Introduction (instead of summarizing)

It is known that in the products of distortions of a sinusoidal signal in amplifiers, predominantly harmonic components appear that are multiples of the fundamental frequency nf, where n = 1, 2, 3, …. ∞. These distortion products can be isolated in steady state using spectrum analyzers, as well as in summary form using THD meters.

Any amplifier (except the ideal one) has a limited bandwidth from above, which imposes, in addition to non-linear distortions, additional linear distortions: phase shift, change in signal amplitude.

If the amplifier has a closed input (non-DC amplifier), then in addition to linear and non-linear distortions, transient distortions occur in the distortion products, which are often confused with linear distortions.

In DC amplifiers, it is often necessary to use a servo control system, which, if implemented incorrectly, can also introduce additional transient distortion and non-linear distortion in the low-frequency region.

Phase and gain margins often require the use of an inductor at the output of the amplifier. The presence of inductance is also often the cause of additional distortion introduced by amplifiers when operating on a real reactive load.

In a number of operational amplifiers, in the speed parameters section, such a parameter as tPD (time Propagation Delay) has been added. On the horizontal sections of the group delay (Group Delay) tPD = GD. Developers who understand the meaning of this parameter began to indicate its value in the specifications. In high quality amplifiers, this parameter rarely exceeds 100 ns!

An RC circuit time constant with this value corresponds to a cutoff frequency of 1.6 MHz. I've seen rave reviews for 2.2 MHz DC amplifiers on numerous occasions.

And now imagine that we have an ideal amplifier (but we doubt it) and to make sure that there are no introduced distortions, we will measure the vector errors. To do this, it is enough to use the Hafler SWDT method [13] and compare the output signals with each other, Fig. A.

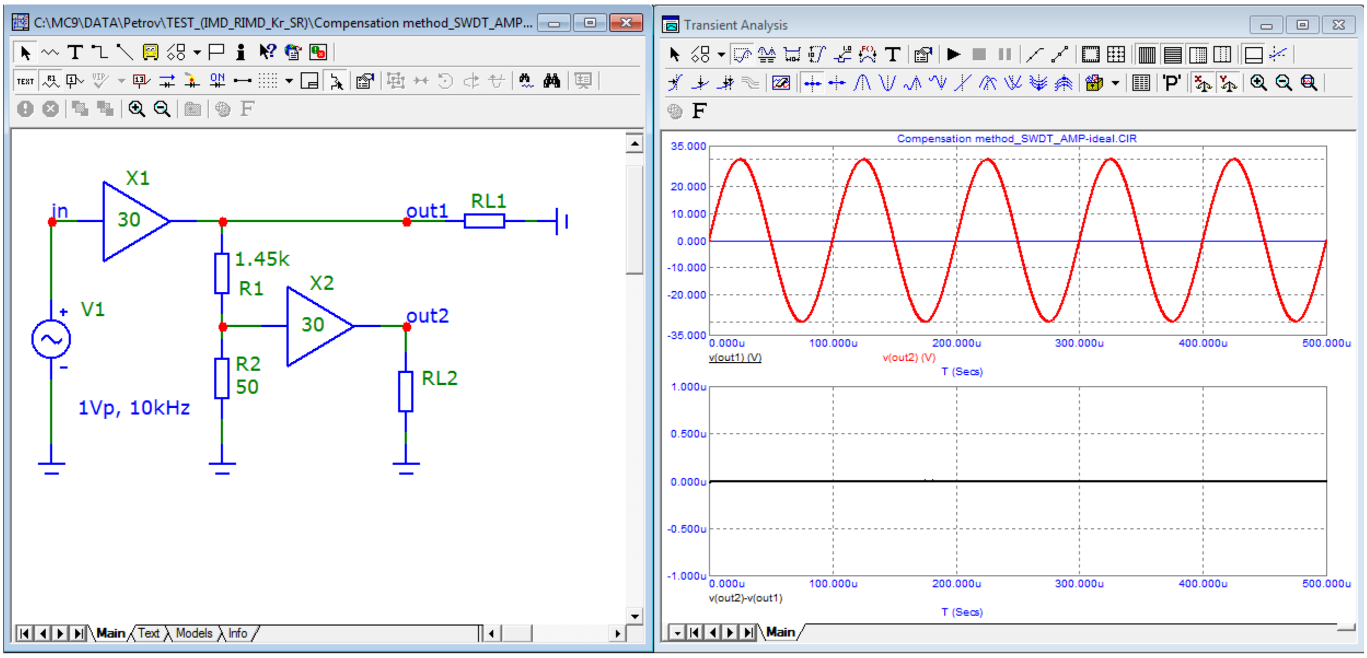

Fig. A

As you can see, the difference between the output signals is zero, which corresponds to the absence of any introduced distortions.

And now let's give a signal in the form of bursts, fig. B

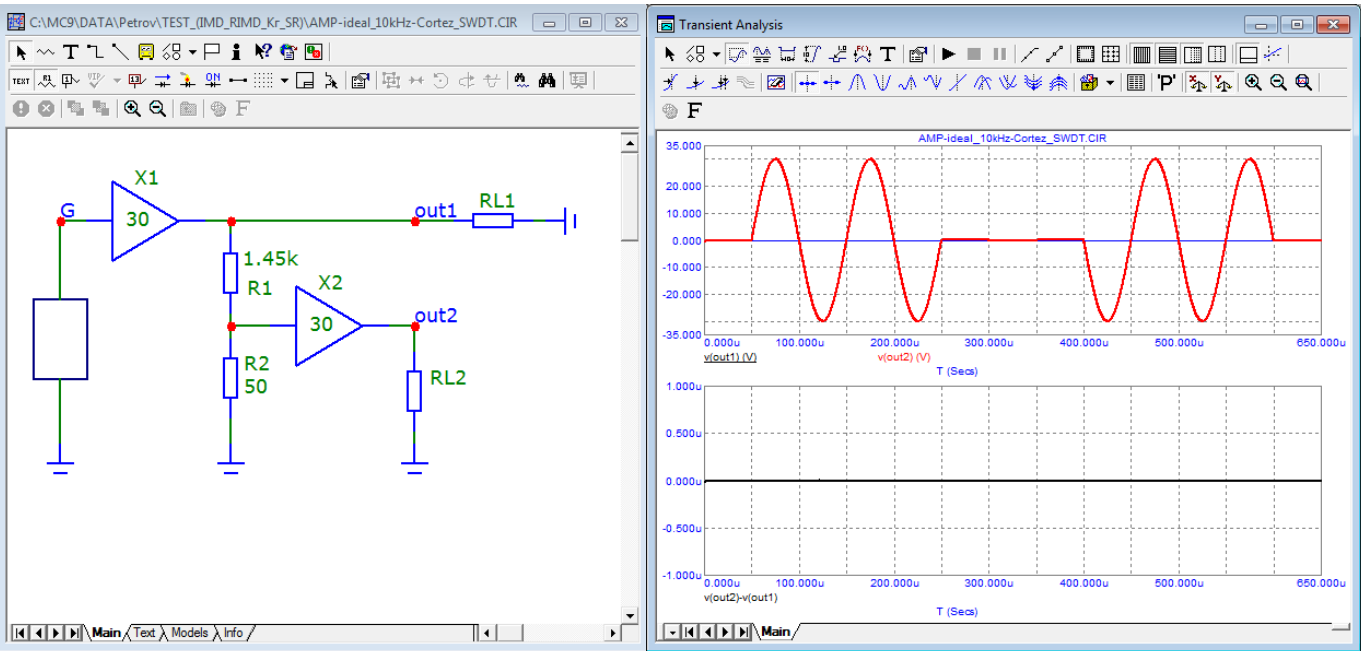

Fig. B

As the test showed, even with such a complex signal at the output of the amplifier under test, there are no additional spectral components that scare in a number of scientific publications. However, remember that we are dealing with an ideal amplifier whose input capacitance is zero, the signal propagation delay (time Propagation Delay) is also zero. This is what is required for the perfect operation of the amplifier, as Cyrill Hammer [20] spoke about.

However, let's move from an ideal amplifier to a model of a real amplifier having a signal propagation delay of 1 µs and introducing negligible non-linear distortions in the form of the 3rd harmonic with a level of 3 µV, Fig. C.

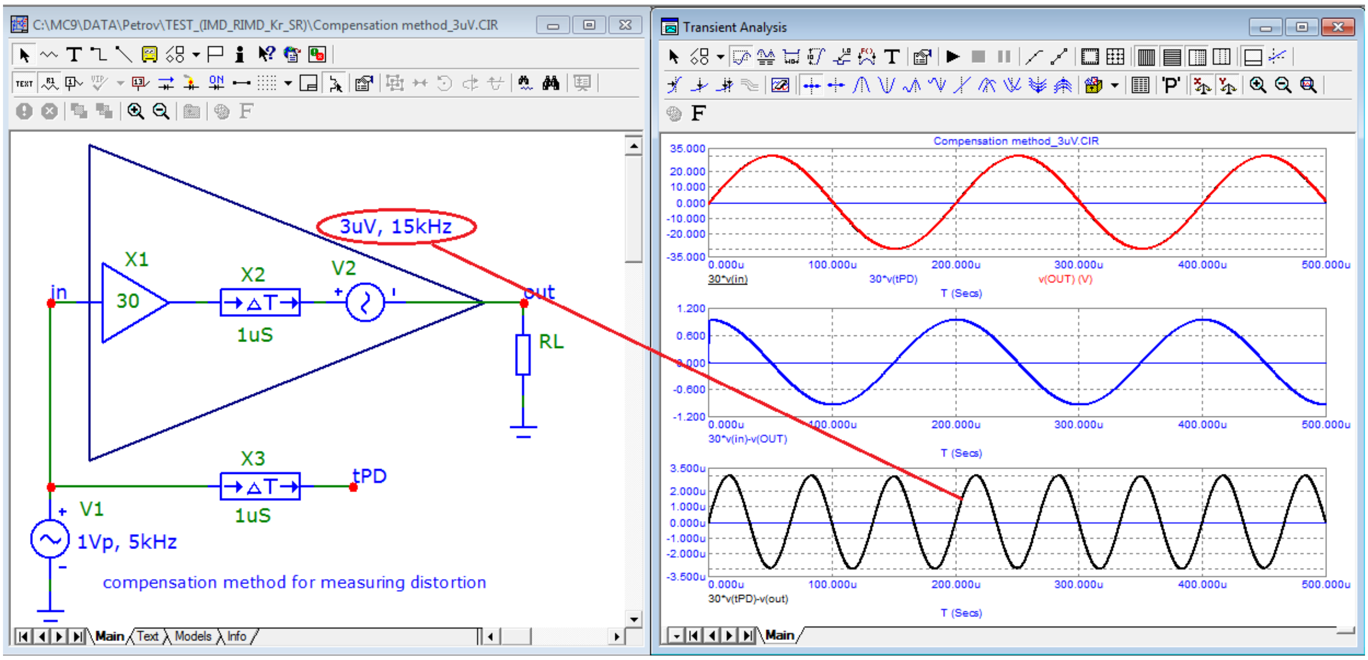

Fig. C

Figure C shows a block diagram of an amplifier consisting of three components: an ideal amplifier X1 with Ku = 30, an ideal delay line X2 for 1 µs simulating the delay time of the signal in the amplifier and a generator V2 (15 kHz, 3 uV) simulating the distortion introduced by the amplifier.

Let's apply a signal with a frequency of 5 kHz and a level of 1 V (peak) to the input of the amplifier. In this case, the oscillator signal V2 will be the third harmonic.

Let us measure the vector errors (SWDT) and distortions of the modeled amplifier using the compensation method.

On the first graph, we will display the output voltage and the normalized input signal and the input signal delayed by the time it passes through the amplifier (i.e., by the time tPD). Signal normalization consists in multiplying them by Ku, i.e. by 30.

Since the delay of the output signal and its “distortion” (3rd harmonic) are negligible compared to the signal period of 200 μs and its amplitude, all three signals merge into one line (top red graph).

The second graph is obtained by subtracting the output voltage from the normalized input voltage and represents the Hafler vector error or SWDT.

For a more accurate measurement of the distortion introduced by the amplifier, it is necessary to subtract the output signal from the normalized tPD signal, which is shown in the third graph. As you can see, the subtraction result gave us the 3rd harmonic in its purest form: essentially the same signal as V2.

Note.

It is advisable to use the compensation method for measuring distortions at the design stage of an amplifiers. No less successfully can this method be used to evaluate a previously developed amplifier without using computer simulation methods.

When measuring distortion with the compensation method, it is important to accurately measure both the delay time of the signal at the frequency under test and the gain. This greatly affects the measurement error.