ELECTRONICS

UDC 621.317.7 (045)
DOI:10.18372/1990-5548.63.14525

I. Yu. Sergeyev

ADAPTIVE HIGH SPEED MEASURING CONVERTER OF AVERAGE VOLTAGE VALUES

Department of Aviation Computer-Integrated Complexes, National Aviation University, Kyiv, Ukraine
E-mail: sergeyevi@i.ua

***Abstract*—*The analysis of the measuring converter of average value voltage using the iteratively integrating method of conversion and its comparison with the analysis the generalized block diagram of the iteratively integrating measuring converter were performed. As a result of comparing the circuit of the measuring converter of average voltage values, which implements the iteratively integrating conversion method, with the generalized structural diagram of the iteratively integrating measuring transducer, the basic equations describing this device are obtained. As a result of the analysis of the generalized structural diagram of the iteratively integrating measuring transducer, an engineering solution is proposed that improves the parameters of the measuring converter of average voltage values by adapting it to the influence of changes in the input voltage frequency. This allows us to improve the dynamic characteristics of the converter of average voltage values when the input voltage frequency changes, which is directly related to the increase in the speed of the converter in the given frequency range of the input voltage or, which is equivalent in this case, to the extension of the frequency range of the input voltage, while maintaining the specified performance. It is proposed to adapt the considered converter of average voltage values to a change in the frequency of the input voltage periodically with a predetermined one, based on a priori information about the nature of the frequency change, periodically or occasionally, as the frequency changes.*

Index Terms—Measuring converter; generalized structural diagram; measuring converter of average voltage values; iterative integrating conversion method; iteratively correction of errors; dynamic characteristics.

I. INTRODUCTION

This article continues the series of publications by the author, united by the common theme of the analysis of the generalized structural diagram of the iteratively integrating measuring converter. It is devoted to the application of the results of an earlier analysis of the above generalized scheme for an engineering solution to create a specific embodiment of measuring converter using the iteratively integrating method of conversion, in particular, to the improvement of measuring converter of average value voltage.

Measuring converter of average value voltage using the iteratively integrating method of conversion [1] – [10] are widely used in measurement technology due to their high metrological characteristics, in particular, high fast action with a fairly high conversion accuracy. However, this advantage is realized in a relatively narrow frequency range of the input voltage or current, since its change leads to a change in the speed of the iterative process of correction of the measuring converter error (transient process of establishing the output voltage). As a result, at certain values of the frequency (at the edges of the range of its change), the condition for convergence of the correction process is violated.

II. PROBLEM STATEMENT

In Figure 1 shows example of functional circuits of the measuring converter of average value voltage using the iteratively integrating method of conversion.

The iteratively integrating conversion method implemented in these devices involves cyclic operation and the establishment of the output voltage (directly associated with iterative additive error correction), described by a geometric progression. Such a process is associated with such a concept as process convergence. An important indicator of convergence in this case is the denominator of geometric progression.

The condition for convergence of the error correction process is the inequality $|Q| < 1$, where Q is the denominator of geometric progression that describes the process of correction of the error of the transducer. $Q = 1 - K_{SH} K_{BA} / fR2C$, where K_{SH} and K_{BA} are the transfer coefficients of the corresponding blocks, f is the frequency of the input signal [1], [6] and [7].

The maximum speed (i.e., in the case when the transient process of setting the output voltage of the measuring converter after changing the frequency f ends in one cycle of the error correction process) corresponds to the equality $Q = 0$.

©National Aviation University, 2020
http://jrnl.nau.edu.ua/index.php/ESU, http://ecs.in.ua

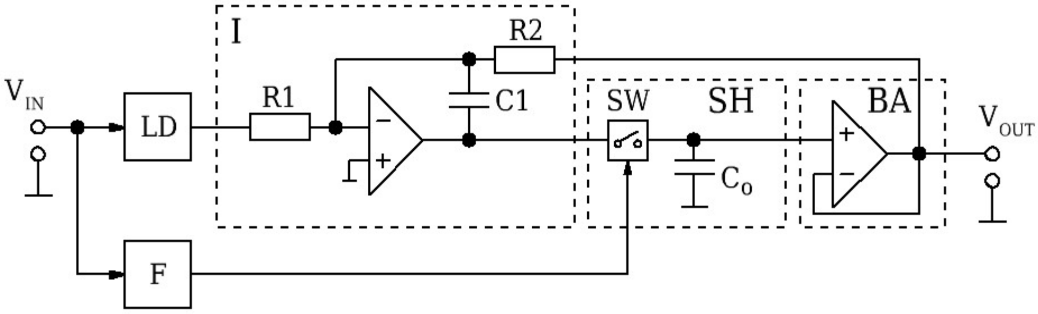

Fig. 1. Examples of measuring converters of average voltage value using the iteratively integrating method of conversion

It follows that if the maximum speed is achieved at a frequency $f = f_H$, then the boundary frequency values corresponding to the boundaries of the convergence range of the error correction process can be determined from the conditions of convergence by substituting the boundary values Q: +1 and –1, i.e. $f_{min} = f_H / 2$ and $f_{max} = \infty$.

However, we are most often interested in not the frequency range of the input signal corresponding to the convergence region of the conversion error correction process, but the values of the frequencies within which the specified speed of the measuring converter is stored.

For this, we can use the expression given by the author in [1], relating the boundary values of the frequencies f_1 and f_2 with a given number of cycles n of the error correction process, with the error of the nth cycle of the error correction process γ_n, with the initial and final, respectively, values U_0 and U_∞ of the output voltage of the measuring converter

$$f_{1,2} = \frac{m_2 K_{SH} K_F}{R2C\left(1 \pm \sqrt[n]{\left|\frac{\gamma_n U_\infty}{\Delta U}\right|}\right)}, \quad (1)$$

where $\Delta U = U_\infty - U_0$, m_2 is the coefficient of the multiplicity of the sampling period and the input voltage period.

We use the results of the analysis of the generalized block diagram of an iteratively integrating transducer, carried out by the author in [1], [6], [8]–[10].

Compare the circuit of the converter of average voltage values shown in Fig. 1, with a generalized structural diagram of an iteratively integrating measuring converter, considered in the above-mentioned works of the author.

Here, the block LD and the resistor $R1$ act as a block C_X; $R2$ serves as the reverse converter BC; an operational amplifier with capacitor $C1$ in integrator I (the circuit in Fig. 1) serves as an integrator I of a generalized block diagram; SH sample-storage unit (key SW with capacitor C_0) in fig. block I fulfills the role of a similar block SH in the generalized block diagram; the voltage follower BA serves as the block C_2 of the generalized block diagram.

By comparing the circuit of converters of average voltage values and the generalized structural diagram of an iteratively integrating measuring converter, equations can be written to determine the error γ_n, the number of cycles n for given γ_n, initial U_0 and steady-state U_∞ output voltages and denominator Q of geometric progression, which describes the process of correction of the measuring converter error.

The corresponding formulas for converter of average voltage values is shown in Fig. 1 are tabulated where $\Delta U = U_\infty - U_0$; the square brackets in the expressions for determining the value of n mean that the whole part of the value defined by the expression in square brackets is taken. From the condition of maximum speed, we can determine the corresponding frequency value f_H.

The expressions given in the Table I allow us to study the changes in the dynamic properties of the converter of average voltage values when the frequency of the input voltage changes. The limiting value of the denominator of the geometric progression corresponding to the given values of the error γ_n, the steady-state voltage U_∞ and the voltage increment ΔU is determined by the inequality for finding $|Q_{1,2}|$. The number of error correction cycles corresponding to the boundary values of the frequency $f_{1,2}$ at given error values γ_n, steady-state voltage U_∞ and voltage increment ΔU is determined by the expression for finding $n_{1,2}$. If the changes in the frequency $\pm \Delta f$ relative to the nominal value of f_H are sufficiently small, then, taking into account the inequality $1 - f_H / f = 1 - f_H / (f_H \pm \Delta f) \cong \mp \Delta f / f_H$, the corresponding expressions are converted, respectively, to a more convenient form.

TABLE I. MEASURING CONVERTER OF AVERAGE VOLTAGE VALUE

$$\gamma_n = \frac{Y_n - Y_\infty}{Y_\infty} = -\frac{\Delta Y Q^n}{Y_\infty}$$

$$n = \left[\frac{\ln\left|\frac{\gamma_n Y_\infty}{\Delta Y}\right|}{\ln|Q|} \right] + 1$$

$$Q = 1 - \frac{K_{SH} K_{BA}}{R2C} = 1 - \frac{f_H}{f} \approx \frac{\Delta f}{f}$$

$$f_H = \frac{K_{SH} K_{BA}}{R2C}$$

$$|Q_{1,2}| = |1 - \frac{f_H}{f_{1,2}}| \le \sqrt[n]{|\frac{\gamma_n U_\infty}{\Delta U}|}$$

$$\gamma_n = -\frac{\Delta U}{U_\infty}\left(1 - \frac{f_H}{f_{1,2}}\right)^n \approx -\frac{\Delta U}{U_\infty}\left(\frac{\Delta f}{f_H}\right)^n$$

$$n_{1,2} = \left[\frac{\ln\left|\frac{\gamma_n U_\infty}{\Delta U}\right|}{\ln\left|1 - \frac{f_H}{f_{1,2}}\right|} \right] + 1$$

$$n = \left[\frac{\ln\left|\frac{\gamma_n U_\infty}{U}\right|}{\ln\left|1 - \frac{f_H}{f_{1,2}}\right|} \right] + 1 \approx \left[\frac{\ln\left|\frac{\gamma_n U_\infty}{U}\right|}{\ln\left|\frac{\Delta f}{f}\right|} \right]$$

III. SOLUTION OF THE PROBLEM

Let us consider the possibilities of improving the considered converter of average voltage values, in particular, improving the dynamic properties of the converter of average voltage values when the frequency of the input voltage changes.

Such an improvement in dynamic properties is directly related to an increase in the speed of this converter in a given frequency range of the input voltage, or, which in this case is equivalent, to an extension of the frequency range of the input voltage, while maintaining a given conversion speed.

This can be done by adapting the converter of average voltage values to changing the frequency of the input voltage in the ways determined by the analysis of the generalized structural diagram of an iteratively integrating measuring converter, carried out by the author in the works mentioned above.

The most preferred solution in this case is the effect on the transmission coefficients of the converter blocks, as a result of which the boundaries of the frequency range defined by expression (1) can be significantly expanded.

The implementation of such an adaptation of the considered converter of average voltage values to a change in the frequency of the input voltage is possible by affecting the transmission coefficients of the blocks included in its composition.

In this case, this can be done either by changing the resistance of the resistor *R*2 or the capacitance of the capacitor C1 inversely proportional to the change in the frequency of the input voltage, or by changing the transmission coefficients of an additional unit, for example, a scaled voltage converter, at any point in the chain, consisting of a sampling-storage unit SH and a voltage follower BA. It is most convenient to connect this scaled voltage converter to the output of the voltage follower BA.

It is advisable to periodically adapt the converter of the average voltage values when change the frequency of the input voltage periodically with the set period , on the basis of a priori information about the nature of the frequency change, or episodically, as the frequency changes.

Since in the process of adaptation a step change of the above values is made, then to solve the question of what quantity and at what time (within the correction error cycle of the converter) to change, you can use the results of the analysis performed by the author in [1], [10] of the generalized block diagram of the iteratively integrating measuring converter for the case of a sudden change in the multiplicative errors of the blocks included in the measuring converter. At the same time, a forced change in the transfer coefficients of the blocks must be considered as a change in their multiplicative errors.

It should be noted that if adaptation is carried out by changing the resistance of the resistor *R*2 or the transmission coefficient of an additional scale voltage converter included in the conversion circuit before the integrator, and the moment of changing its transmission coefficient within the conversion cycle is located before or after the pulses, controlling the closure of the corresponding keys, then a surge in the output voltage of the converter will not be observed. In any other embodiment, adaptation by changing the transfer coefficient of any of the blocks will result in a surge in the output voltage of the converter (i.e., converter error that will be corrected in subsequent conversion cycles).

An example of the implementation of the adaptation described above is the converter of average voltage values proposed by the author in [11] and shown in Fig. 2.

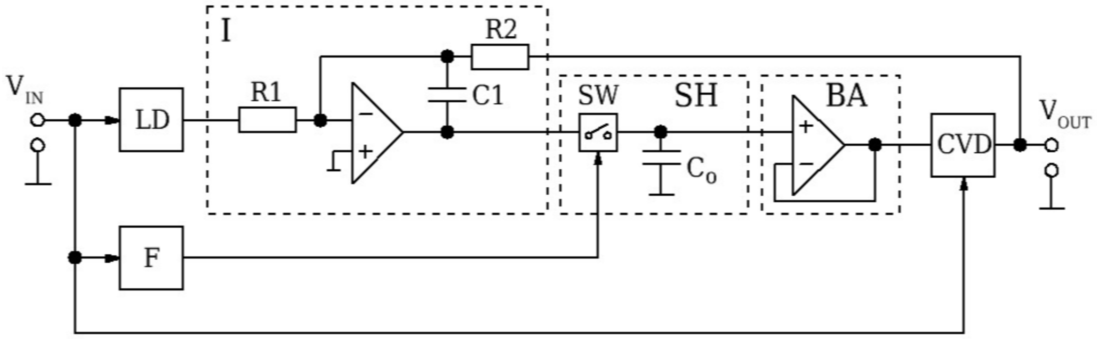

Fig. 2. Converter of average voltage values with adaptation to changing the frequency of the input voltage

IV. CONCLUSION

From the analysis of the voltage average converter using the iteratively integrating method of conversion and its comparison with the analysis the generalized block diagram of the iteratively integrating converter, we can draw the following conclusions.

1) As a result of comparing the circuit of the converter of average voltage values, which implements the iteratively integrating conversion method, with the generalized structural diagram of the iteratively integrating measuring transducer, the basic equations describing this device are obtained.

2) As a result of the analysis of the generalized structural diagram of the iteratively integrating measuring converter, an engineering solution is proposed that improves the parameters of the converter of average voltage values by adapting it to the influence of changes in the input voltage frequency. This allows us to improve the dynamic characteristics of the converter of average voltage values when the input voltage frequency changes, which is directly related to the increase in the speed of the converter in the given frequency range of the input voltage or, which is equivalent in this case, to the extension of the frequency range of the input voltage, while maintaining the specified performance.

3) It is proposed to adapt the considered converter of average voltage values to a change in the frequency of the input voltage periodically with a predetermined one, based on a priori information about the nature of the frequency change, periodically or occasionally, as the frequency changes.

REFERENCES

[1] I. Sergeyev, *“Research and Development of Integrating Measurement Converters with the Iterative Additive Correction of Errors,”* Ph. D. (Engineering) Thesis, Kyiv Politechnical Institute, Kyiv, Ukraine, 1978. (in Russian).

[2] Yu. Tuz, and I. Sergeyev, "An iterative converter of time interval to the voltage," *Measurement Equipment*, no. 7, pp. 15–17, 1976. (in Russian).

[3] Yu. Tuz, *Structural Methodsof Impruving Accuracy of Measuring Devices, manual*, Kyiv, Vyshcha Shkola, 1976. (in Russian).

[4] V. Gubar, I. Sergeyev, and V. Fediv, USSR Patent 661,525, G 06 G, 7/26, 05.05.79. bull. 17 (in Russian).

[5] I. Sergeyev, "Analysis of the Potentiation Digital-to-Analog Converter Without Accounting of Imperfection its Blocks," *Electronics and Control Systems*, no. 4(46), Kyiv: NAU, pp. 52–57, 2015. https://doi.org/10.18372/1990-5548.46.9964

[6] I. Sergeyev. "Structural Scheme of the Measurement Converter which Uses an Iteratively Integrating Conversion Method," *IEEE: 2016 4nd International Conference*. October 18–20, 2016: abstracts. Kyiv, 2016, pp. 210–213.
https://doi.org/10.1109/MSNMC.2016.7783144

[7] I. Sergeyev, *Measurement Converter which Uses an Iterative-Integrating Conversion Method*, XIII Int. Conf. AVIA-2017, 19–21 April 2017: Kyiv, 2017, pp. 3.18–3.23.

[8] I. Sergeyev. "Analysis of the Generalized Structural Scheme of the Iterative-Integrating Measuring Convertor," *Electronics and Control Systems*, no. 2(52), Kyiv: NAU, pp. 52–57, 2017. https://doi.org/10.18372/1990-5548.52.11868

[9] I. Sergeyev. "On the Question of Analyzing of the Interative-Integrating Measuring Converter," *IEEE: 2017 4nd International Conference (APUAVD)*, October 17–19, 2017: abstracts, Kyiv, 2017, pp. 259–261. https://doi.org/10.1109/APUAVD.2017.8308824

[10] I. Sergeyev. "Analysis of Errors of the Measuring Converter Which Results from an Abrupt Change of Additive Errors of its Blocks,". VIII Int. Conf. AVIA-2018, 10–12 October, 2018. Kyiv, vol. 1, 2018, pp. 23.13–23.19.

[11] Yu. Tuz, I. Sergeyev, USSR Patent 603,912, G 06 G, 7/26, 05.05.78. bull. 15 (in Russian).

Received January 21, 2020.

Sergeyev Igor. Candidate of Science (Engineering). Associate Professor.
Aviation Computer-Integrated Complexes Department, National Aviation University, Kyiv, Ukraine.
Education: National Technical University "KPI", Kyiv, Ukraine, (1973).
Research interests: automation of technological processors, measurement transducers.
Publications: 210.
E-mail: sergeyevi@i.ua

І. Ю. Сергєєв. Адаптивний високошвидкісний перетворювач середнього значення напруги
Проведено аналіз перетворювача середнього значення напруги, що використовує метод ітеративно-інтегруючого перетворення та його порівняння з аналізом узагальненої структурної схеми ітеративно-інтегруючого перетворювача. В результаті порівняння схеми перетворювача середніх значень напруги, в якій реалізований метод ітеративно-інтегруючого перетворення, з узагальненої структурної схемою итеративно-інтегруючого вимірювального перетворювача, отримані основні рівняння, що описують цей пристрій. В результаті аналізу узагальненої структурної схеми ітеративно-інтегруючого вимірювального перетворювача запропоновано технічне рішення, що покращує параметри перетворювача середніх значень напруги шляхом адаптації його до впливу змін частоти вхідної напруги. Це дозволяє поліпшити динамічні характеристики перетворювача середніх значень напруги при зміні частоти вхідної напруги, що безпосередньо пов'язано зі збільшенням швидкості перетворення в заданому діапазоні частот вхідної напруги або, що еквівалентно в цьому випадку, відбувається розширення діапазону частот вхідної напруги при збереженні заданої швидкодії. Пропонується адаптувати розглянутий перетворювач середніх значень напруги до зміни частоти вхідної напруги періодично з наперед заданим значенням періоду на основі апріорної інформації про характер зміни частоти, або епізодично в разі зміні частоти.
Ключові слова: вимірювальний перетворювач; узагальнена структурна схема; перетворювач середніх значень напруги; метод ітеративно-інтегруючого перетворення; ітеративна корекція похибок; динамічні характеристики.

Сергєєв Ігор Юрійович. Кандидат технічних наук. Доцент.
Кафедра авіаційних комп'ютерно-інтегрованих комплексів, Національний авіаційний університет, Київ, Україна.
Освіта: Національний технічний університет України «КПІ», Київ, Україна (1973).
Напрямок наукової діяльності: автоматизація технологічних процесів, вимірювальні перетворювачі
Кількість публікацій: 210.
E-mail: sergeyevi@i.ua

И. Ю. Сергеев. Адаптивный высокоскоростной преобразователь среднего значения напряжения
Проведен анализ преобразователя среднего значения напряжения использующего метод итеративно-интегрирующего преобразования и его сравнение с анализом обобщенной структурной схемы итеративно-интегрирующего преобразователя. В результате сравнения схемы преобразователя средних значений напряжения, в которой реализован метод итеративно-интегрирующего преобразования, с обобщенной структурной схемой итеративно-интегрирующего измерительного преобразователя, получены основные уравнения, описывающие это устройство. В результате анализа обобщенной структурной схемы итеративно-интегрирующего измерительного преобразователя предложено техническое решение, улучшающее параметры преобразователя средних значений напряжения путем адаптации его к влиянию изменений частоты входного напряжения. Это позволяет улучшить динамические характеристики преобразователя средних значений напряжения при изменении частоты входного напряжения, что напрямую связано с увеличением скорости преобразования в заданном диапазоне частот входного напряжения или, что эквивалентно, в этом случае происходит расширение диапазона частот входного напряжения при сохранении заданного быстродействия. Предлагается адаптировать рассматриваемый преобразователь средних значений напряжения к изменению частоты входного напряжения периодически с заранее заданным значением периода на основе априорной информации о характере изменения частоты, или эпизодически в случае изменении частоты.
Ключевые слова: измерительный преобразователь; обобщенная структурная схема; преобразователь средних значений напряжения; метод итеративно-интегрирующего преобразования; итеративная коррекция погрешностей; динамические характеристики.

Сергеев Игорь Юрьевич. Кандидат технических наук. Доцент.
Кафедра авиационных компьютерно-интегрированных комплексов, Национальный авиационный университет, Киев, Украина.
Образование: Национальный технический университет Украины «КПИ», Киев, Украина, (1973).
Направление научной деятельности: автоматизация технологических процессов, измерительные преобразователи.
Количество публикаций: 210.
E-mail: sergeyevi@i.ua