Lecture Notes in Networks and Systems 447

Xin-She Yang
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Amit Joshi *Editors*

Proceedings of Seventh International Congress on Information and Communication Technology

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Lecture Notes in Networks and Systems

Volume 447

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Preface

The Seventh International Congress on Information and Communication Technology will be held during 21–24 February 2022 in a hybrid mode and organised by Global Knowledge Research Foundation. The associated partners were Springer and InterYIT IFIP, Activate Learning, City of Oxford College, UK. The conference will provide a useful and wide platform both for display of the latest research and for exchange of research results and thoughts. The participants of the conference will be from almost every part of the world, with backgrounds of either academia or industry, allowing a real multinational multicultural exchange of experiences and ideas.

A great pool of more than 1100 papers were received for this conference from across 95 countries among which around 300 papers were accepted and will be presented through digital platforms during the two days. Due to the overwhelming response, we had to drop many papers in the hierarchy of the quality. Total 42 technical sessions will be organised in parallel in 4 days along with a few keynotes and panel discussions in hybrid mode. The conference will be involved in deep discussion and issues which will be intended to solve at global levels. New technologies will be proposed, experiences will be shared, and future solutions for design infrastructure for ICT will also be discussed. The final papers will be published in four volumes of proceedings by Springer LNNS Series.

Over the years. this congress has been organised and conceptualised with collective efforts of a large number of individuals. I would like to thank each of the committee members and the reviewers for their excellent work in reviewing the papers. Grateful acknowledgements are extended to the team of Global Knowledge Research Foundation for their valuable efforts and support.

I look forward to welcoming you to the 7th Edition of this ICICT Congress 2022.

Amit Joshi, Ph.D.
Organising Secretary, ICICT 2022
Director—Global Knowledge Research Foundation
Ahmedabad, India

Contents

Accuracy of Potentiometric Methods for Measuring Ion Activity in Solutions

O. M. Vasilevskyi, V. M. Sevastianov, K. V. Ovchynnykov, V. M. Didych, and S. A. Burlaka

Abstract Structural realizations of the digital ion selective transducers, constructed on different rutotom principles are proposed: ADC of the successive approximation, time-pulse conversion and voltage to frequency conversion. Corresponding conversion equations are obtained, their static characteristics are constructed, measurements errors, emerging as a result of using one or another construction principles are investigated. As a result of the research, it was found that in order to improve the measurement accuracy, it is advisable to introduce an additional measuring temperature channel. To ensure high accuracy of ion activity measurement in the lower measurement range of 0.3 pX and to take into account the temperature deviation by 1 degree Celsius, it is necessary to construct a temperature measuring channel with a relative error of 0.05%.

Keywords Ion selective electrodes · Static characteristics · Errors · Measuring

1 Principles of the Digital Ion Selective Transducer Realization and Their Mathematical Models

1.1 Ion Selective Transducer Built on the Principle of ADC of Sequential Approximation

Realization of a digital potentiometric ion selective transducer for measuring the activity of substance ions can be performed on the base of ADC of the successive

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approximation in its structure. Structural diagram of such transducer is presented in Fig. 1.

As it is seen from Fig. 1 digital ion selective transducer comprises: ion selective electrode pX, reference electrode pX_C, scale converter (SC) that performs function of non-inverted amplification, analog-to-digital converter (ADC), central processing unit (CPU), reprogrammed read only memory (EEPROM), controller for data transfer via the serial port RS232 to the computer (PC) and liquid crystal display (LCD). Signal from the output of ion selective electrode pX is amplified by the scale converter to level of reference value, set by the reference electrode, where ADC functions and further it passes to (HI) input of ADC. ADC transforms the voltage value into binary code.

Model transformation equation of the suggested digital transducer of ions activity, built on the principle of successive approximation, using analog-to-digital converter, has the form:

$$N_{\mathrm{ADC}} = \left(U_0' - \alpha(273.15 + t)n_a^{-1} pX_i\right)k(U_{\mathrm{ref}})^{-1}2^m, \tag{1}$$

where U_{ref}—is the value of the reference voltage of ADC, set by the reference electrode; m—is the ADC bit rate; k—is amplification factor of the scale converter; α—is temperature coefficient of steepness S that equals $198.4 \times 10^{-3}/°C$; t—is the temperature of the environment being analyzed ($°C$); U_0'—graduation voltage, which is determined by the selection of the reference point; pX_i—concentration of ions; n_a—is the charge of ion [1–4].

Characteristic of the conversion equation of the digital ion selective transducer of ions activity, built on the principle of the successive approximation is shown in Fig. 2.

It is seen from the obtained characteristics of the dependence of ADC code change on the activity of ions that the function of the transformation of the digital potentiometric ion selective transducer of ions activity is linear.

Taking into account the conversion function (1) mathematical model of the quantization error of the digital potentiometric transducer of ions activity is described by the expression:

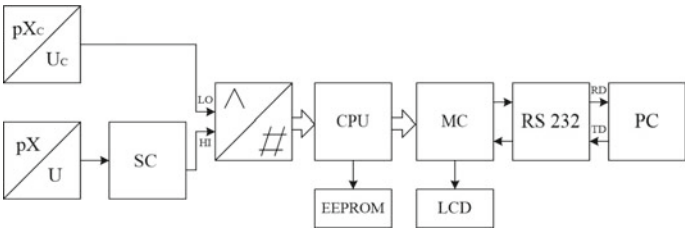

Fig. 1 Structural diagram digital potentiometric transducer of ions activity, built on the principle of ADC of serial approximation

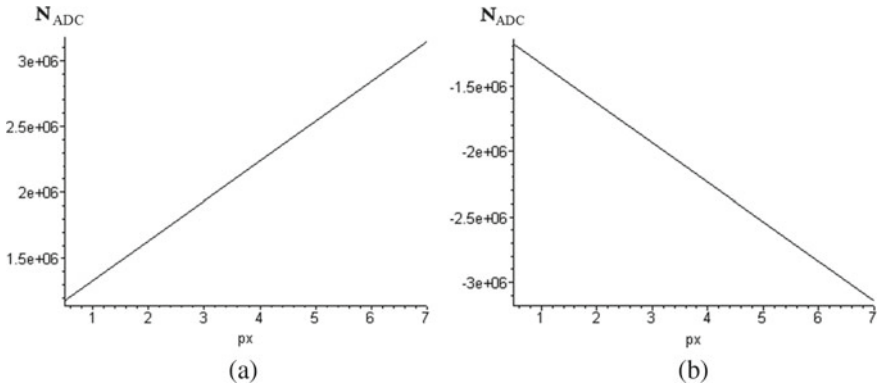

Fig. 2 Characteristics of ions activity change while realization of the digital transducer, built according to the principle of the analog-to-digital conversion of the successive approximation: **a** while measuring of negatively changed ions; **b** while measuring of positively changed ions

$$\delta_{\text{ADC}} = U_{\text{ref}}\left(U_0' - \alpha(273.15 + t)n_a^{-1} pX_i\right)^{-1}\left[k2^m\right]^{-1}100\%. \tag{2}$$

Analyzing the obtained mathematical model of the error (4) it is seen that it decreases while measuring greater values of pX ions activity and its change characteristic is nonlinear (Fig. 3).

As it is seen from the obtained characteristic of the digital transducer of ions activity error change (Fig. 3) the methodical component of the error does not exceed $8.6 \times 10^{-5}\%$ and is of nonlinear character. Ways of the methodical error decrease is the increase of the number of bits, but this will lead to the increase of digital transducer cost.

Determination of the amplitude changes of the analytical signal of ion selective electrode by means of ADC causes a number of problems, dealing with the necessity of the simultaneous provision of high capacity, fast acting, accuracy and cost. That

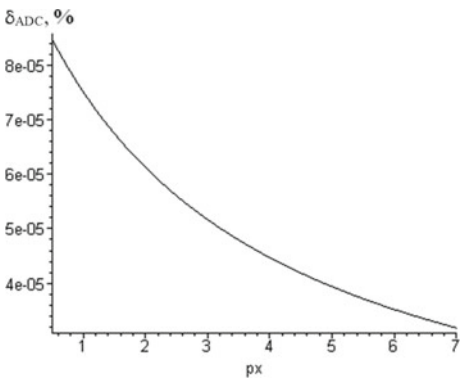

Fig. 3 Characteristic of the error change of the ions activity transducer, based on the principle of analog-to-digital conversion of the successive approximation

is why, the second variant of the circuit realization of digital ion selective transducer of ions activity, based on the principle of time-pulse conversion is proposed.

1.2 Ion Selective Transducer, Built on the Principle of Time-Pulse Conversion

For measuring the instantaneous voltage values from the outputs of ion selective electrodes instead of analog–digital conversion unit the principle of time-pulse conversion, based on the sawtooth generator and comparators could be used. Also in order to improve the accuracy the additional temperature measuring channel can be added [1–4]. Structural diagram of the digital ion selective transducer of ions activity, built on the principle of time-pulse conversion is shown in Fig. 4. In such transducer of ions activity the measured voltage is converted in time interval T_x with further quantization by the pulses of the reference frequency f_0 of the quartz-crystal resonator of the microcontroller. Temperature measuring channel is realized according the similar principle (time-pulse conversion), as the primary converter thermoresistive converter will be used, and non-inverting operation amplifier will be used as the scale converter.

Basic element of the structural realization of time-pulse conversion method is comparison device (CD), realized on two comparators, sawtooth generator G_U and RS-trigger T. Quantization of the time interval by the pulses of the reference

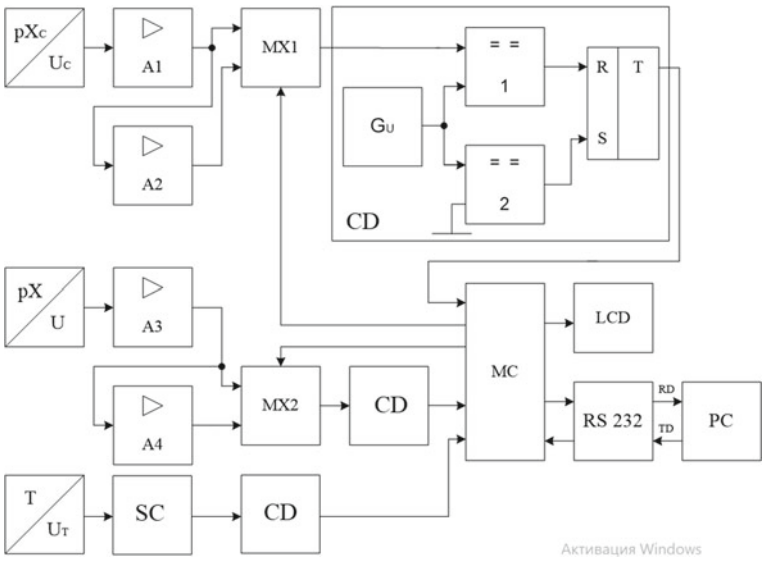

Fig. 4 Structural diagram of digital transducer of ions activity, built on the principle of time-pulse conversion

frequency f_0 is performed in the microcontroller by means of the built-in analog comparator and coincidence circuit.

Digital transducer of ions activity, built on the principle of time-pulse conversion (Fig. 4) comprises: ion selective electrode pX, reference electrode pX_C, operational amplifiers (A1–A4), multiplexers (MX1, MX2), comparison devices (CD), microcontroller (MC) and liquid crystal display (LCD). Comparison devices consist of the sawtooth generator, two comparators and RS-trigger. Additional temperature measuring channel comprises thermoresistive converter, scale converter (SC) and CD.

Signals from the outputs of the reference electrode pX_C, ions selective electrode and thermoresister reach the operational amplifiers (OA), it should be noted that the OA in the measuring channel of ion activity are provided in two variants—for the measurement of both positive and negative voltages from the outputs of ion selective electrodes. This is connected with the fact that in the process of measuring negatively charged ions the voltage at the output of the electrodes will be positive and in the process of measuring positively charged ions the voltage is negative. Process of measuring positively and negatively charged ions is controlled by microcontroller using multiplexors. After the amplification, voltage signals enter the comparison device (CD), where they are converted into the time interval T_x. Further by means of the built-in analog comparators, the allocated time interval is filled with pulses of the reference frequency f_0. Number of pulses, which entered in the allocated by means of the comparison device (CD) time interval is determined by the expression:

$$N_{U/T} = k\left(U_0' - \alpha(273,15 + t)n_a^{-1} pX_i\right)Kf_0 \tag{3}$$

where k—is the amplification factor of the operational amplifier (OA); K—is proportionality coefficient, which depends on the steepness of linearly varying voltage of the generator G_U; f_0—are pulses of the reference frequency of the quartz-crystal resonator of the microcontroller.

Static characteristics of the digital transducer of ions activity, built on the principle of time-pulse conversion are presented in Fig. 5.

Error of the measuring channel of ions activity, taking into account model conversion Eq. (3) is described by the expression:

$$\delta_{U/T} = \left[k\left(U_0' - \alpha(273.15 + t)n_a^{-1} pX_i\right)Kf_0\right]^{-1} 100\%. \tag{4}$$

Analysis of the obtained expression of the error of the measuring channel of ions activity, built on the principle of time-pulse conversation shows that the error decreases with the increase of pX ions activity and its changing characteristic is nonlinear (Fig. 6).

Possible ways of the quantization error decrease (4) is the increase of the reference frequency f_0 value, proportionality coefficient K and amplification factor k.

As it is seen from the obtained characteristic of the error change (Fig. 6) its maximum value does not exceed $2.45 \times 10^{-5}\%$ and is 3.5 times less than the error of

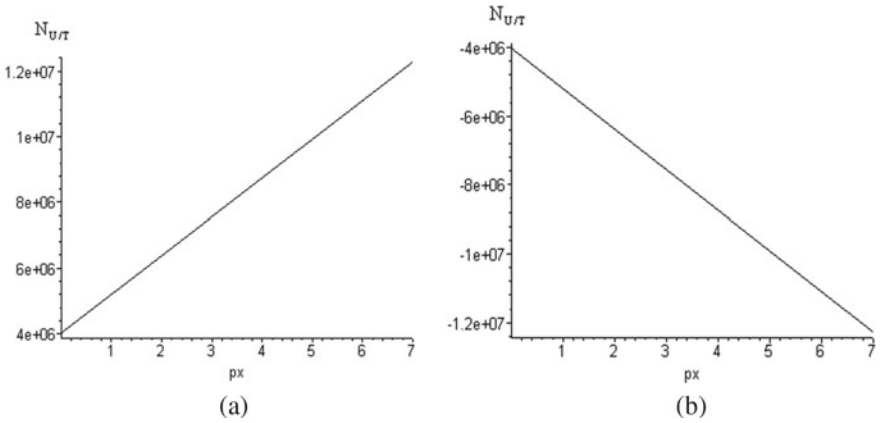

Fig. 5 Static characteristics of digital transducer of ions activity, built on the principle of time-pulse conversion: **a** while measuring negatively charged ions; **b** while measuring positively charged ions

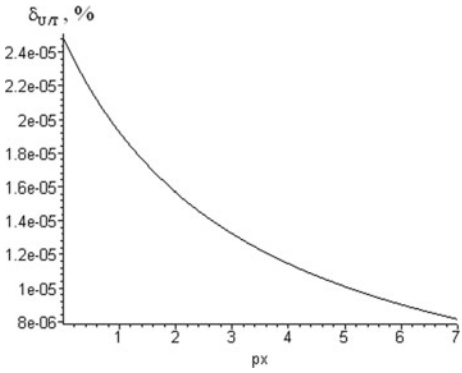

Fig. 6 Characteristic of the error variation of the ions activity measuring channel, built on the principle of time-pulse conversion

the digital transducer, built on the base of ADC of the successive approximation [1, 2]. The drawbacks of this principle of construction are low noise immunity, caused by the nonlinearity of the varying voltage of the generator G_u and instability of the comparator response level. That is why, we will investigate the third variant of the digital transducer of ions activity, based on the principle of voltage to frequency conversion.

1.3 Ion Selective Transducer, Built on the Principle of Voltage into Frequency Conversion

For the comparison with the previous realizations of the digital transducers of the ions activity the third variant of the digital potentiometric transducer, built on the

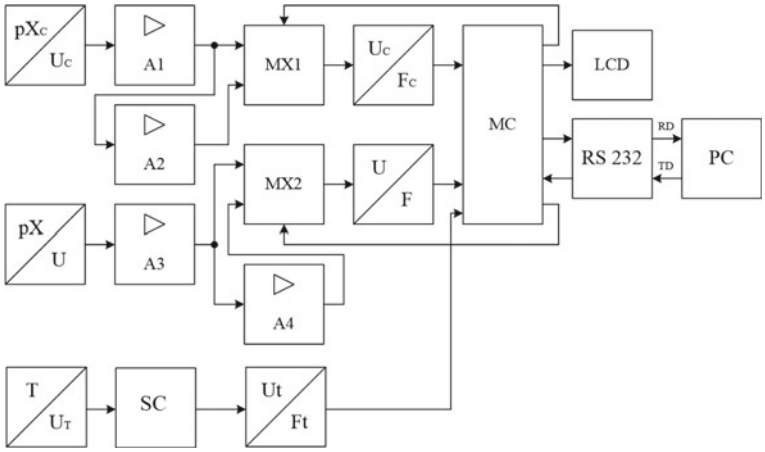

Fig. 7 Structural diagram of the digital transducer of ions activity, built on the base of voltage into frequency convertors

principle of voltage to frequency conversion is suggested. Structural diagram of such digital transducer is shown in Fig. 7.

The device comprises: ion selective converter (pX/U), reference electrode (pX_C/U_C); two operation amplifiers in each of measuring channels (MC) of ions activity (A1–A4) to provide measuring of both positive and negative values of pX; multiplexors (MX1 and MX2); voltage into frequency converters (VFC) (U_C/F_C and U/F) for the conversion the potentials of the reference electrode U_C/F_C and ion selective electrode U/F into frequency; microcontroller (MC); liquid crystal display (LCD); voltage levels converter (RS232) for data transfer to the computer (PC). Also temperature measuring channel (MC), consisting of the thermoresistive converter, scale converter (SC) and voltage into frequency converter (VFC). Conversion equation of the suggested digital transducer of ions activity, built on the principle of U/F conversion has the form:

$$N_{\mathrm{U/F}} = U_{\max} f_0 \tau \left[\left(U_0' - \alpha(273,15 + t) n_a^{-1} pX_i \right) k \right]^{-1} \tag{5}$$

where $U_{\max}$—is the value of the reference voltage of UFC (10 V); $\tau = \mathrm{RS}$—constant of UFC time, used for setting the full-scale output frequency of the quartz-crystal resonator of the microcontroller ($R = 1$ kOhm, $C = 47$ mF); f_0—is the frequency of the quartz-crystal resonator of the microcontroller (20 MHz); k—is amplification factor of OA [2].

Representations of the conversion Eq. (5) of the digital transducer of ions activity, built on the principle of voltage into frequency conversion, are shown in Fig. 8.

From the obtained characteristics of the number of pulses change dependence on the ions activity it is seen that the conversion function of the given transducer is

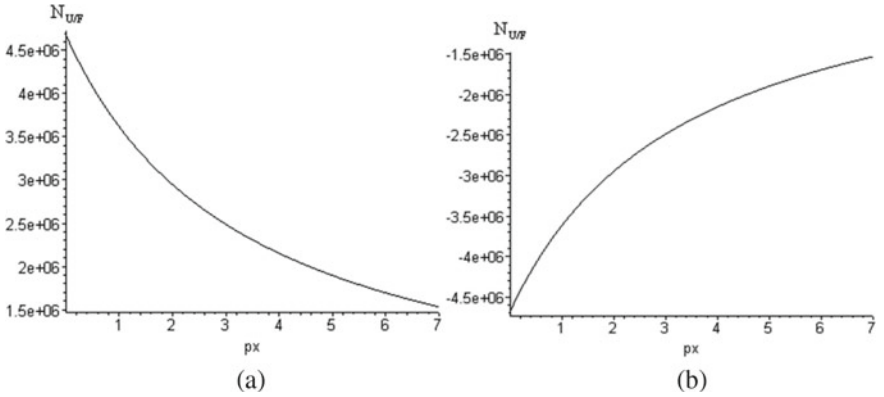

Fig. 8 Static characteristics of the measuring channel of ions activity, built on the principle of voltage into frequency conversion: **a** while measuring negatively charged ions; **b** while measuring positively charged ions

not linear but nonlinearity of VFC in the wide range of frequencies change does not exceed $2 \times 10^{-3}\%$.

Error of the digital transducer of ions activity, built on the base of voltage into frequency converter with the account of the conversion Eq. (5) is described by the expression:

$$\delta_{\mathrm{U/F}} = k\left(U_0' - \alpha(273.15 + t)n_a^{-1} pX_i\right)[U_{\max}\tau f_0]^{-1}100\%. \tag{6}$$

Characteristic of the transducer error change (6) is shown in Fig. 9.

Analysis of the obtained equation of the relative error of the ions activity transducer, built on the principle of voltage into frequency conversion shows that it increases with the increase of the measuring range of ions activity pX, and its change characteristic is linear (Fig. 9). Linearing of the error characteristic of the digital

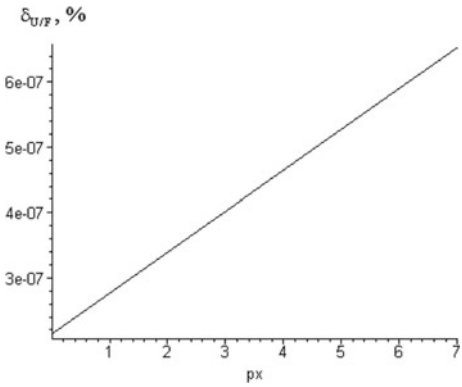

Fig. 9 Characteristic of the error variation of ions activity measuring channel, built on the principle of voltage into frequency conversion

transducer of ions activity enables to introduce easily the corrections if necessary. As it is seen from Fig. 9, maximum error of the digital transducer does not exceed $6.5 \times 10^{-7}\%$ which is 37 times less than the error of the digital transducer, built on the principle of time—pulse conversion and 130 times smaller than the maximal error of the digital transducer, built on the principle of analog-to-digital conversion of the successive approximation. Possible ways of decreasing the relative error of the digital transducer (6) is the increase of the reference frequency value f_0 and time constant τ.

All the characteristics of the errors changes are built in the range of ions activity change from 0.3 to 7 pX at the temperature of 20 °C. As it is seen from the obtained characteristics of the relative errors change (Figs. 3, 6 and 9) the smallest value of the error $7.7 \times 10^{-7}\%$ has the third variant of the realization of the digital ion selective transducer of ions activity, based on the principle of voltage into frequency conversion. The only drawback of such realization is nonlinearity of the static characteristic. However, the range of binary code change is great and this nonlinearly is of minor importance for measuring ions activity.

2 Conclusions

Thus, on the base of the above-mentioned, the conclusion can be made that the best variant of realization of the unified system of the automated control of humus constituents in the soil with increased methodical component of the control reliability will be the system, built on the base of the improved method of the ionometry, using in the structure of measuring channel (MC) method and means of voltage into frequency conversion. Also in the process of construction of the system of the automated control the combination of the method of voltage into frequency conversion with the method of time-pulse conversion is possible, for instance, usage of one of the methods in temperature MC, and other method—in MC of ions activity or vice versa.

References

1. Vasilevskyi O, Didych V et al (2018) Method of evaluating the level of confidence based on metrological risks for determining the coverage factor in the concept of uncertainty. In: Proceedings Volume 10808
2. Vasilevskyi OM, Kulakov PI et al (2017) Vibration diagnostic system for evaluation of state interconnected electrical motors mechanical parameters. In: Proceedings of SPIE 104456C
3. Fuchigami T (eds) (2014) Fundamentals and applications of organic electrochemistry
4. Flow Analysis with Spectrophotometric and Luminometric Detection (2012)