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INFLUENCE OF THE INPUT OFFSET VOLTAGE OF DIFFERENTIAL AMPLIFIER IN THE STRUCTURE OF AN INTEGRATING MEASURING STRAIN GAUGE BRIDGE[1]

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Abstract: *offset voltage has a very strong effect on the operation of the measuring strain gauge bridge due to the low voltage values that come from both sides of the strain bridge circuit in case of imbalance. This voltage is inherent and cannot be compensated in any way. in the proposed design of strain gauge converter operational amplifier model OPA134PA is used, which allows additional adjustment of the offset voltage through a trimmer potentiometer. Experiments show the offset voltage influence in the measuring circuit and the need for precise preliminary setting. The obtained results are presented in tables and graphics herein, and corresponding conclusions are made.*

Keywords: *Converter, Measuring, offset voltage, Strain gauge bridge,*

JEL Codes: *L60*

INTRODUCTION

Integrating measuring strain gauges are a special class of devices designed to measure non-electrical values - mechanical force and torque in real time (Stoyanov, S., & Zaharieva S. 2017). They have undoubted advantages, though their settings are more complex and strongly dependent on both the elements used and the circuit design.

Fig. 1 shows a general circuit of an integrating measuring strain gauge (Stoyanov, S., 2014). The circuit consists of an integrator OA1, comparator OA2, differential amplifier OA3 and a measuring bridge. The bridge circuit includes four strain gauges R. The two measuring diagonals are wired toward the inputs of the differential amplifier, and its output is connected to the inverting input of the integrator. The output of the integrator leads to the inverting input of the comparator, whose non-inverting input is connected to the output of the converter through resistor R2. A voltage divider is realized by the resistors R3 and R4, as the middle point of the divider is connected to the non-inverting input of the integrator.

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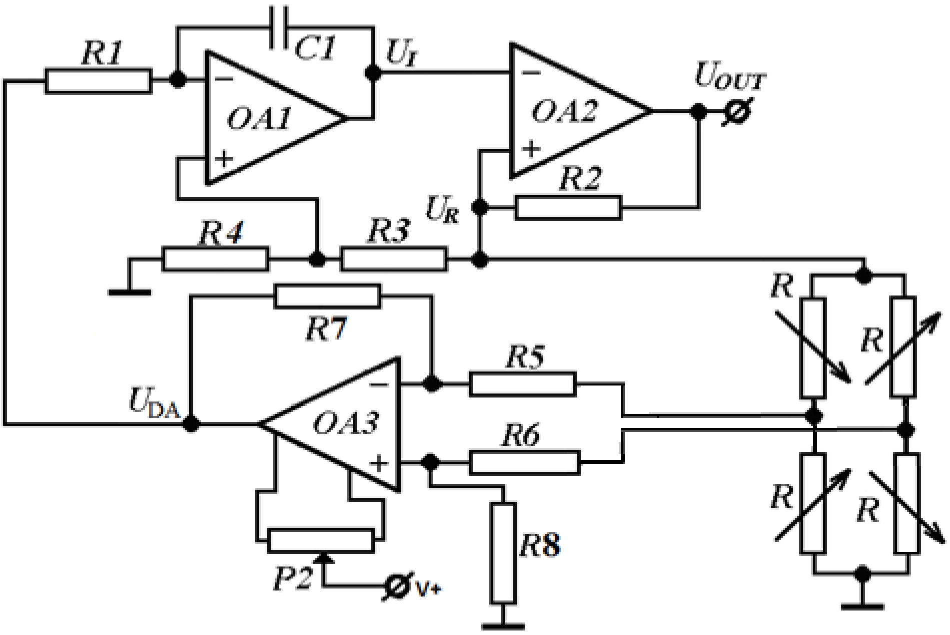


Fig.1. Integrating measuring strain gauge

The offset voltage correction of the differential amplifier is performed by trimmer potentiometer P2. The purpose of the study is to investigate the influence of the offset voltage on the output frequency and the nonlinear behavior of the converter in general.

EXPOSITION

When studying the accuracy of structural blocks and components in measuring devices a metrological analysis has to be performed for the influence of the non-informational parameters of each block. One of the main blocks in the converter is the differential amplifier. Its main purpose is adjustable amplification of the small changes in the resistance of the strain gauges when measuring forces and moments. Taking into account that the relative change in resistance is very small (parts of a percentage), corresponding to low voltages obtained in the two measuring diagonals of the bridge circuit, it can be concluded that it is necessary to study the effect of offset voltage in the converter in general.

In the circuit of fig. 1 the residual voltage e_{01} of the operational amplifier of the differential amplifier is constant in sign and appears in series with the output voltage of the comparator, so it can be represented by an equivalent change in the output voltage of the comparator:

$$U_{out}^{+} + |U_{out}^{-}| = 2U_{out}, \quad U_2^{+} = U_{out} - e_{0d} \quad \text{и} \quad |U_2^{-}| = U_{out} + e_{0d}, \qquad (1)$$

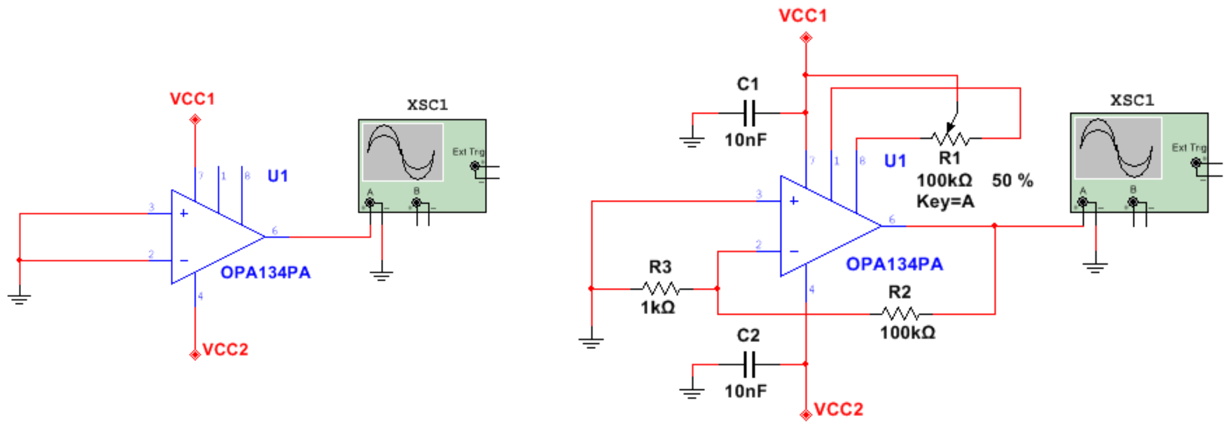
and for the relative multiplicative error δT0d of the initial period caused by e_{0d} similarly we get:

$$\delta f_{0d} = \frac{1 - e_{0d}/U_{out}}{e_{0d}/U_{out}} = \frac{1 - \delta U_{0d}^2}{\delta U_{0d}^2} = \frac{1}{\delta U_{0d}^2} - 1 = \frac{1}{S_{0d}\delta U_{0d}} - 1 = \frac{k_{01}}{\delta U_{0d}} - 1 \qquad (2)$$

where: $S_{0d} = \delta U_{0d} = e_{0d} / U_{out}$ represents the sensitivity of the converter to the non-informative parameter e_{01};

- k_{0d} - coefficient of suppression of the influence of the non-informative parameter e0d (coefficient of invariance of the scheme compared to the non-informative parameter e0d).

To study the influence of residual voltages, the operation of the differential amplifier was modeled in Miltisim. Three schemes for residual stress testing with ORA type OPA134PA have been developed. The results obtained by simulating the operation of scheme 1 are given in table 1, scheme 2 in table 2 and scheme 3 in table 3.



Simulation circuit 1 Simulation circuit 2

Fig. 2. Simulation models (circuit 1 and circuit 2) for offset voltage determination.

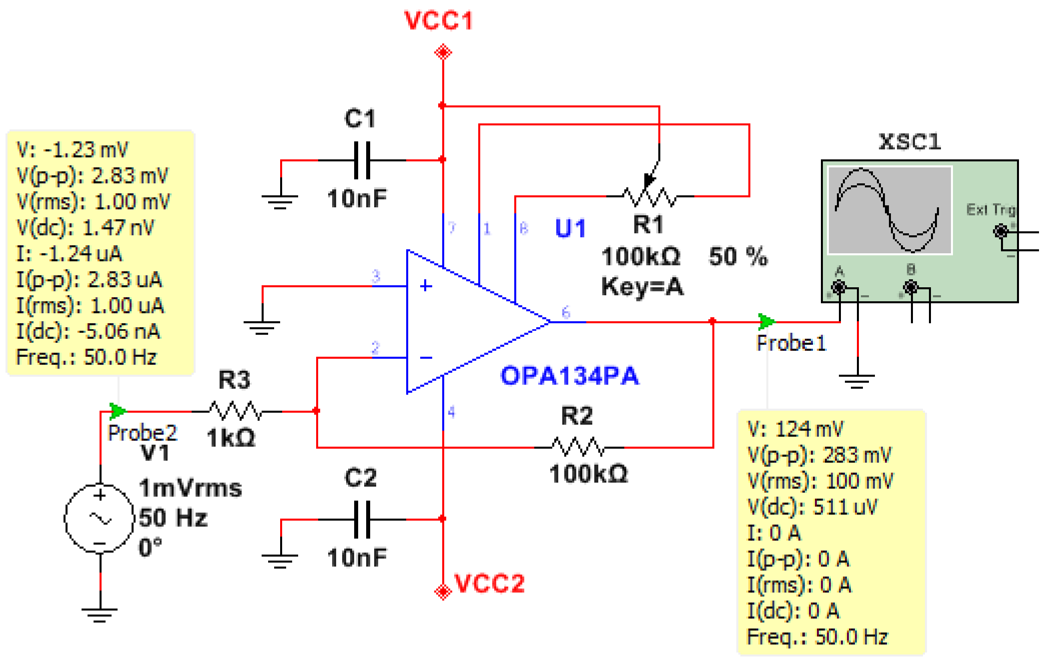


Fig.3. Simulation model (circuit 3) for offset voltage determination.

Table 1. Results for simulation model – circuit 1.

Vcc, [V]	±2.5	±5	±9	±12	±15	±18
Uout, [V]	1.687	4.181	8.168	11.15	14.064	14.173
Δ = Vcc-Uout	±0.813	±0.819	±0.832	±0.85	±0.936	±3.827

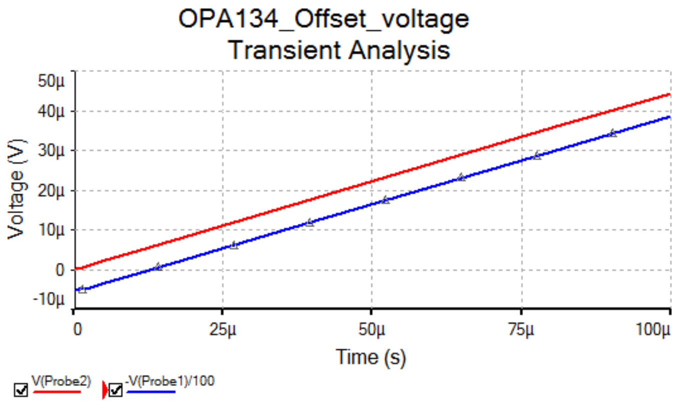
Table 2. Results for simulation model – circuit 2.

Vcc, [V]	±2.5	±5	±9	±12	±15	±18
Uout, [μV]	511.582	511.832	512.232	512.532	512.832	513.132
Vos, [μV]	5.11582	5.11832	5.12232	5.12532	5.12832	5.13132

Table 3. Results for simulation model – circuit 3.

Vcc, [V]	±2.5	±5	±9	±12	±15	±18
Uout(dc), [μV]	511-512	512	512	512-513	513	513
Vos, [μV]	5.11-5.12	5.12	5.12	5.12-5.13	5.13	5.13

The circuit in Fig. 1 shows that the difference Δ is about 1 V at supply voltages up to ± 15 V - Table 1. According to circuit 2 in fig.1 an inverting amplifier with Ku = 100 is realized. The values of the offset voltage are about 5 μV and do not depend on the supply voltage - table 2. Capacitors C1, C2 and potentiometer P1 also have no effect in the simulation. The circuit 3 in Fig. 3 has an inverting amplifier with with Ku = 100 feeded with AC voltage: voltage amplitude is 1 mV with frequency of 50 Hz, applied to the inverting input of OA. The values of the offset voltage are also about 5 μV - Table 3 and do not depend on the supply voltage. Capacitors and potentiometers also have no effect in the simulation investigation.



Start time: 0 s, End time: 0.0001 s
Offset voltage, Input: AC supply U_{rms} = 1 V; Vcc = ±2.5 V

Fig. 4. Transient analysis of circuit 3.

Fig. 4 shows the Transient analysis of circuit 3 comparing the input and output AC voltage of the OA. The ascertained difference is 5 μV, as seen in fig. 4, which confirms the results obtained for circuit 2. Precise simulation results for the offset voltage are obtained from circuit 2.

Looking at the simulation results for OA type OPA134PA it is concluded that the simulation model is imperfect and the present offset voltage cannot be compensated in any way. This voltage leads to an additive error in the measuring converter.

The lowest values of offset voltage have the operational amplifiers OA produced by BJTT technology or FET technology - in contrast to OA MFET technologies. The latter are fast OAs with very small residual currents, but the offset voltage is about 10 times higher.

The experimental study of the offset voltage is performed testing the scheme in Fig.6 and the experimental equipment is shown in Fig. 5. The supply voltage is ± 4V. To exclude the harmful effect of mains voltage ripple (Stoyanov, S., Vasilev, R. & Zaharieva S., 2017) battery power is used. For the comparator and integrator operational amplifier (OA) type LME49720NA is used - 2 units in one housing. The differential amplifier is realized using OA type ORA134PA with the following parameters: Offset Voltage: ± 0.5 ÷ ± 2mV, Input Offset Voltage: ± 1 ÷ ± 3mV at TA = –40 ° C to 85 ° C. All resistors have a tolerance of ± 1% and TCR ± 100ppm. The simulation of the strain gauge measuring bridge is realized with two variable R arms with the help of a sample voltage divider P1 with accuracy class 0,1. The capacitor C1 is polystyrene with a tolerance of ± 5%. The adjustment of the residual voltage is performed with the trimer potentiometer P2.

Fig.5. Experimental testing equipment.

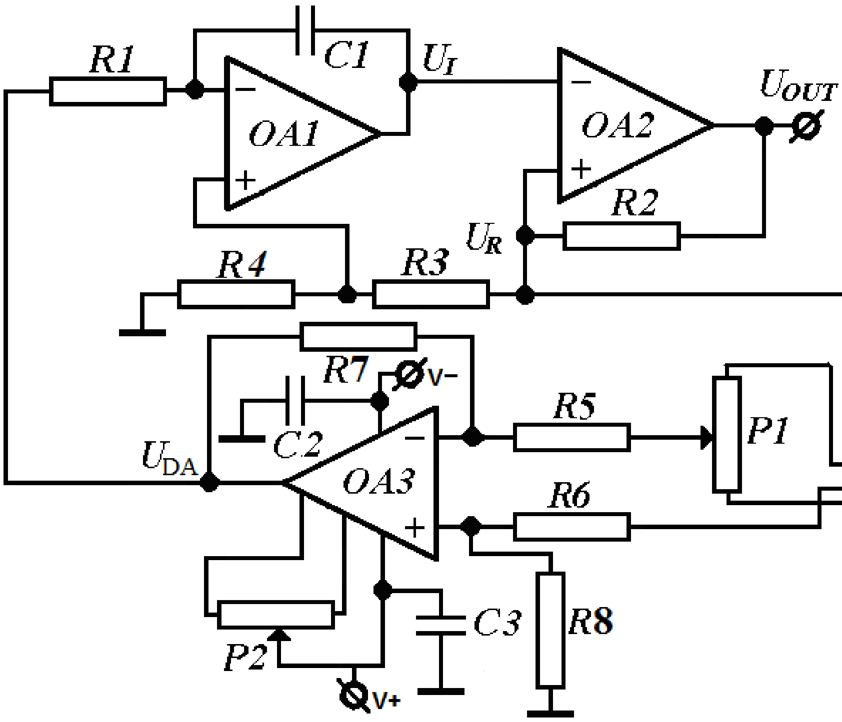


Fig.6. Operating circuit of an integrating measuring strain gauge.

The obtained results are given in table 4 and table 5. Table 4 shows the values of the output frequency obtained at different values of the residual voltage and positive and negative imbalance of the strain gauge bridge.

Table.4. Obtained experimental results.

DR [Ω]	*f_{out}, [Hz] npu Uio= [mV]*					
	0	10	20	30	40	50
0,5	2011	2009	2001	1991	1986	1975
0,4	1911	1906	1902	1886	1883	1873
0,3	1812	1799	1801	1784	1779	1770
0,2	1714	1698	1706	1694	1689	1675
0,1	1614	1593	1615	1585	1576	1562
0	1515	1489	1517	1482	1473	1467
-0,1	1416	1390	1408	1376	1371	1363
-0,2	1318	1281	1297	1275	1272	1264
-0,3	1219	1179	1193	1172	1171	1162
-0,4	1119	1079	1088	1071	1068	1060
-0,5	1009	991	1002	978	970	963

Based on the obtained experimental results, the reduced nonlinearity error γout is calculated (Gigov, Hr., 2013), (Stoyanov, S., 2016). The maximum value of the reduced error in the experimental part was determined, which is 0.21956% at zero values of the residual voltage. At residual voltage values of 10mV, the maximum reduced error of nonlinearity is about 0.5%, and at a residual voltage of 20-50mV - about 1%.

Table. 5. Calculated non-linearity normalized error.

DR [Ω]	*f_{out}, [Hz] при Uio= [mV]*					
	0	10	20	30	40	50
0,5	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
0,4	0,01996	-0,11788	0,09009	-0,36525	-0,1378	-0,07905
0,3	0,11976	-0,51081	-0,11011	-0,0691	-0,23622	-0,17787
0,2	0,21956	0,078585	0,49049	1,115499	1,141732	0,612648
0,1	0,01996	-0,31434	0,890891	-0,76012	-1,12205	-1,16601
0	0,11976	-0,21611	0,19019	-0,16782	-0,1378	0,612648
-0,1	0,11976	0,275049	-0,91091	-0,46397	-0,03937	-0,27668
-0,2	0,21956	-0,70727	-1,11111	0,029615	0,255906	0,217391
-0,3	0,11976	-0,01965	-0,41041	-0,16782	0,059055	-0,07905
-0,4	0,01996	0,176817	-0,51051	0,029615	-0,1378	-0,07905
-0,5	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000

CONCLUSION

The influence of the offset voltages of the integrating converter designed for measuring mechanical forces and torques in real time has been studied by means of simulation and experimental testing. In the investigated measuring device the offset voltage mainly affects the additive error. Reduced nonlinearity error is calculated when the converter operates with different offset voltages. The obtained results show that it is necessary to carefully adjust the scheme, otherwise the nonlinearity increases about five times.

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