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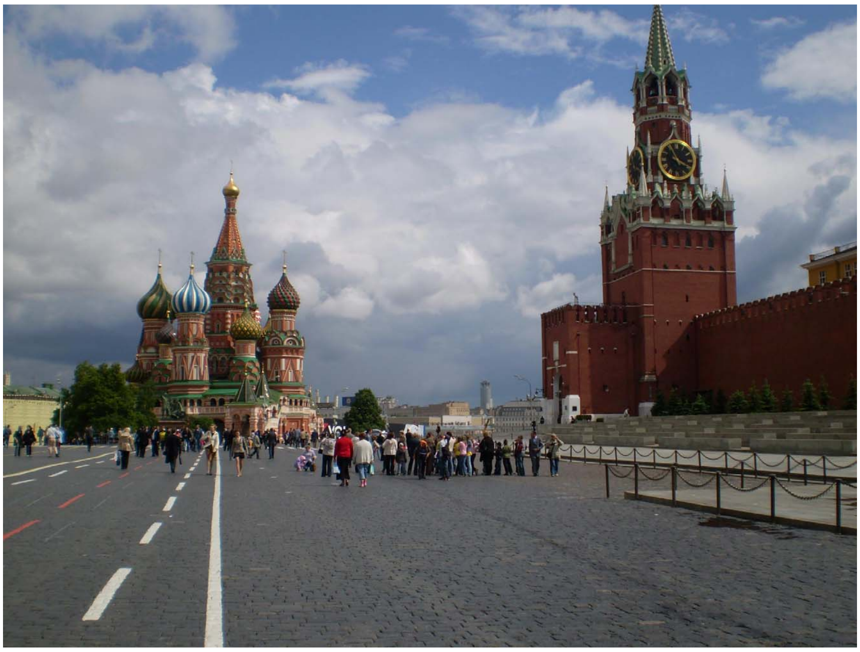

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Methods of Slew Rate Verification of Operational Amplifier Macro Model

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***Abstract*—Three methods of operational amplifier (Op amp) slew rate verification are considered. These methods are illustrated through the example of SPICE macro models of Op amp LMH6642 by Texas Instruments and OP37 by Analog Devices.**

Keywords—operational amplifier; macro model; LTSpice; circuit simulation; verification; slew rate.

I. Introduction

Circuit simulation is very important, because it allows significant time-to-market reducing.

A standard to create a system of circuit simulation de facto became SPICE program [1], developed at the Department of Electrical Engineering and Computer Sciences, University of California, Berkeley. The systems based on SPICE core include: HSPICE (MetaSoftware), ORCAD (Cadence Design Systems, Inc.), IS_SPICE (Intusoft), MicroCap (Spectrum Software), Altium Designer (Altium), Dr. Spice and ViewSpice (Deutsch Research), and LTSpice (Linear Technology). The widespread use of software for circuit simulation created a growing demand for the models of electrical components that should, on the one hand, to adequately describe the characteristics of the component and, on the other hand, not to bring in too much detailing which can lead to problems of convergence. Responding to this need leading companies, the manufacturers of electrical components, started to ensure the manufactured appliances with models and also their publication on the Internet.

One of the most popular electrical components (devices) in the analog circuitry is an operational amplifier.

The main advantage of the operational amplifiers in analog circuit design is that adding a small amount of external components allows creating a wide variety of schemes of functional units used in various devices and equipment including measuring instruments.

A few years ago, SPICE-op amp macro models poorly correlated with the reality. Recognizing this, in 1995, as part of the alliance companies Electronic Industry Alliance (EIA), a council on macro models (Compact Model Council) was established; AMD, Analog Devices, Avanti, BTA Technology, Cadence Design System, Conexant System, Hewlett Packard , Hitachi, Motorola, IBM, Intel, Lucent Technology, NEC, Philips System, Texas Instruments and others joined it. The objective of CMC is standardization and solution of model quality problem [2].

Currently, SPICE macro models of Op amp, in most cases, adequately describe the real devices. However, it is impossible to ensure that Op amp meets its stated characteristics, so the check of each Op amp macro model before usage is an urgent task complicated by the need to select a set of verification methods for each parameter.

Consider this process through the example of one of the main parameters determining the dynamic properties of Op amp – the slew rate.

II. Purpose and Objectives

The purpose of this work is to verify a slew rate of operational amplifiers on the basis of methods based on different test circuits.

To accomplish the purpose of this work, the following tasks were performed:

- based on an analysis of the published data, a selection of methods for slew rate verification was made;
- according to the selected methods, a slew rate verification of Op amp LM6642 and OP37 was made.

III. Theoretical Part

In theory, to determine the slew rate SR, as an input action, an input signal in the form of a step (Fig. 1) is used.

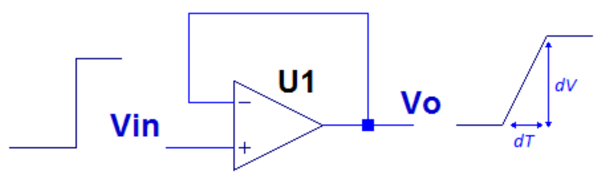

Fig. 1. Theoretical interpretation of slew rate

And the slew rate itself is defined as the derivative of the output voltage with respect to time:

$$SR = \frac{dVo}{dt}, \tag{1}$$

where V_0 – Op amp output voltage.

The smallest slew rate is obtained by a unity gain, and that is why this value is shown in the reference data.

From exposure to a sinusoidal signal at the input of Op amp:

$$V_0(t) = V_0 \sin(2\pi ft). \tag{2}$$

Slew rate has the form of:

$$SR = \frac{dV_0}{dt} = 2\pi fV_0 \cos(2\pi ft). \tag{3}$$

With finite value of slew rate a decrease in the amplitude of the output voltage of the amplifier, with the frequency of the input signal (Fig. 2), is related.

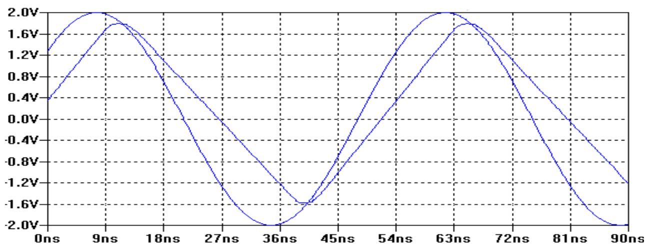

Fig. 2. Influence of slew rate on the amplitude and shape of the output voltage

IV. Experimental Part

As practice shows, different authors, and producers of Op amps use different methods for determining the specified [3].

Texas Instruments offers a method based on the simulation of test circuit shown in Fig. 3 [4]. To the input of circuit a signal in the form of a series of pulses is supplied, and from the output (in the point out) the derivative of the output voltage with respect to time, equal (as shown above) to the value of slew rate, is removed.

The authors of the portal eCircuit Center [5] propose a method based on the circuit shown in Fig. 4. To the input of circuit a signal (a step) is supplied, and from the output (in the point out), the output voltage is removed (Fig. 5); the slew rate is calculated as the ratio of the increment of the output voltage at the time. This approach is consistent with the method of measuring of slew rate set by GOST (USSR State Standard) 23089.10-83.

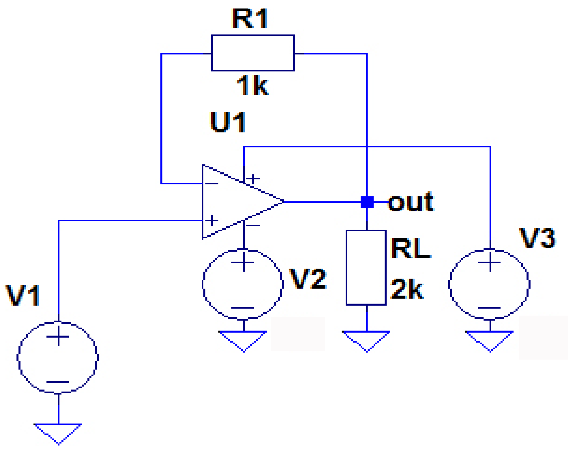

Fig. 3. Circuits for the calculation of slew rate (Texas Instruments)

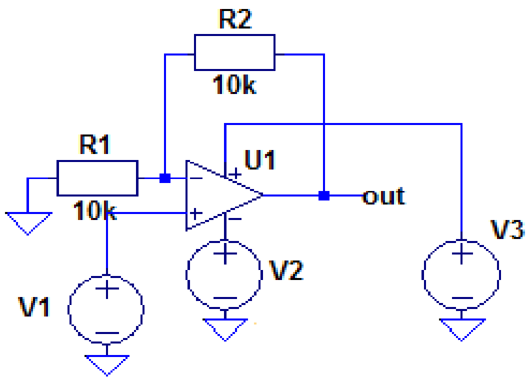

Fig. 4. Circuits for the calculation of slew rate (eCircuit Center)

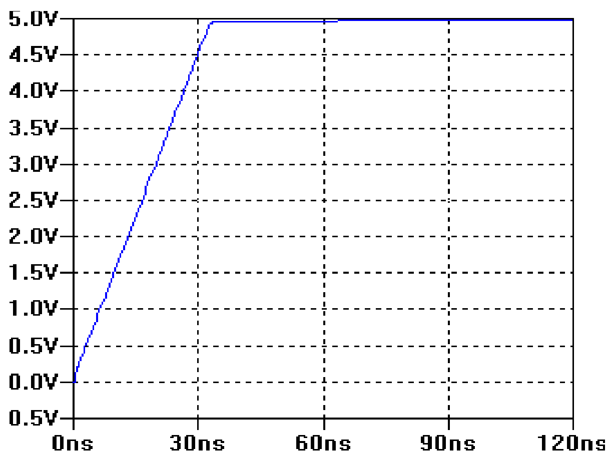

Fig. 5. Slew rate as shown in Fig. 4

The graph (Fig. 6) shows that SR = 130V / µs, and according to the graph (Fig. 5), the output voltage for 30ns increases up to 4.5V, and it corresponds to SR = 150V / µs.

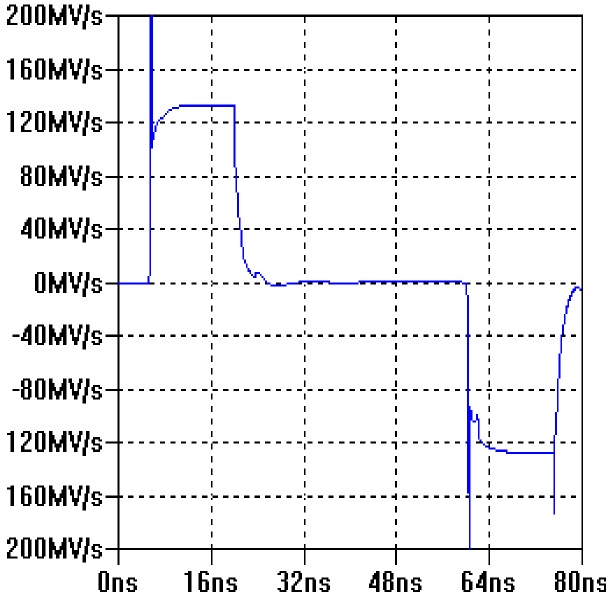

Fig. 6. Slew rate as shown in Fig. 3

Another method of slew rate determination is as follows. To the input of test circuit (Fig. 7), a sinusoidal signal, by increasing the frequency until the output voltage becomes triangular, is given.

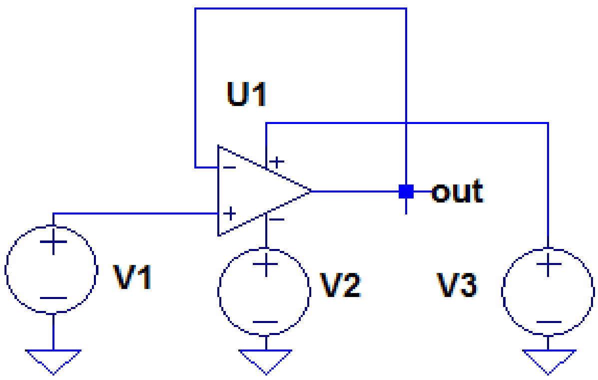

Fig. 7. Test circuit

Slew rate is defined as increase of the output voltage for the appropriate time. From Fig. 8 we obtain SR = 134V / µs.

In all three cases, the values are close to 130V / µs that are corresponding to the datasheet of the simulated operational amplifier LMH6642.

Verification of slew rate of Op amp macro model OP37 by Analog Devices is made according to the proposed methods.

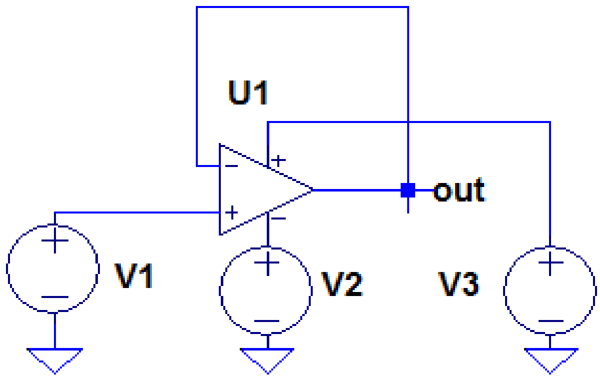

Fig. 8. Simulation results

Fig. 9, 10 and 11 shows the results of test circuit modeling (Fig. 3, 4 and 7).

From the results shown in Fig. 9, 10, one can uniquely determine the slew rate which in the first case is 11V / µs, and in the second case – 15V / µs that are corresponding to the range: 11–17V / µs indicated in the datasheet.

The simulation results shown in Fig. 11 can be explained by the presence of high frequency sinusoidal oscillations of small amplitude superimposed on the impulse output voltage (Fig. 12, 13).

Their presence significantly alters the derivative of Op amp output voltage with respect to time and, respectively, does not allow the slew rate to be determined.

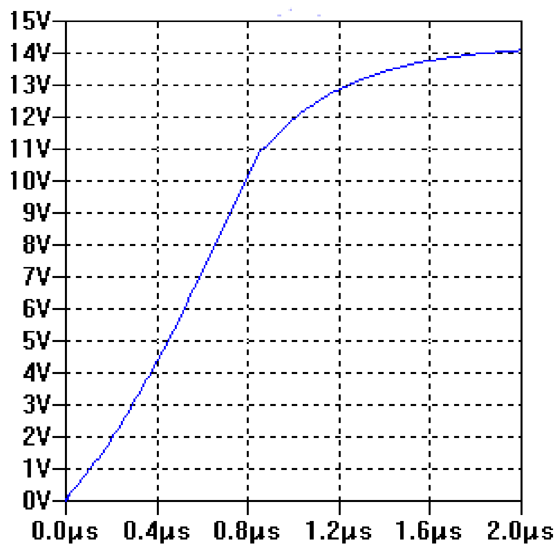

Fig. 9. Simulation results of Op amp OP37 (Fig. 3)

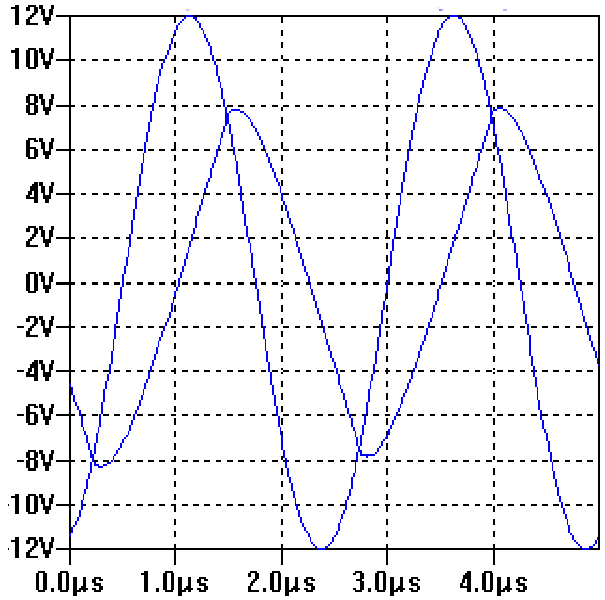

Fig. 10. Simulation results of Op amp OP37 (Fig. 7)

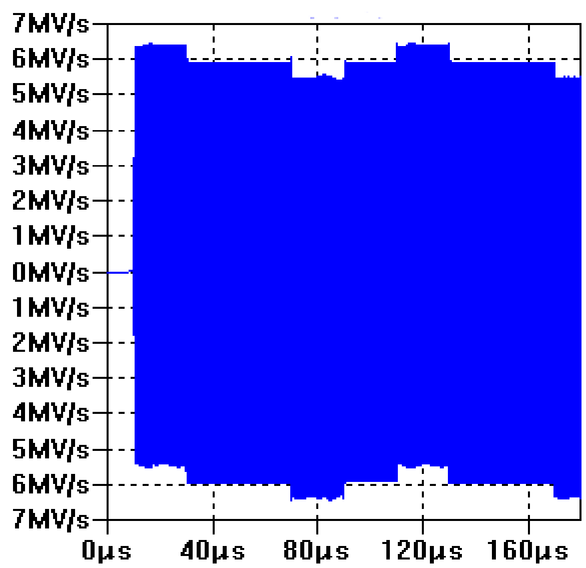

Fig. 11. Simulation results of Op amp OP37 (Fig. 4)

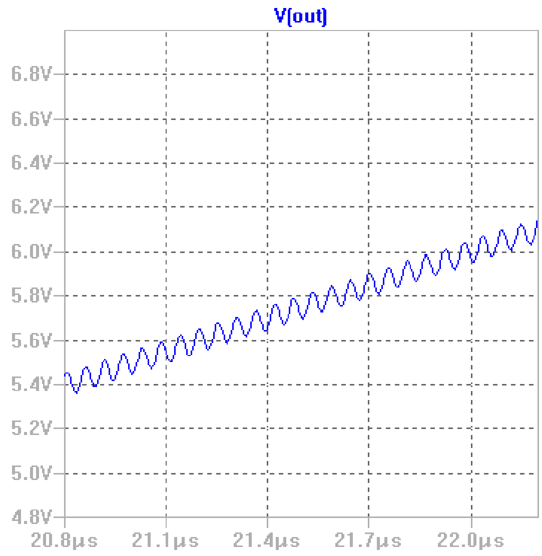

Fig. 12. Simulation results of test circuit (Fig. 4)

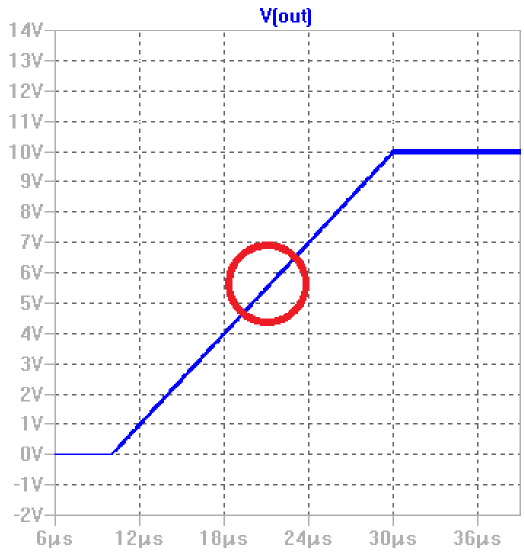

Fig. 13. Simulation results of test circuit (Fig. 4)

V. CONCLUSION

It should be noted that the methods proposed by Texas Instruments to verify the slew rate does not provide a guaranteed result, so for verification of this parameter, it is useful to have several test circuits.

The time and efforts, spent on the verification of macro models and documentation of the verification results, are one-off, and the results, gained from the above, are repeatedly used in daily activities.

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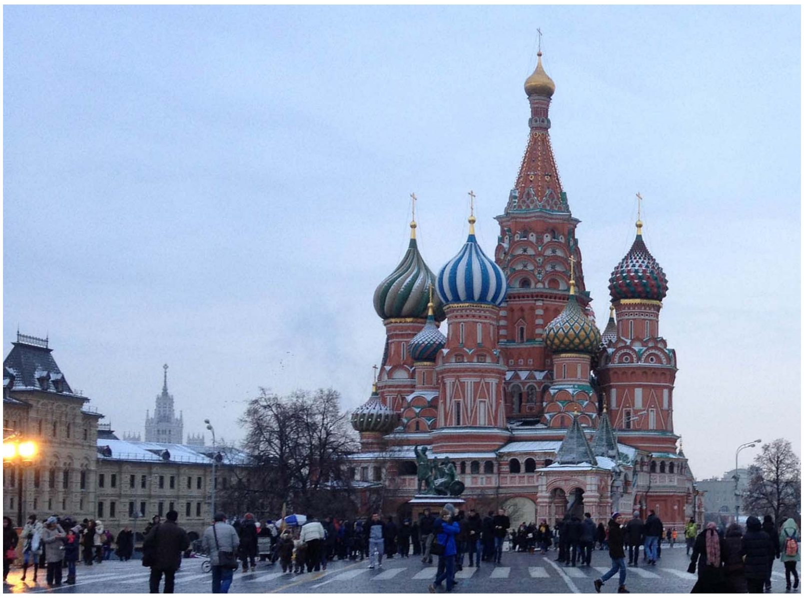

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