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Simulation Of Quantization Error By The Rounding Level Of Input Samples.

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ABSTRACT

The article presents the results of modeling the quantization error depending on the rounding level of the input calculations. For the model we are considering, quantization noise is the input noise. As a result, the statistical characteristics of the input noise depending on the level of their rounding were obtained.
Keywords: quantization error, input noise, quantization intervals.

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INTRODUCTION

Measurements are always accompanied by a level quantization operation. The essence of this operation is reduced to rounding the value of the measured value to any value of the model value. This leads to the appearance of a specific error - the level of quantization noise [1, 2].

In the study of the measuring algorithm (1) of determining the time constant as the main informative parameter when measuring electrical capacitance at a constant current, for discrete action systems, the assessment of the effect of a quantization operation on a level on a measurement result is also an important task for this work [3, 4].

$$\tilde{\tau} = \frac{2\Delta t \cdot (E_0 - u(t_1))}{-u(t_3) + 4u(t_2) - 3u(t_1)}, \quad (1)$$

where: E_0 – EMF voltage source;

$\tilde{\tau}$ - estimation of the time constant of measuring circuits (MC);

$u(t_1)$, $u(t_2)$, $u(t_3)$ - values of voltage function samples at time t_1, t_2, t_3 respectively during the transition process.

Quantization error is introduced by rounding the value of the measured value to the value of the model value and depends on these two values.

The value of the measured value *x* can be rounded off:

1) To the lower limit of the quantization interval and is in the range

$$[-q; 0];\ x \in [-q; 0].$$
$$kq - q \le x \le 0, \quad (2)$$

where:

k – quantization interval number;

q – level quantization step.

2) To the upper limit of the quantization interval and is in the range

$$[0;+q];\ x \in [0;+q].$$
$$0 \le x \le kq + q. \quad (3)$$

3) To the midpoint of the quantization interval and is in the range

$$[-q/2;+q/2];\ x \in [-q/2;+q/2].$$
$$kq - 0{,}5q \le x \le kq + 0{,}5q. \quad (4)$$

In all these cases, the absolute quantization error (quantization noise) is defined as:

$$\Delta q = kq - x, \quad (5)$$

and is a periodic function [1].

RESULTS AND DISCUSSION

For the model we are considering, quantization noise is the input noise.

In mathematical modeling of the system, one more parameter is used - the relative quantum q / E_0 in terms of level (quantization step). The parameter was set in the range from 10^{-4} to 10^{-12}. The quality of rounding (quantization) is estimated using the standard deviation function available in Microsoft Excel for a period equal to the time constant of the measuring circuit $\tilde{\tau}$.

The simulation of the quantization procedure is performed using the built-in functions of the Microsoft Excel spreadsheet processor:

- **rounding up** (number; number of digits) - rounding to the nearest larger one;
- **rounding down** (number; accuracy) - rounding to the nearest integer in modulus.

Quantization at the midpoint of the quantization interval is defined as the average of rounding up and rounding down.

The change in the absolute error of rounding off the input samples as a function of the simulation time of the transient process of the measuring signal processing system of a capacitive transducer is shown in Figure 1.

The change in the relative error of quantization at $q / E_0 = 10^{-5}$ depending on the time of the simulation of the transition process is shown in Figure 2.

The normalized autocorrelation function of the absolute error of the input samples for $q / E_0 = 10^{-5}$ is shown in Figure 3.

The correlation time (NACF time at R (0) / 10) does not exceed the sampling time *transients* $\Delta t_{disk}=0{,}001$.

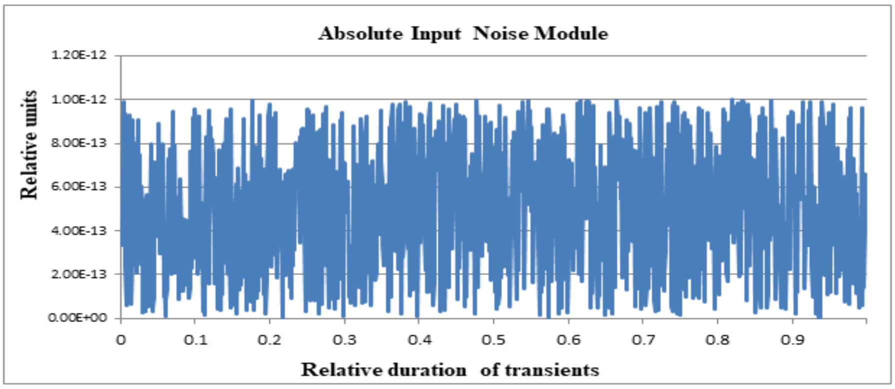

Figure 1: The change in the absolute error of rounding off the input samples - absolute noise

The analyzed random process (absolute quantization error) corresponds to white noise, for which the "memory of the past" is completely absent.

The absolute quantization error is uniformly distributed in the range from 0 to - q with the minimum value d = - 1.98 · 10^{-8}, the maximum b = - 9.99 10^{-6}, and the average ρ = -5.1 10^{-6}.

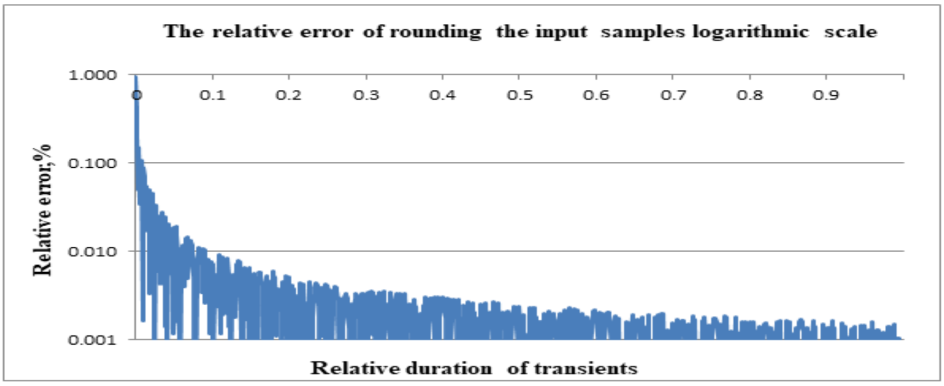

Figure 2: The change in relative error depending on the duration of the transition process

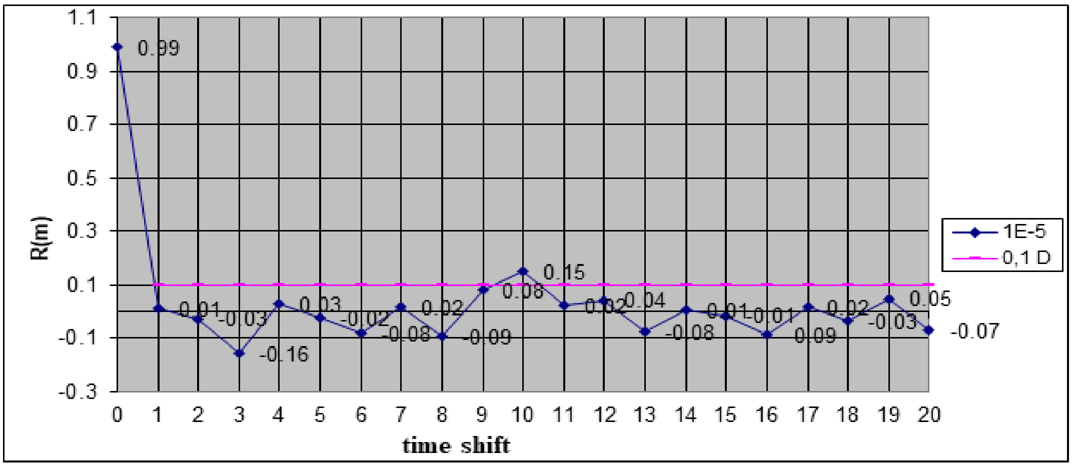

Figure 3: Normalized autocorrelation function of the absolute error of the input samples

The standard deviation of the absolute quantization error is σ = 2,87·10^{-6}. Theoretical values ***σ*** for uniform distribution [3] is equal to:

σ(Δ) = d – b/2√3 = 2,88·10^{-6}, (6)

and is - 0.1% of the calculated.

CONCLUSION

The statistical characteristics of the input noise depending on the rounding level of the input samples are presented in Table 1.

Table 1: Statistical characteristics of input noise depending on the rounding level of input samples

Entry noise	Relative rounding rate:								
	1·10^{-12}	1·10^{-11}	1·10^{-10}	1·10^{-9}	1·10^{-8}	1·10^{-7}	1·10^{-6}	1·10^{-5}	1·10^{-4}
Average noise, %	4,23·10^{-10}	4,2·10^{-9}	4,1·10^{-8}	3,7·10^{-7}	3,2·10^{-6}	2,9·10^{-5}	3,5·10^{-4}	4,7·10^{-3}	5,1·10^{-2}
Standard deviation, %	2,45·10^{-9}	2,4·10^{-8}	2,5·10^{-7}	1,4·10^{-6}	8,9·10^{-6}	7,3·10^{-5}	1,8·10^{-3}	3,4·10^{-2}	3,8·10^{-1}

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