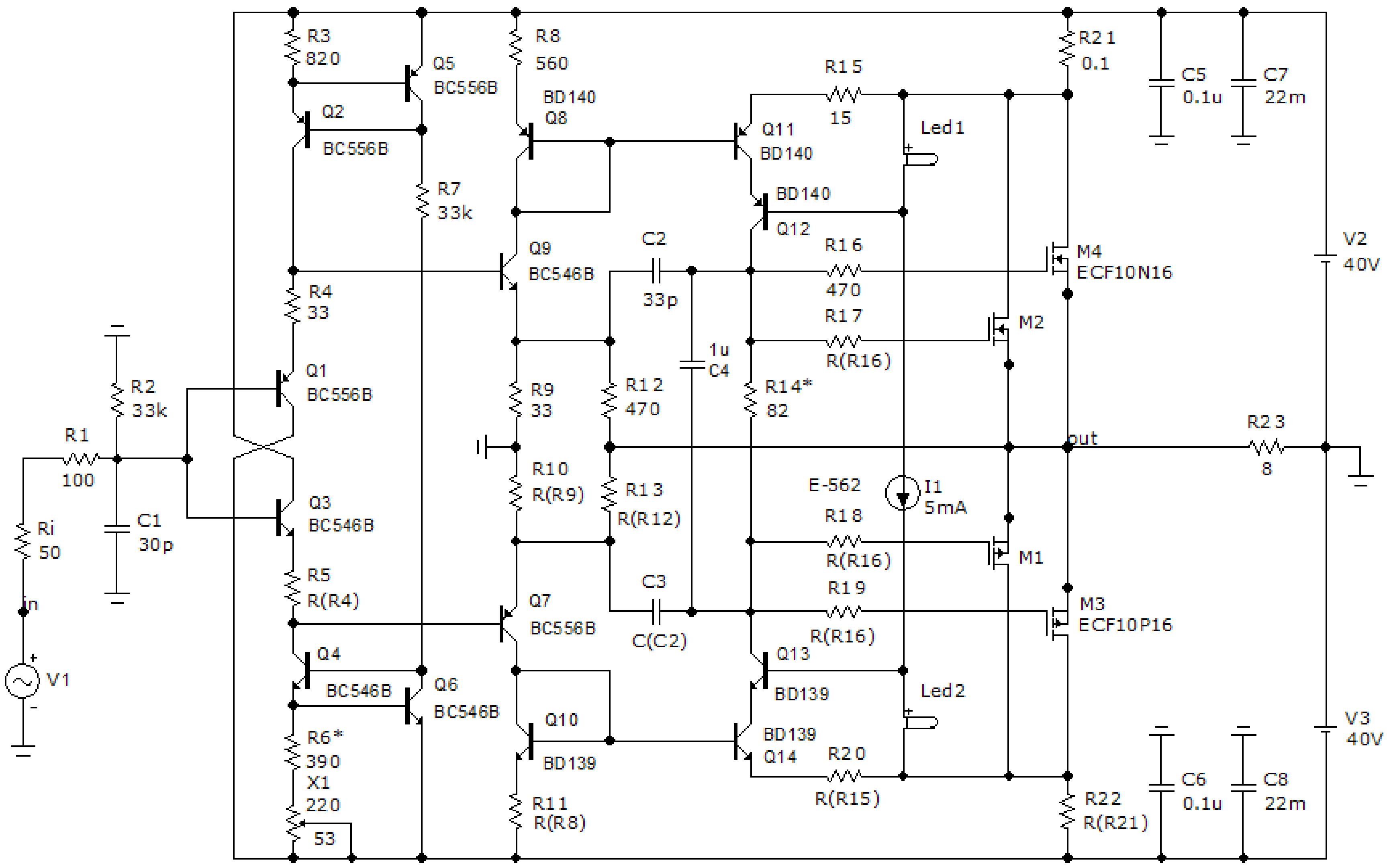

Figure: 1

The quiescent current of the output transistors of 200 + -20 mA per transistor is set by selecting the resistor R14. Zero at the output is set with the trimmer X1, if necessary, select R6. I1 is a 5 mA current stabilizing diode of the E-562 type or similar, in the absence of a current stabilizing diode, you can use a GST on a JFET transistor with a 8.2 ... 10 kΩ resistor connected in series. The LEDs are green, you can also use yellow, white or blue, it is important that the voltage drop across the LED is at least 2 V.

The Bode diagram is shown in Fig. 2

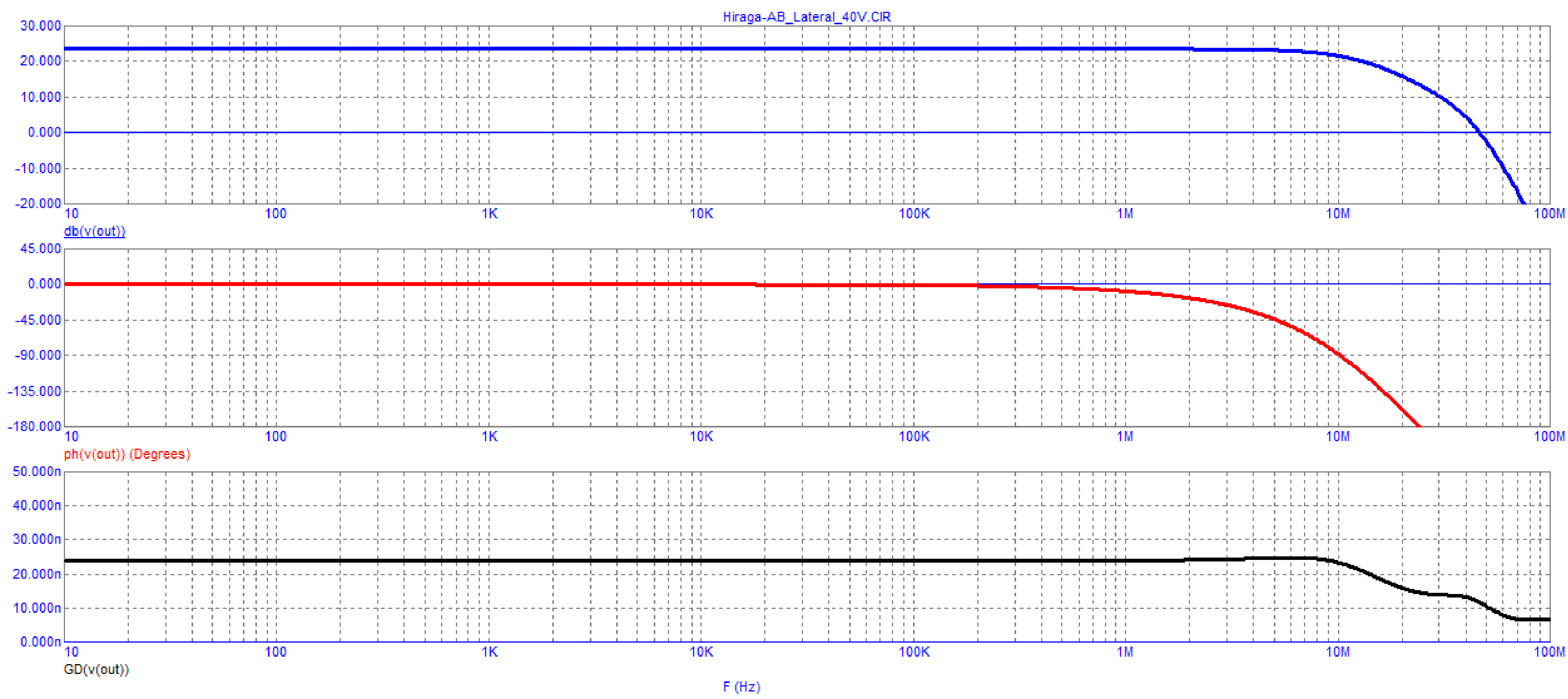

Figure: 2

From the Bode diagram, it can be seen that the delay is 22 ns and is constant from units of Hz to 10 MHz. Let's check the stability margins of the amplifier. To do this, remove the loop gain graph, Fig. 3

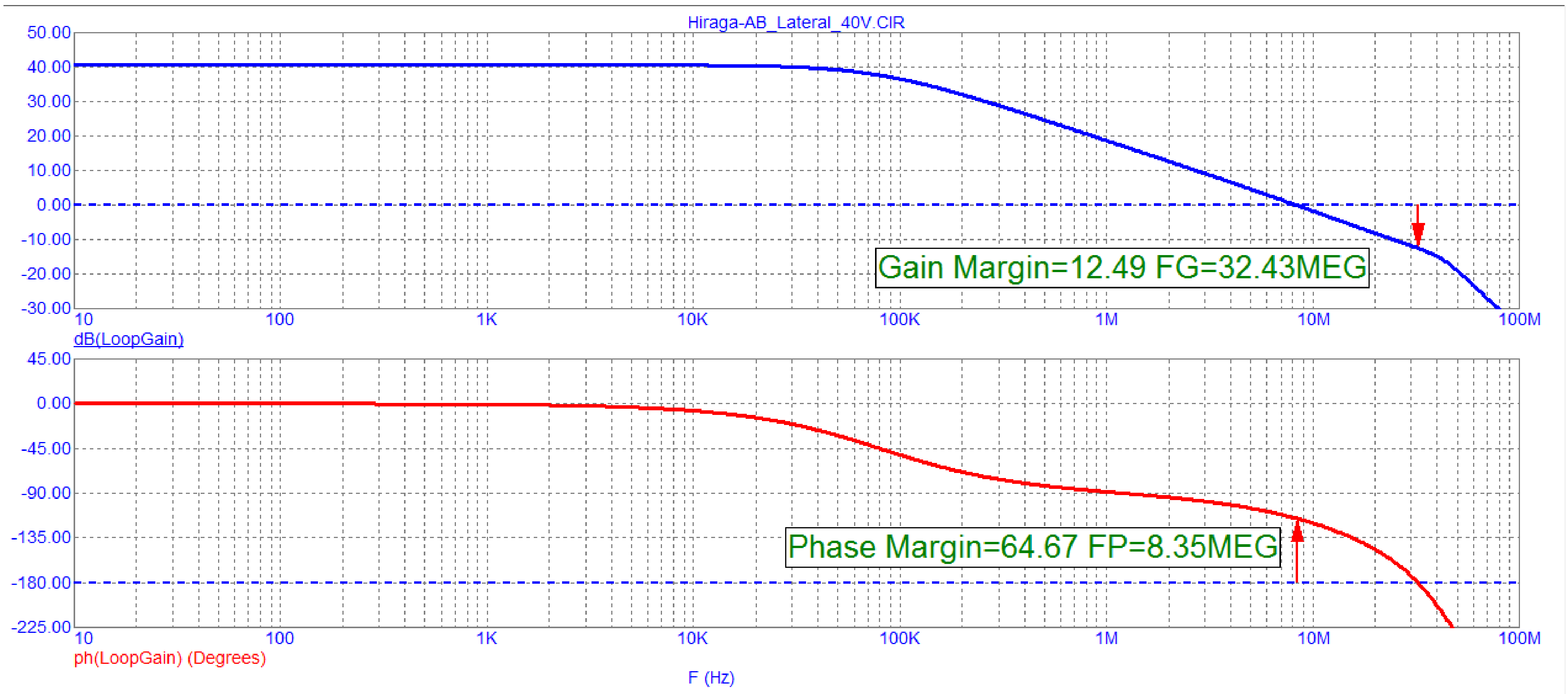

Figure: 3

The loop gain is 40 dB and is constant throughout the sound bandwidth. The frequency of the first pole is 80 kHz. Let's measure the traditional dependence of the harmonic distortion factor on frequency at an output voltage of 30 V (peak), Fig. 4

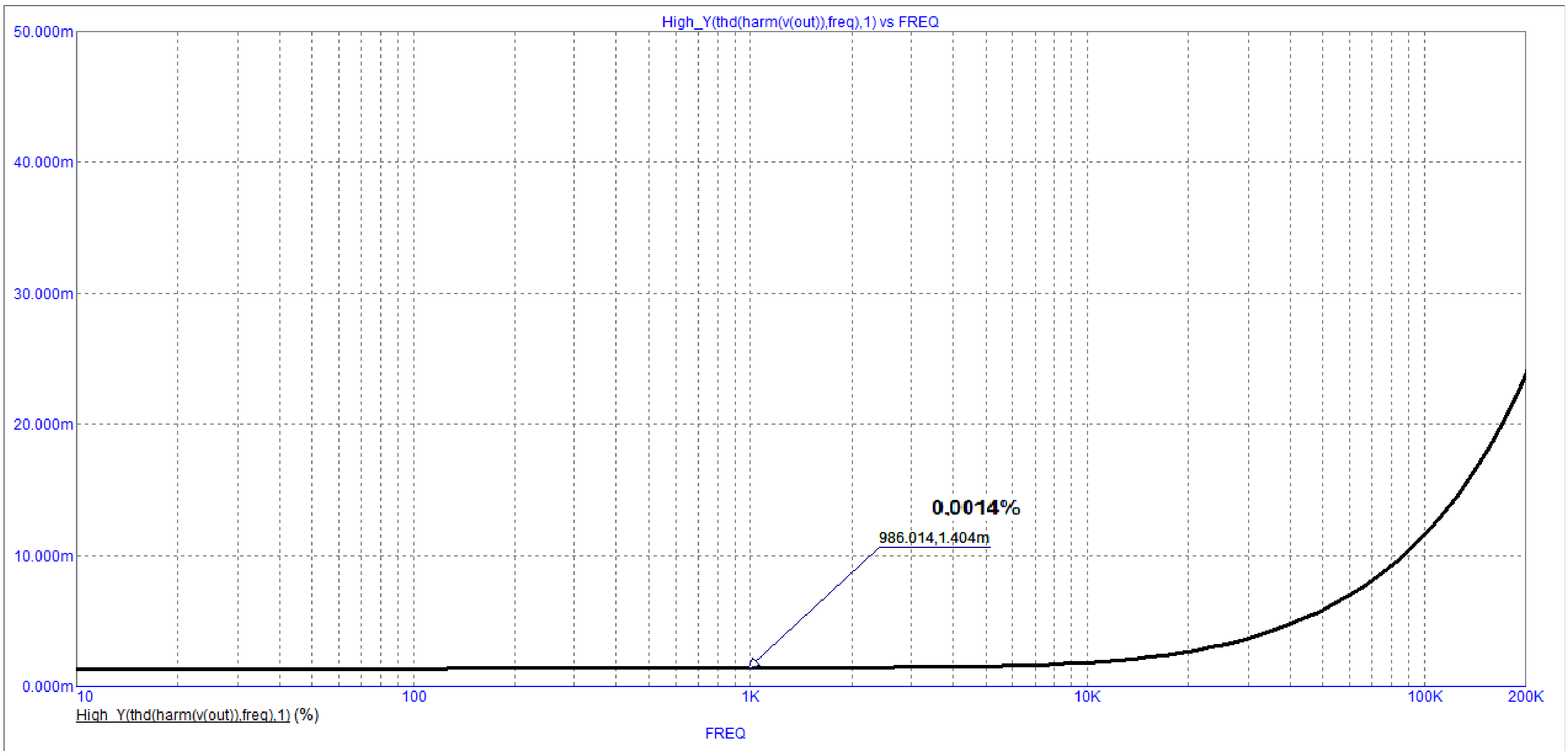

Figure: 4

Figure 4 shows that Kg is equal to 0.0014% practically up to 10 kHz and increases to 0.002% at a frequency of 20 kHz. Above 20 kHz, there is a gradual increase in distortion and by the frequency of 200 kHz it reaches
0.024%.

It is generally accepted that it is important to have a low level of distortion not only at maximum power, but also at a power of about 1 W, Fig. five

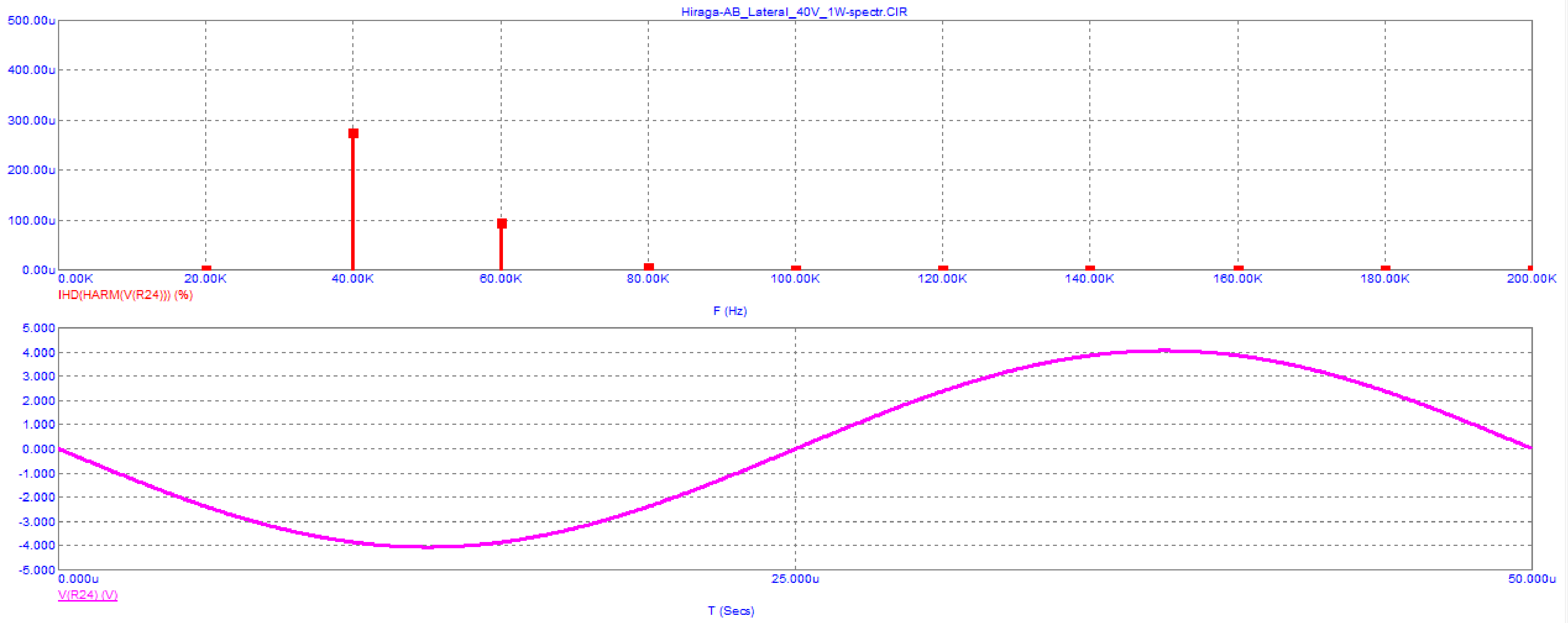

Figure: five

With an output power of about 1 W, the level of distortion at a frequency of 20 kHz does not exceed 0.0003%.

Let's measure the intermodulation distortion, fig. 6

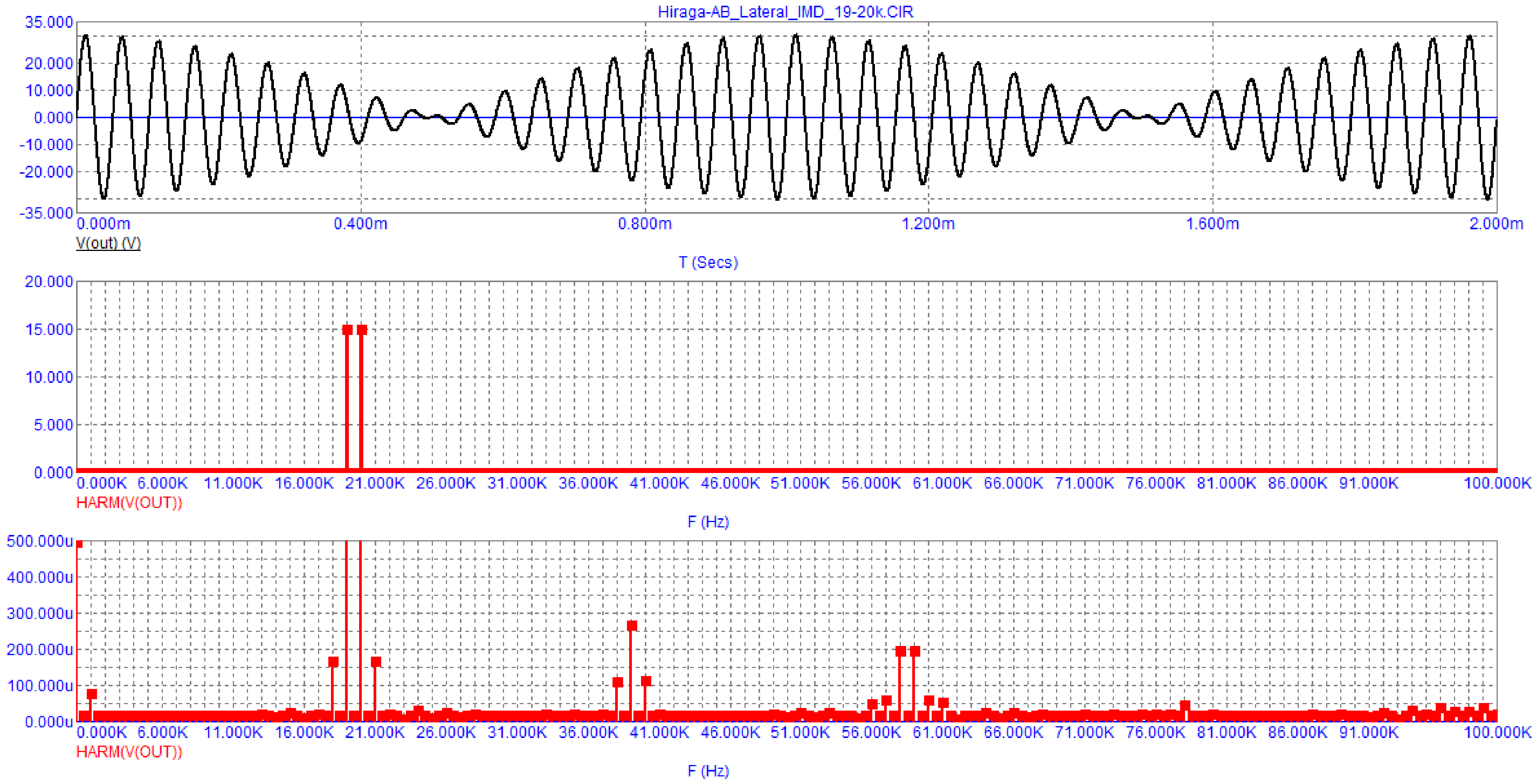

Figure: 6

IMI of the first order is less than 100 µV, the noise bias is negligible (about 30 µV) due to the low signal propagation delay.

Let's measure the rate of rise of the output voltage, Fig. 7

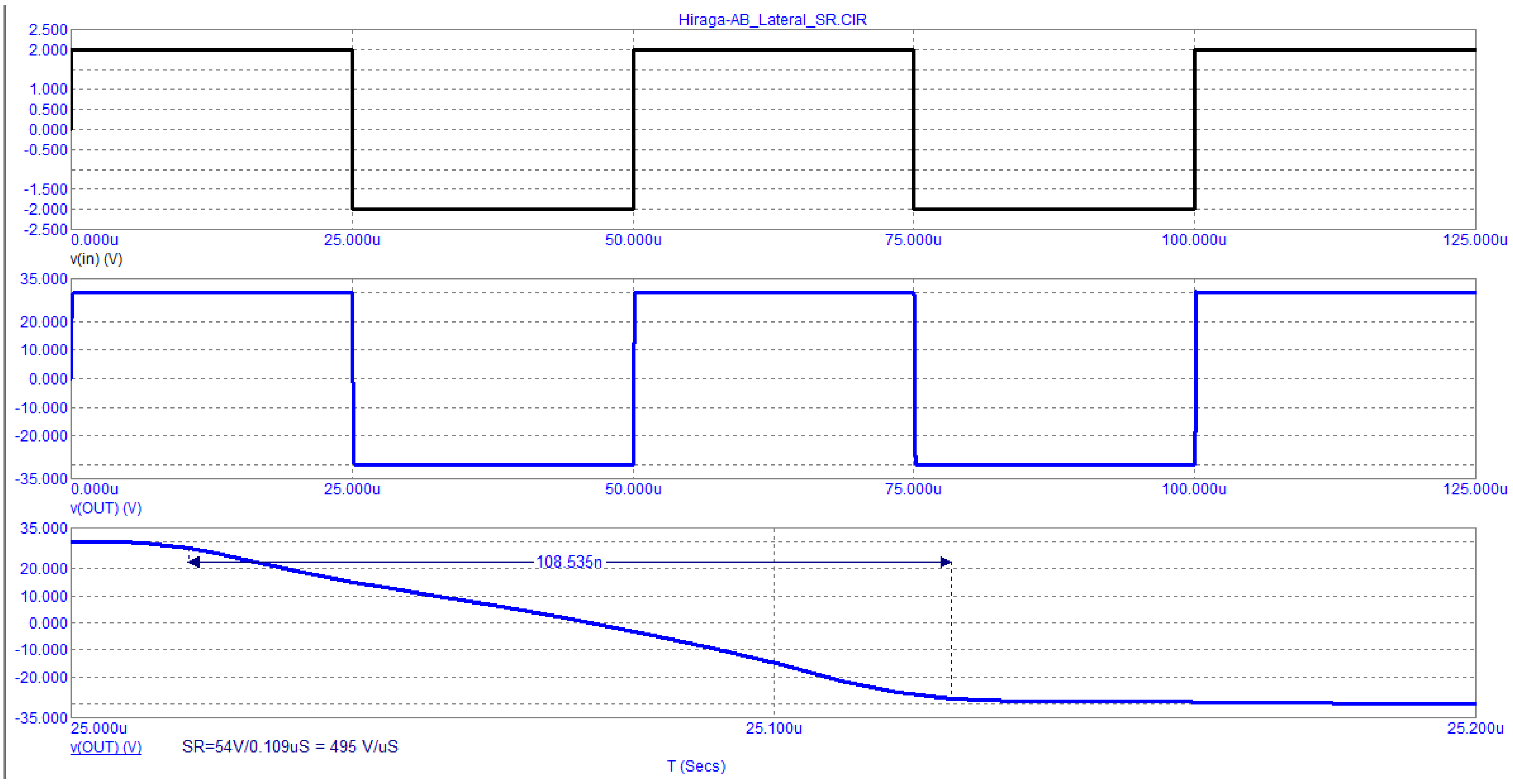

Figure: 7

Before being fed to the input of the amplifier, the ideal waveform is passed through a first-order low-pass filter with a cutoff frequency of 5 MHz. The slew rate of the output voltage with this filter is 495 V / μs. Let us convert this value to the reduced slew rate (PSN). To do this, divide SR by by the voltage amplitude: 495/54 = 9.2 1 / μs.

Let's check the amplitude characteristic of the model at a frequency of 1 MHz before the clipping mode, Fig. eight

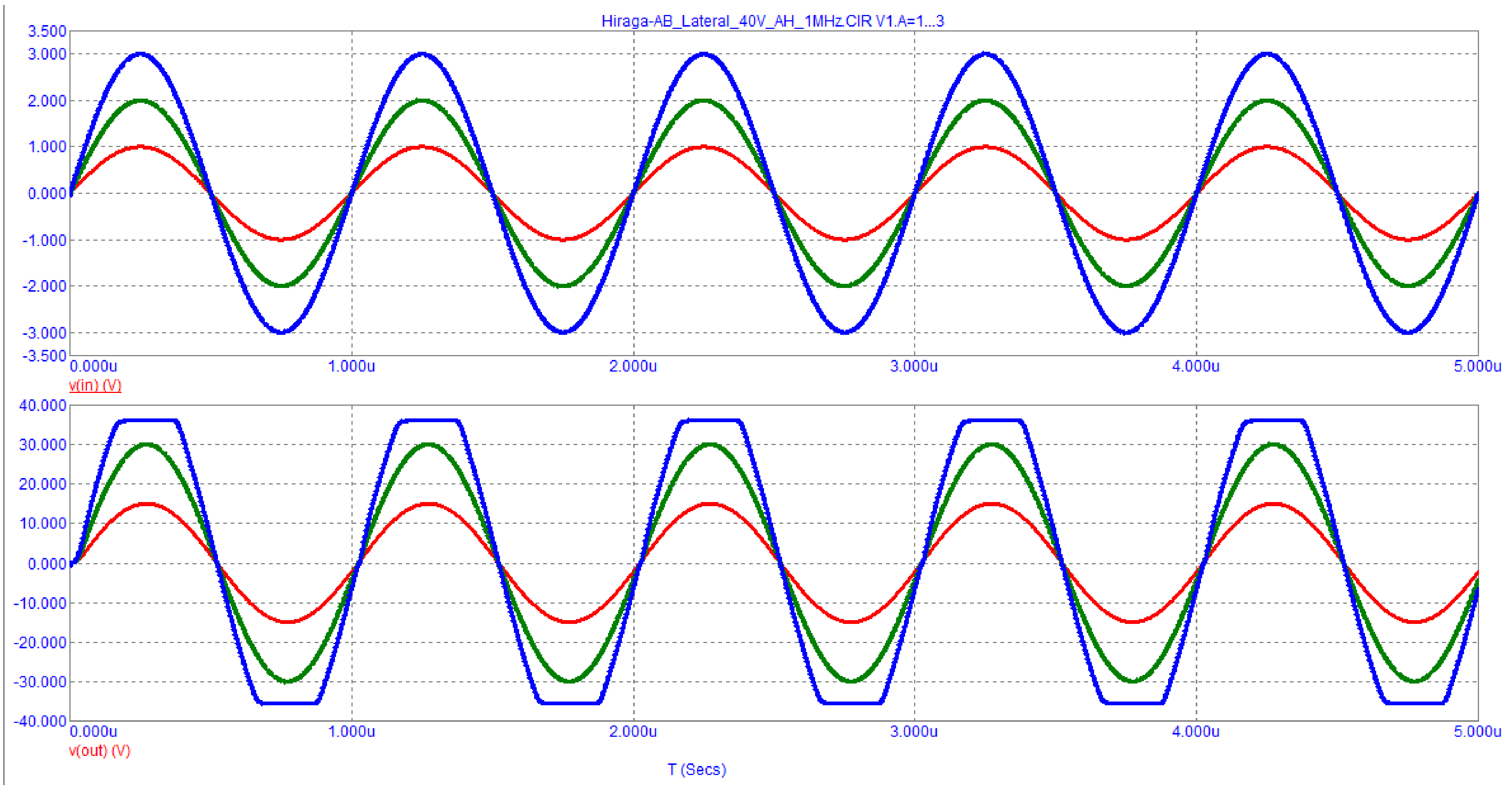

Figure: eight

Even at 1 MHz, clipping is quite "soft"

It is known that class AB amplifiers are characterized by switching distortion. To combat this type of distortion, many attempts have been made to reduce them to a minimum. However, no invention has completely solved this problem. Let's check the introduced distortions using a special filter [1], Fig. nine

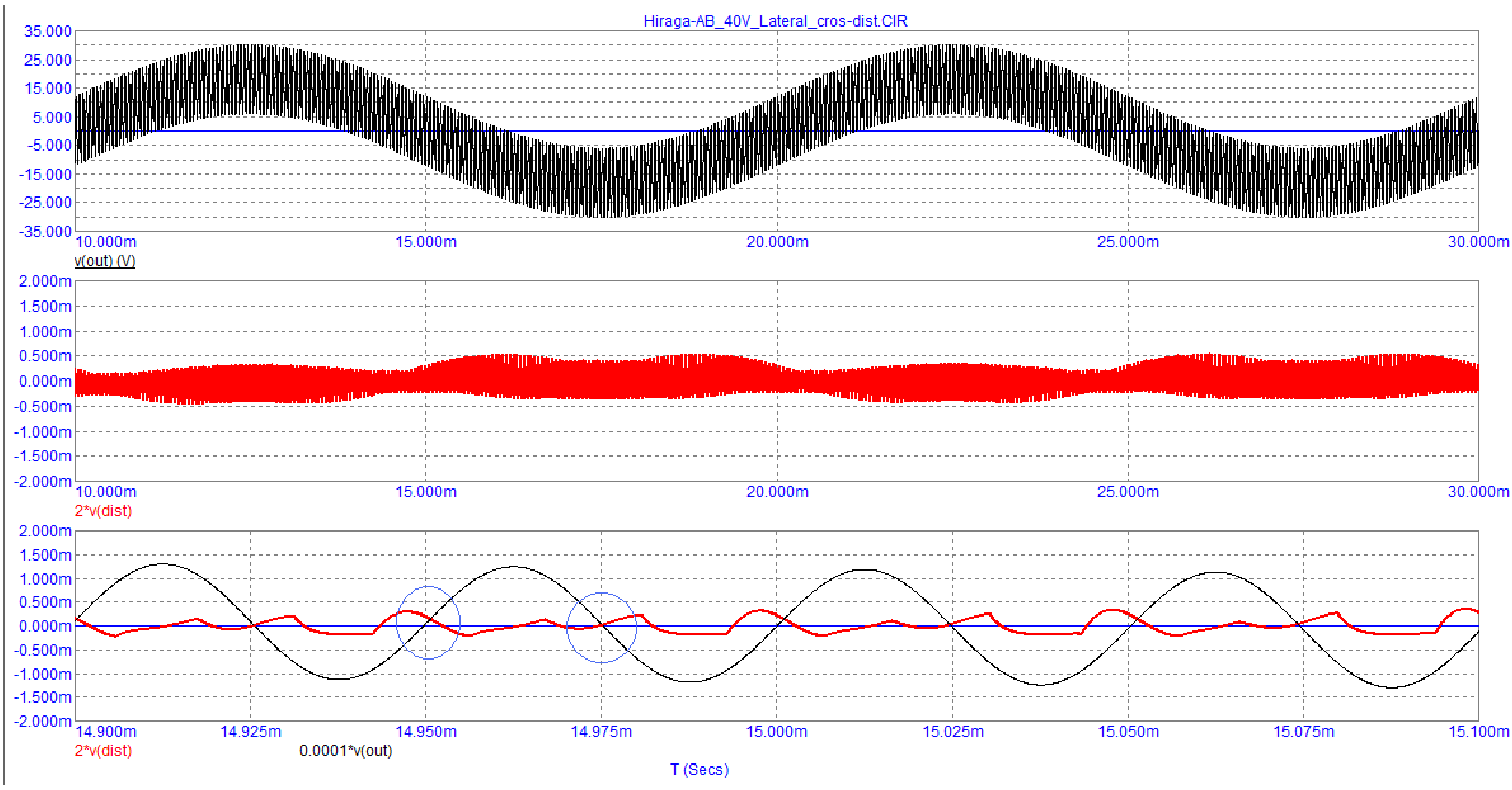

Figure: nine

Filter [1] allows to measure switching distortions at one highest frequency of the audio range, ie at a frequency of 20 kHz. In this case, the measurements were carried out by a two-frequency method in which an additional frequency of 100 Hz was used. With pronounced switching distortions on the 2nd graph, as a rule, there is a characteristic increase in distortions opposite to the transitions of the output signal (top graph) through zero. In the third chart, we see distortion products (red) that are low and soft in nature. The black color shows the output signal attenuated by 10 thousand times to synchronize the distortion products, i.e., for greater clarity.

Let's measure the output impedance of the amplifier in one of the traditional ways by applying voltage through the load to the output of the amplifier, Fig. ten

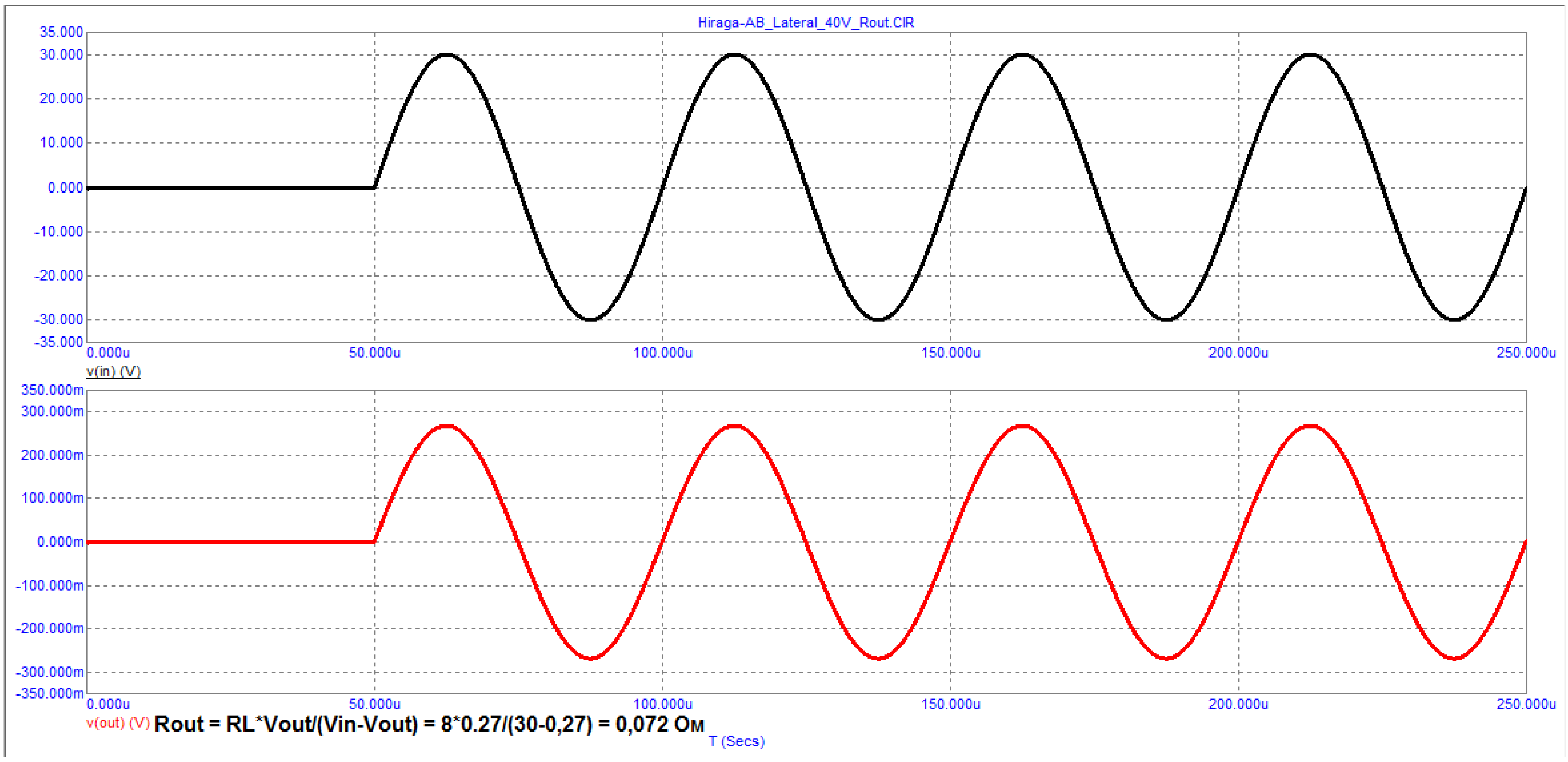

Figure: ten

The result of measuring the output resistance showed that it is equal to 72 mOhm or 0.072 Ohm. There is another original measurement method described in the books by Bob Cordell and Douglas Self using a ramp voltage also applied through the load to the amplifier output, Fig. eleven

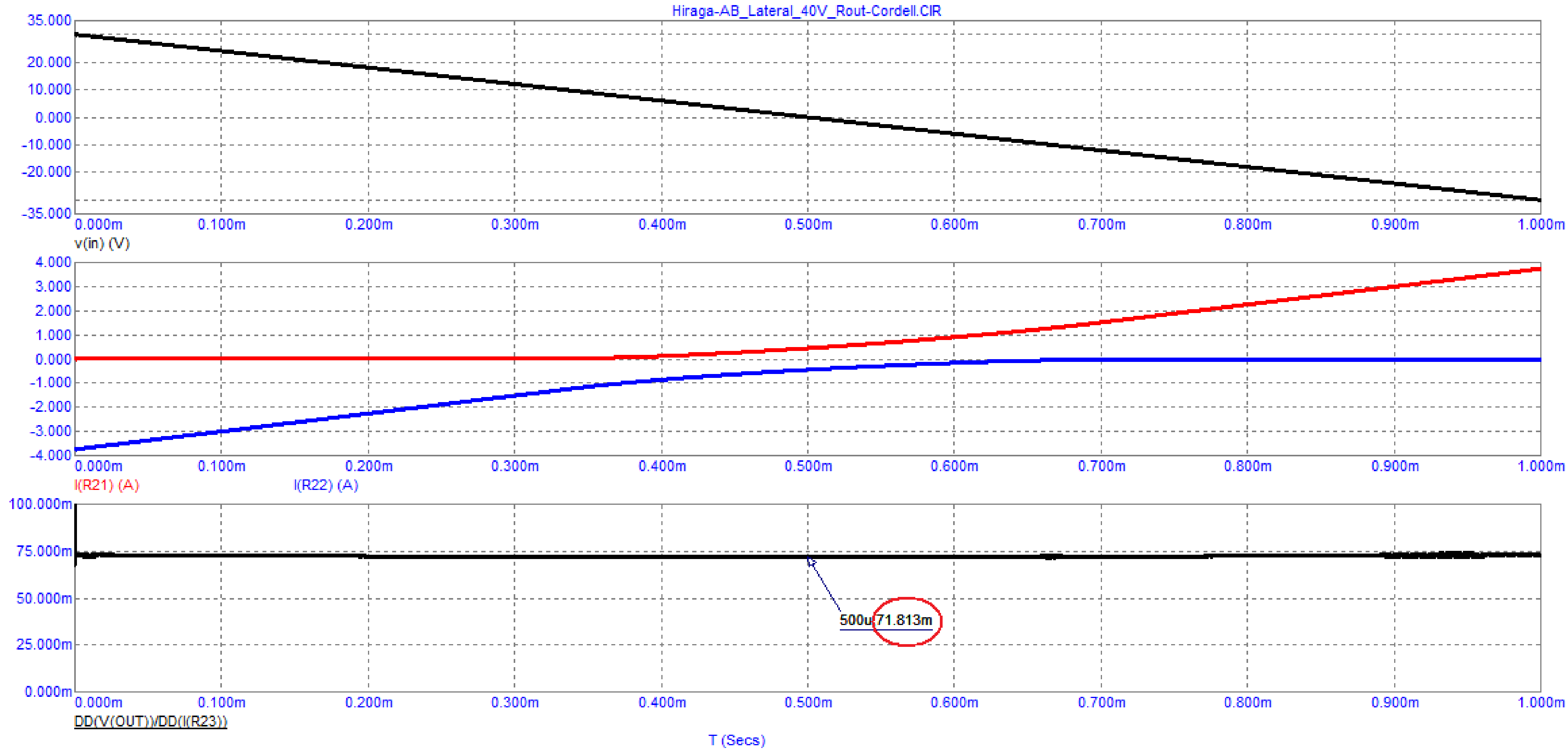

Figure: eleven

The first graph shows that a linearly decreasing voltage from 30 to minus 30 V is applied across the load. The second graph shows the currents of the VC arms. And the third graph shows a graph of the output resistance, the value of which coincides with the previous measurement. The advantage of this method is also that we can see the linearity of the output resistance from the load applied to the output. In this case, it is quite linear, while the damping factor is more than 100.

Until recently, when measuring the UMZCH parameters, they were limited to measuring the output power at various loads (8, 4 sometimes 2 Ohms), bandwidth, harmonic distortion at rated power at a frequency of 1 kHz (rarely at a frequency of 20 kHz in a band up to 80 kHz), intermodulation distortion (not always), damping factor and slew rate of the output voltage. However, as practice has shown, this entire list says little about the correlation with sound quality, except perhaps SR, which they began to cite in the specifications recently.

Back in 1982, I. Dostal in the book [2] drew attention to other types of distortions (he or the translator called them errors), fig. 12 and gave the calculations for them.

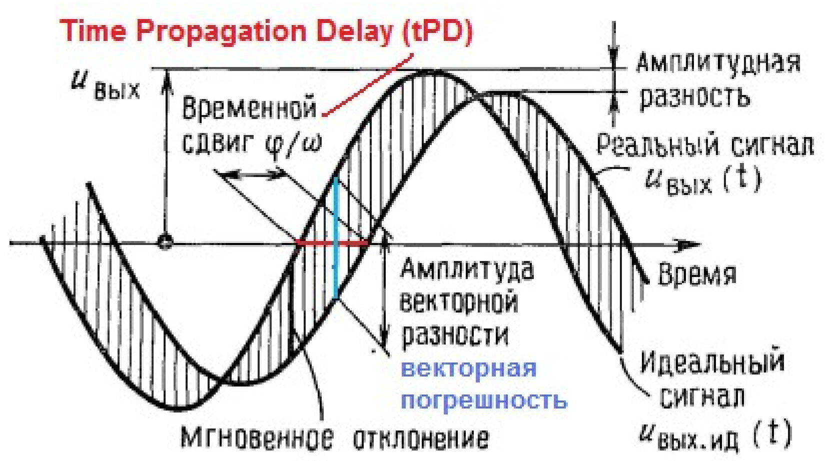

Иллюстрация соотношения между векторной, амплитудной и фазовой ошибками при представлении сигнала в виде функции времени.

Figure: 12

In Figure 12, we see the already familiar distortions of the frequency response (amplitude error) and phase delay (phase error), usually taken using a Bode diagram. Until recently, no one attached importance to the group delay time (CLT), which is associated with the frequency response and phase response and on which the vector error largely depends (highlighted in blue). The author gave two schemes for measuring the vector error - for the inverting and non-inverting amplifiers. At first glance, one might get the impression that the signal transmission delay time does not affect anything (as some ardent critics claim, for example [3]) and are greatly mistaken. Only recently in the specifications for very expensive and declared as reference amplifiers began to cite such a parameter as the Time Propagation Delay. For example, the specification of the Goldmund Telos 5000 amplifier [4] (worth 375 thousand euros per pair) indicates that its GDT is constant from DC to 200 kHz and does not exceed 100 ns. In his work [2], the author showed the physical meaning of the velocity error associated with the GDT, Fig. 13

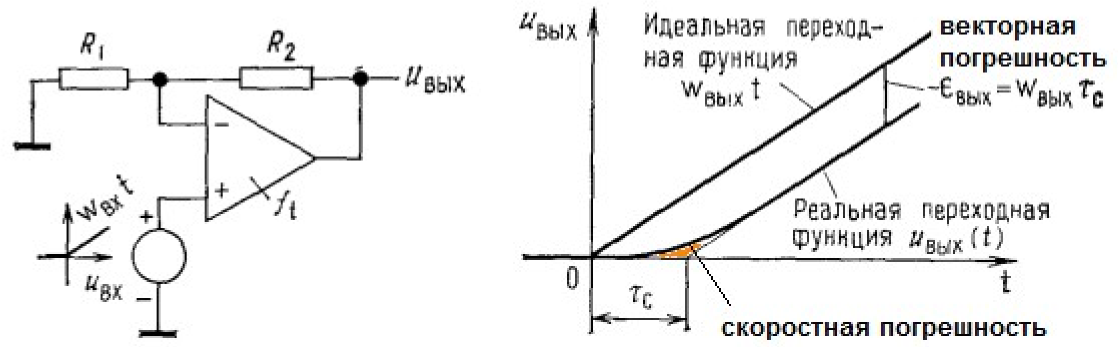

Рис. 9 16. Скоростная погрешность неинвертирующего усилителя при возбуждении его линейно-нарастающим напряжением.

Figure: 13

We can assume that the initial section of the sinusoid is close to a linearly increasing voltage. Let's see how the considered amplifier works at a frequency of 20 kHz. From the graph in Fig. 2 we know that the amplifier's delay is 22 ns. Let's add an ideal delay of 22 ns at the generator output and bring the input signal and the delayed signal to the output level by multiplying by Ku, Fig. fourteen

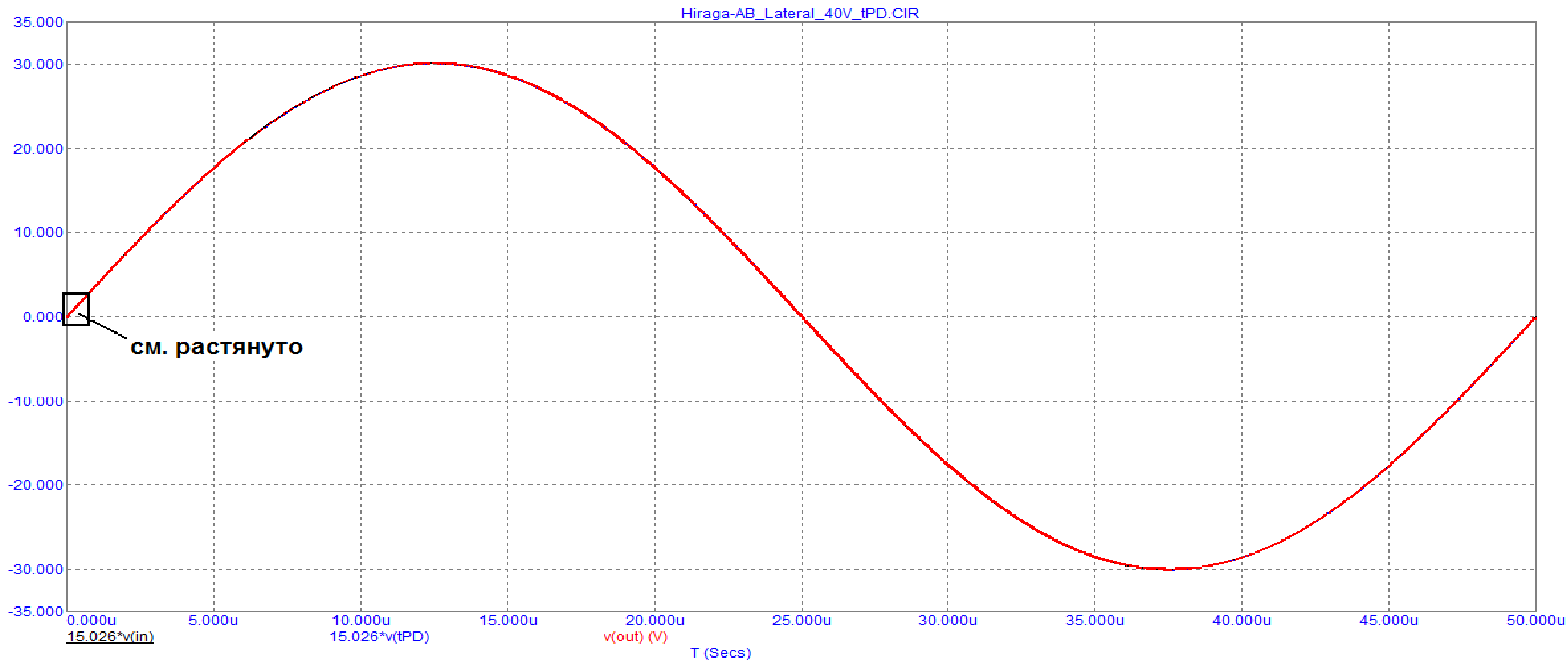

Figure: fourteen

Figure 14 shows 3 signals that merge into one line due to the small group delay. To consider them in more detail (as shown in Fig. 13), we will stretch the initial section, Fig. fifteen

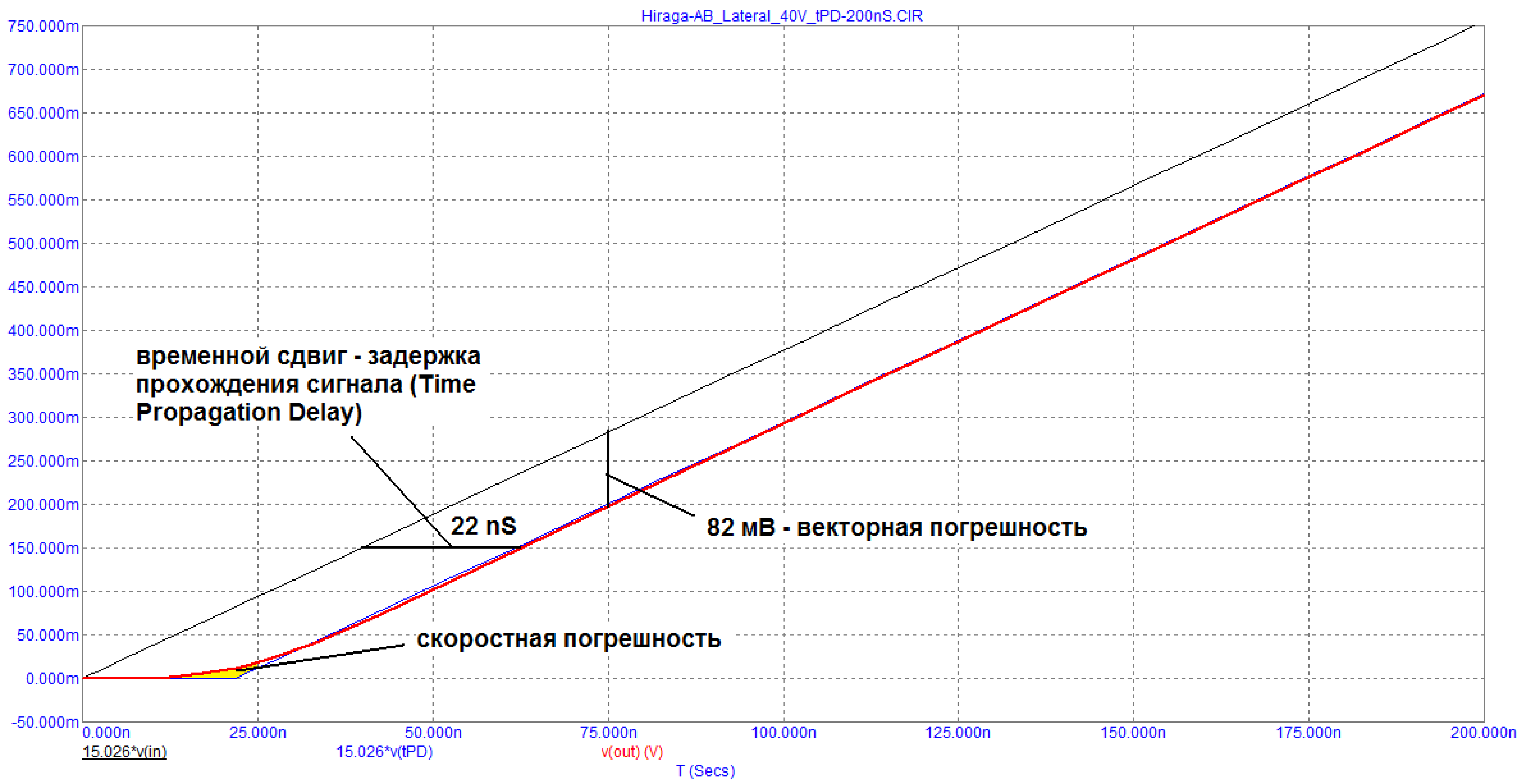

Figure: fifteen

All errors in accordance with I. Dostal's classification are signed in the figure. We also see that the time to reach the steady state takes only 30 ns. The area of the "triangle" highlighted in yellow is nothing more than a velocity error. In this case, this error is negligible: no more than 10 mV in amplitude with an output voltage amplitude of 20 kHz equal to 30 V (peak). I have repeatedly emphasized that it is this type of distortion that is responsible for microdynamics, for the accuracy of amplifying weak signals that are rapidly changing both in frequency and in amplitude.

GVZ behind the linear section should have a smooth decline. The burst of the group delay behind the horizontal section indicates the instability of the amplifier, about the phenomena of a resonant nature. The quality factor of resonances depends on the magnitude of the surge and its width (duration in frequency). Such phenomena cause an increase in the time to reach the steady state and can be of an oscillatory nature, which gives additional coloring to sounds. Such effects are not detected in any way by traditional measurements of parameters on stationary sinusoidal signals. At the design stage, distortions associated with velocity errors can be seen by the Baksandall method [5] using a triangular signal with a frequency of 10 kHz as a test signal. A 10 kHz triangular signal contains a falling series of odd harmonics. The tops of the triangle are nothing more than the beginning of a linearly increasing / decreasing signal according to [2] Fig. 13.

To obtain speed errors (distortions) in their pure form (what is highlighted by a colored triangle), it is necessary to exclude the vector error. To do this, it is enough to subtract from the output signal the input signal delayed for the time delayed delay and reduced to the output level by multiplying by Ku. Considering that the linearity of the group delay of real amplifiers rarely exceeds 200 kHz, the spectrum of the test triangular signal should sometimes be limited using a traditional low-pass filter with a cutoff frequency of 160 ... 200 kHz. In amplifiers such as UPT GVZ constantly from infra-low frequencies.

It is advisable to temporarily transfer models of amplifiers with reshaping capacitors at the input and in the OOS circuit to the DCS and make careful balancing. But even if we do not do this on the test with a triangular signal, this will practically not affect in any way. Problems can arise when used as a test multi-tone signal, for example [6].

Let us check the operation of the model with a test signal of the "triangle" type with a frequency of 10 kHz, Fig. sixteen

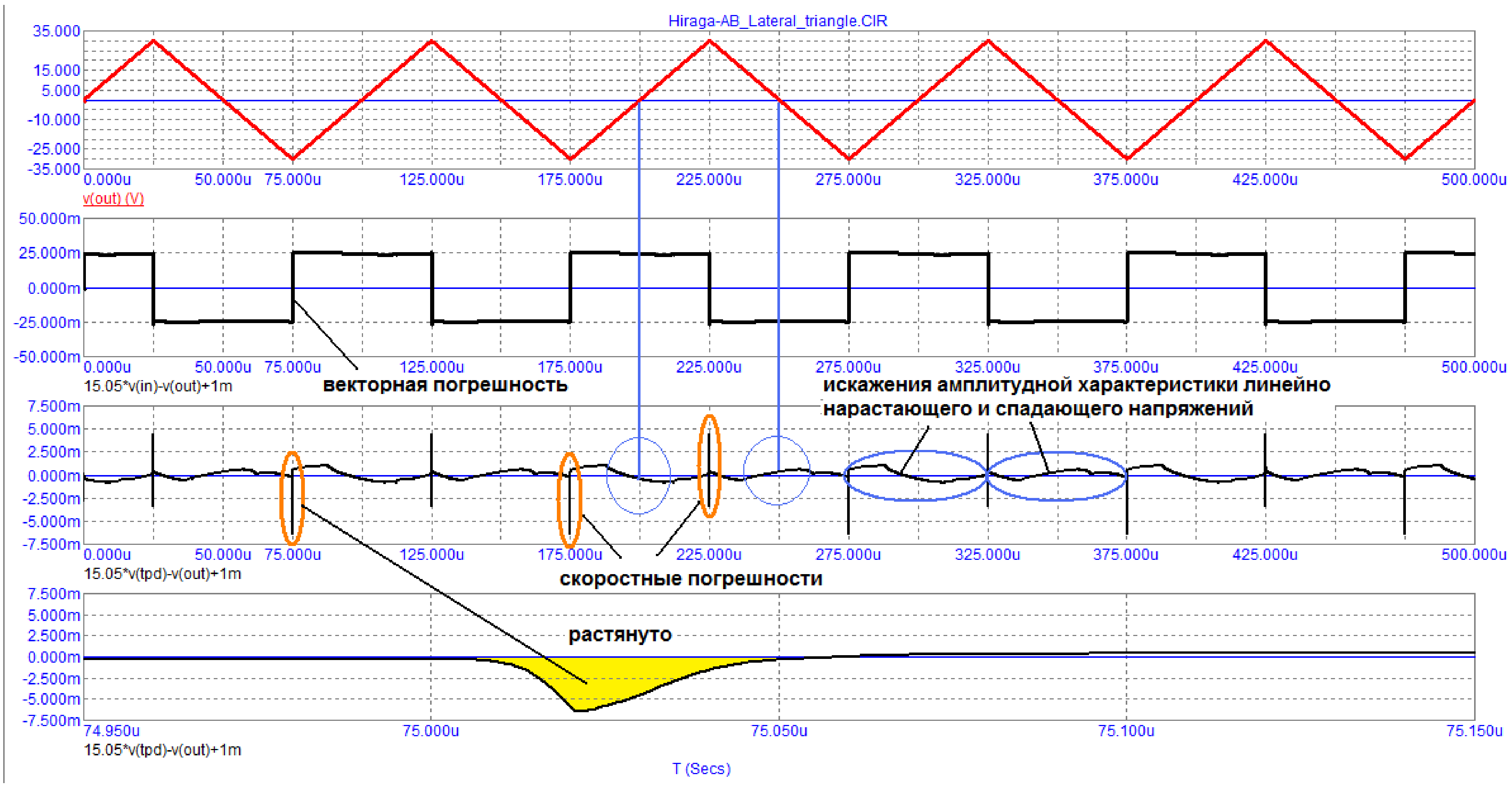

Figure: sixteen

The upper graph shows the output signal, the second graph shows the vector error - the result of subtracting the output voltage from the input voltage level-to-output. The third graph shows the distortions obtained as a result of subtracting the output voltage from the input voltage delayed by the time tPD, adjusted to the output voltage. For greater clarity of the rate errors, the test signal was not processed by the low-pass filter. We can see that the velocity error has an amplitude of up to 7 mV and a total duration of about 30 ns, which is what the amplifier lost at the signal tops. I hope it is clear that speed distortions depend on the reduced slew rate (SSR) of the output signal and occur when the voltage rise / fall direction changes. Hence, the most susceptible to these distortions is precisely the small signals with high values of PSN. I want to draw your attention to the distortion products opposite to zero crossings, they are similar to the distortions in Fig. 9 and have no signs of switching distortions.

If we subtract the other way around, that is, subtract the delayed input signal from the output signal, we get the distortion products in inverse form, Fig. 17

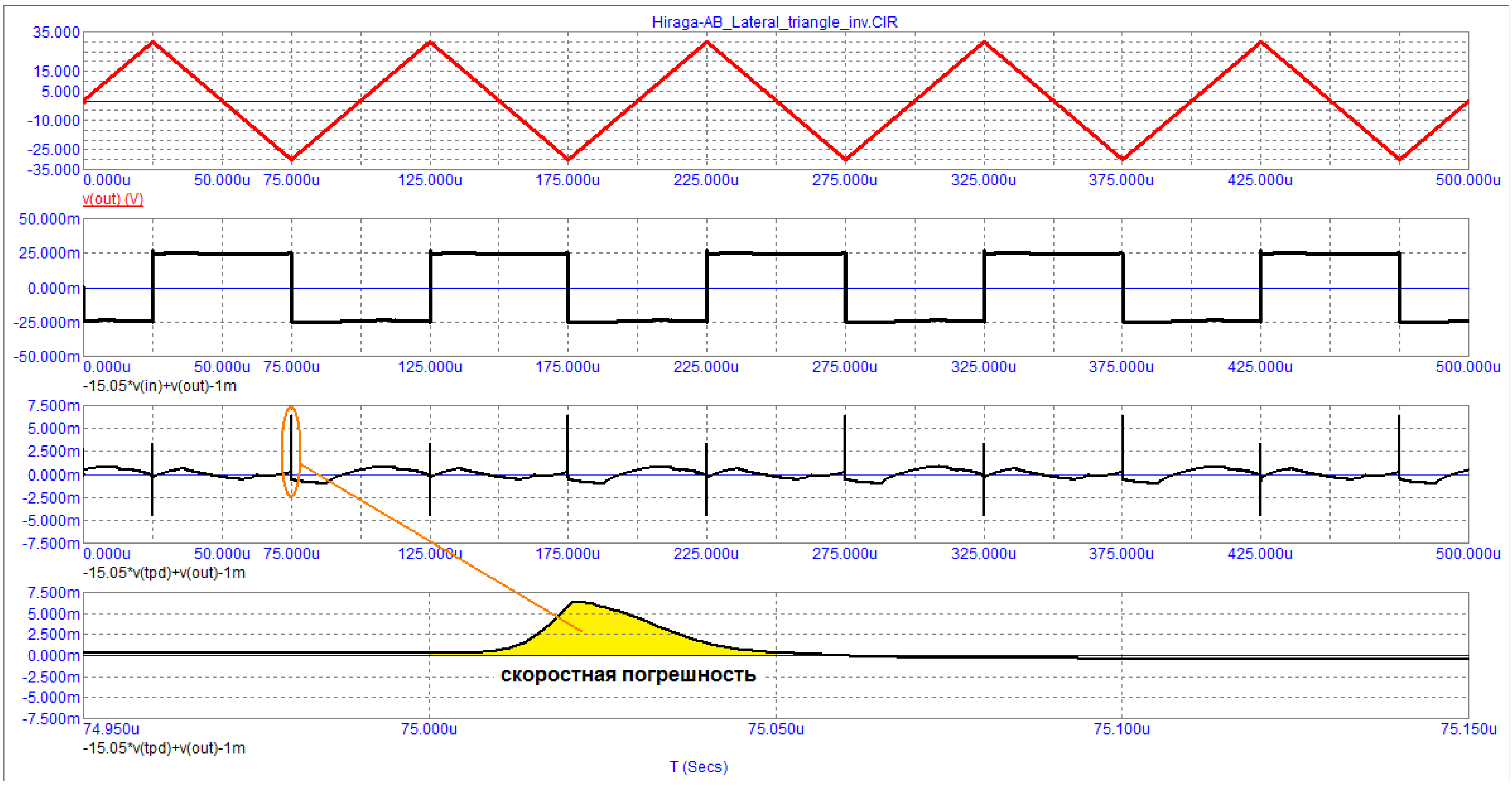

Figure: 17 (the loss at the top of the triangular signal is highlighted in yellow)

A few words about the design

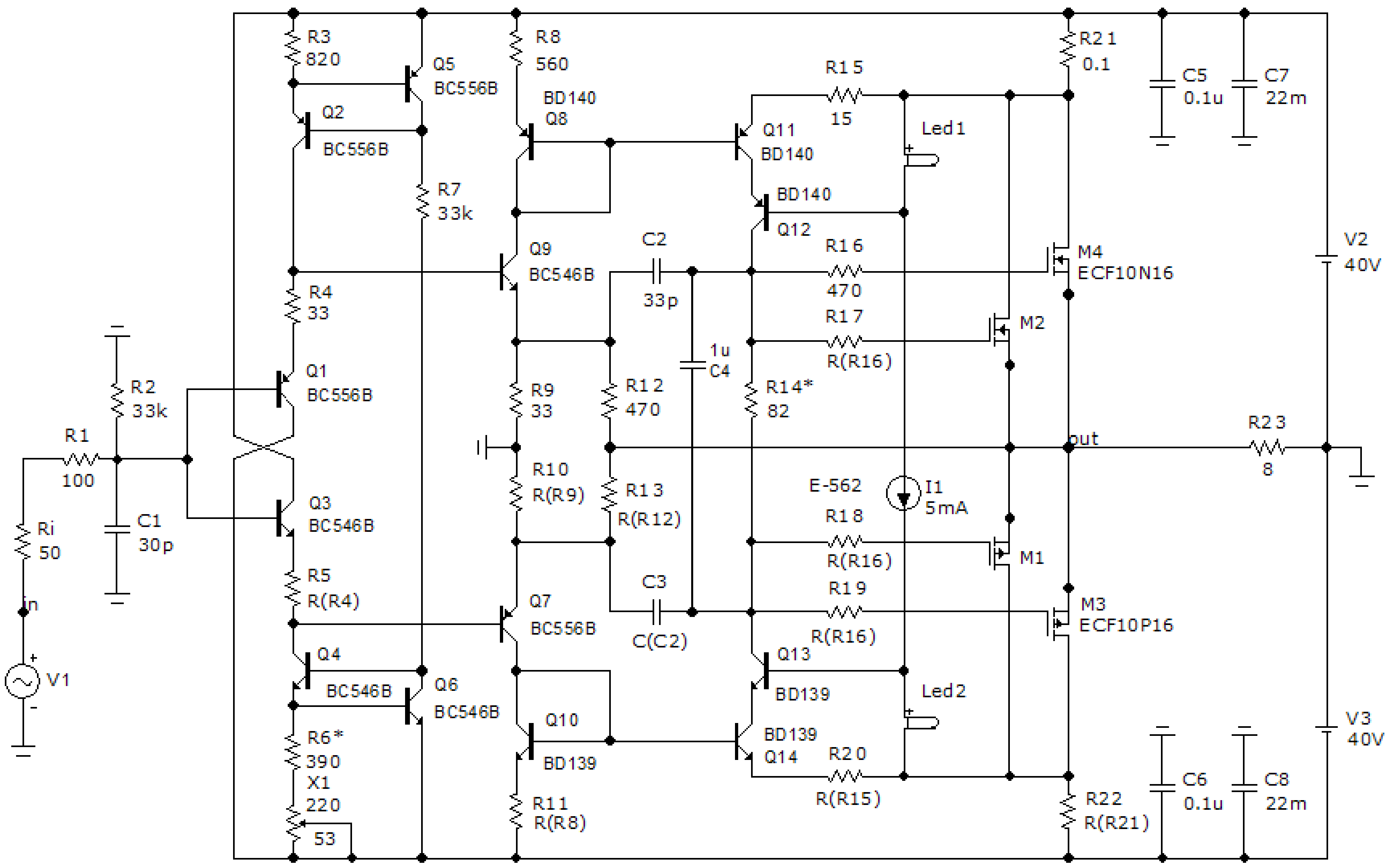

Figure: 1

The emitter circuits of the input repeaters are powered by the GTS. The GST current is controlled by BE-junctions of transistors Q5, Q6. To stabilize the operating modes of the input stages, the transistors Q1 and Q9, as well as Q3 and Q7, must have a thermal contact in pairs and be in the same thermal conditions (as an option, they are located at the same horizontal height or equipped with a common heat sink through a paste). GST transistors Q5, Q6 must also be in the same thermal conditions! (as an option, a metal plate is glued to the thermal paste for all six transistors with the housings set in height)

Transistors Q8, Q11 and Q10, Q14 are large-scale current reflectors and their transistors must in pairs have thermal contact with each other and be in the same thermal conditions. These transistors operate at low EC voltages, so the power allocated to them is low. The maximum current that is required from them is about 100 mA peak at fronts of a meander. For these positions, it is not necessary to use transistors in the TO-126 package, it is quite possible to use low-voltage transistors in the TO-92 package that allow pulse currents of more than 100 mA. Transistors Q11, Q12 and Q13, Q14 form monitored cascodes. Transistors Q12, Q13 must be placed on a common heat sink, as these transistors you can use 2SC5171 / 2SA1930, 2SC6072 / 2SA2190, KSC2690 / KSA1220, 2SC3421 / 2SA1358, 2SD600 / 2SB631, MJE340 / MJE350 and others.

Lateral types BUZ900 / BUZ905, ECF-20N16 / ECF-20P16, 2SK1056 ... 58 / 2SJ160 ... 62 and others can be used as output transistors.

The quiescent current of the output transistors of 200 + -20 mA per transistor is set by selecting the resistor R14. Zero at the output is set with the trimmer X1, if necessary, select R6. I1 is a 5 mA current stabilizing diode of the E-562 type or similar, in the absence of a current stabilizing diode, you can use a GST on a JFET transistor with a 8.2 ... 10 kΩ resistor connected in series. The LEDs are green, you can also use yellow, white or blue, it is important that the voltage drop across the LED is at least 2 V.

A possible variant with a simple modification is shown in Fig. 18

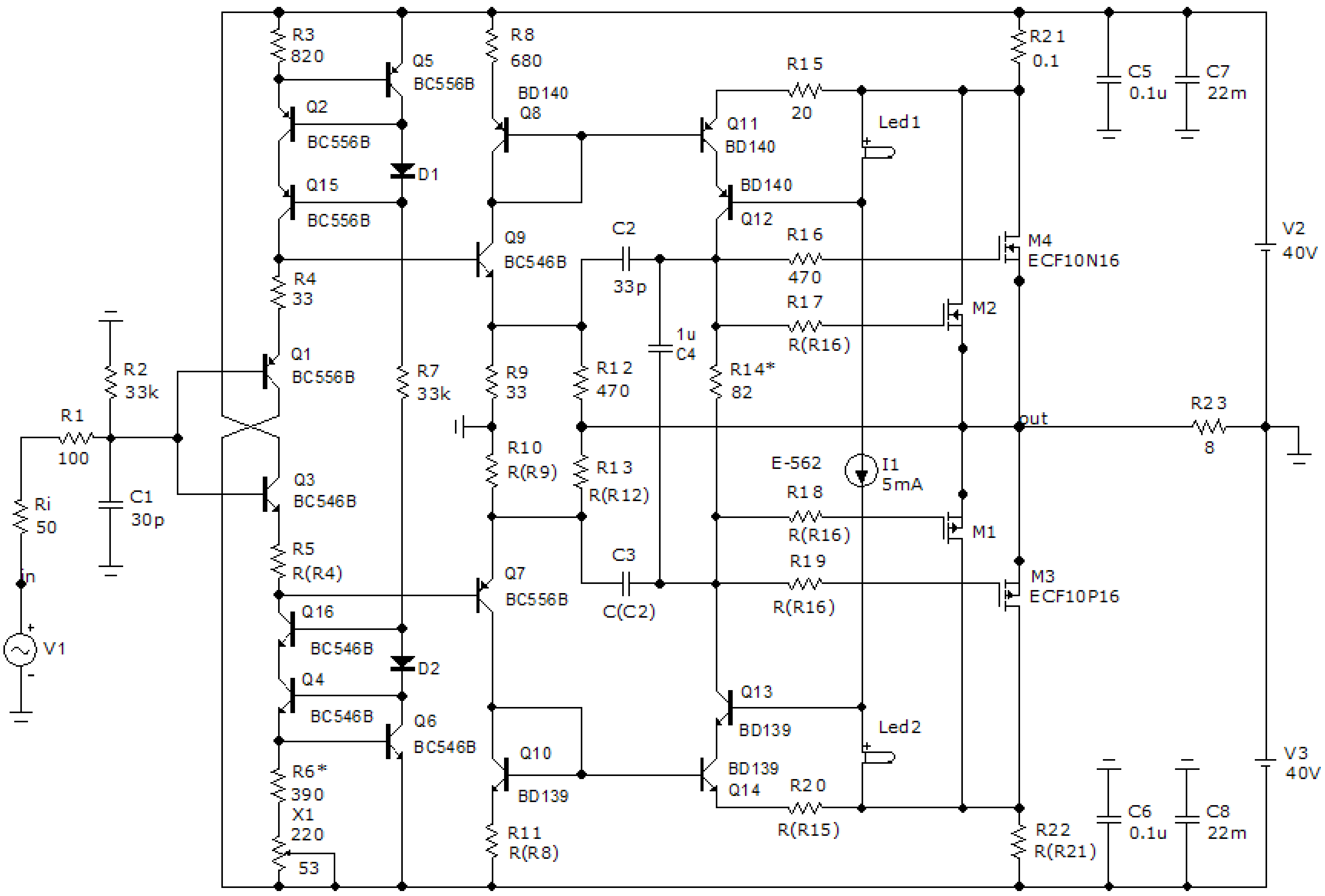

Figure: 18

The addition of 4 elements transforms the GTS feeding input repeaters into cascode repeaters.

Literature:

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3.I. Rogov, Pole of Truth, Radio 2019-04

4. FM Acoustics, RESOLUTION SERIES, http://www.highfidelity.pl/@main-639&lang=en

5. PJBaxandall, "Audible amplifier distortion is not a mystery." Wireless World, November 1977, pp 63 - 66.

6. K.Musatov, Method for measuring the real resolution of an amplifier, http://forum.vegalab.ru/showthread.php?t=34487

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