

Lecture Notes in Networks and Systems 447

Xin-She Yang
Simon Sherratt
Nilanjan Dey
Amit Joshi *Editors*

Proceedings of Seventh International Congress on Information and Communication Technology

ICICT 2022, London, Volume 1

 Springer

Lecture Notes in Networks and Systems

Volume 447

Series Editor

Janusz Kacprzyk, Systems Research Institute, Polish Academy of Sciences,
Warsaw, Poland

Advisory Editors

Fernando Gomide, Department of Computer Engineering and Automation—DCA,
School of Electrical and Computer Engineering—FEEC, University of Campinas—
UNICAMP, São Paulo, Brazil

Okyay Kaynak, Department of Electrical and Electronic Engineering,
Bogazici University, Istanbul, Turkey

Derong Liu, Department of Electrical and Computer Engineering, University
of Illinois at Chicago, Chicago, USA

Institute of Automation, Chinese Academy of Sciences, Beijing, China

Witold Pedrycz, Department of Electrical and Computer Engineering, University of
Alberta, Alberta, Canada

Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland

Marios M. Polycarpou, Department of Electrical and Computer Engineering,
KIOS Research Center for Intelligent Systems and Networks, University of Cyprus,
Nicosia, Cyprus

Imre J. Rudas, Óbuda University, Budapest, Hungary

Jun Wang, Department of Computer Science, City University of Hong Kong,
Kowloon, Hong Kong

The series “Lecture Notes in Networks and Systems” publishes the latest developments in Networks and Systems—quickly, informally and with high quality. Original research reported in proceedings and post-proceedings represents the core of LNNS.

Volumes published in LNNS embrace all aspects and subfields of, as well as new challenges in, Networks and Systems.

The series contains proceedings and edited volumes in systems and networks, spanning the areas of Cyber-Physical Systems, Autonomous Systems, Sensor Networks, Control Systems, Energy Systems, Automotive Systems, Biological Systems, Vehicular Networking and Connected Vehicles, Aerospace Systems, Automation, Manufacturing, Smart Grids, Nonlinear Systems, Power Systems, Robotics, Social Systems, Economic Systems and other. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution and exposure which enable both a wide and rapid dissemination of research output.

The series covers the theory, applications, and perspectives on the state of the art and future developments relevant to systems and networks, decision making, control, complex processes and related areas, as embedded in the fields of interdisciplinary and applied sciences, engineering, computer science, physics, economics, social, and life sciences, as well as the paradigms and methodologies behind them.

Indexed by SCOPUS, INSPEC, WTI Frankfurt eG, zbMATH, SCImago.

All books published in the series are submitted for consideration in Web of Science.

For proposals from Asia please contact Aninda Bose (aninda.bose@springer.com).

More information about this series at <https://link.springer.com/bookseries/15179>

Xin-She Yang · Simon Sherratt · Nilanjan Dey ·
Amit Joshi
Editors

Proceedings of Seventh International Congress on Information and Communication Technology

ICICT 2022, London, Volume 1

 Springer

Editors

Xin-She Yang
Middlesex University
London, UK

Nilanjan Dey
JIS University
Kolkata, India

Simon Sherratt
The University of Reading
Reading, UK

Amit Joshi
Global Knowledge Research Foundation
Ahmedabad, India

ISSN 2367-3370

ISSN 2367-3389 (electronic)

Lecture Notes in Networks and Systems

ISBN 978-981-19-1606-9

ISBN 978-981-19-1607-6 (eBook)

<https://doi.org/10.1007/978-981-19-1607-6>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2023

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.

The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

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

Smart Wearable Shoes Using Multimodal Data for Visually Impaired	1
Ann Nosseir	
Conceptual Framework of Database Development on Bidong Island: The Case Vietnamese Boat People (VBP) Campsite Facilities for Historical Tourism	19
Dazmin Daud, Nursyamillah Annuar, and Antashah Mohd Nor	
An Evaluation of Techniques for Classification of Conditional Sentences and Their Structural Components	29
G. B. Sanjana, Sundar Guntnur, and Shivali Agarwal	
Design of an Assistive Low-Cost 6 d.o.f. Robotic Arm with Gripper	39
Vasile Denis Manolescu and Emanuele Lindo Secco	
An Improved Method for the Sizing of a Stand-Alone Photovoltaic System: Application at Ngoundiane Village in Senegal	57
Pape Made Diouf, Amy Sadio, Papa Lat Tabara Sow, Ibrahima Fall, and Senghane Mbodji	
Blockchain Based Software Engineering Requirements Analysis and Management	75
Bandar Ali Alrami AL Ghadmi, Omar Ahmed Abdulkader, and Ahmad Abdulaziz Alwarhi	
Computer Simulation of the Response of a Semiconductor Wafer with a Self-Affine Pattern in the Form of a System of Coupled Ring Grooves to Electromagnetic Radiation	85
Gennadi Lukyanov, Alexander Kopyltsov, and Igor Serov	

The Computer Engineering in ECG Analysis Based on Scatter Mapping	93
Svetlana Aleksandrova, Irina Kurnikova, Marina Aleksandrova, Nikolay Kislyy, Tatiana Kochemasova, and Maria Zavalina	
Traffic Disturbance Mining and Feedforward Neural Network to Enhance the Immune Network Control Performance	99
Ali Louati, Fatma Masmoudi, and Rahma Lahyani	
The Use of ICT in Personalizing Self-learning in Time of Crisis: A Human Computer Interaction Perspective in a Developing Country	107
Ghada Refaat El Said	
Advanced Processing and Classification of Plant Disease	127
Sufola Das Chagas Silva E Araujo, V. S. Malemath, and K. Meenakshi Sundaram	
Design of an Interactive BB8-Like Robot	137
Mia Innes and Emanuele Lindo Secco	
Transfer Learning in Deep Reinforcement Learning	145
Tariqul Islam, Dm. Mehedi Hasan Abid, Tanvir Rahman, Zahura Zaman, Kausar Mia, and Ramim Hossain	
A Novel Current Control Scheme for Grid-Connected Single-Phase PWM Bridgeless Power Converters	155
Khalid Javed, Lieven Vandeveld, and Frederik De Belie	
Disk Space Management Automation with CSI and Kubernetes	171
Anastasia Shemyakinskaya and Igor Nikiforov	
Accuracy of Potentiometric Methods for Measuring Ion Activity in Solutions	181
O. M. Vasilevskyi, V. M. Sevastianov, K. V. Ovchynnykov, V. M. Didych, and S. A. Burlaka	
Evaluating Effect of Microsoft HoloLens on Extraneous Cognitive Load During Simulated Cervical Lateral Mass Screw Placement	191
Dmitriy Babichenko, Edward G. Andrews, Stephen P. Canton, Eliza Beth Littleton, Ravi Patel, Dukens Labaze, and Andrew Mills	
Network Modeling—A Convenient Way to Study IP Networks	203
Ivan Nedyalkov and Georgi Georgiev	
A New Innovation Concept on End-user’s Contextual and Behavioural Perspectives	213
Reem Aman, Shah J. Miah, and Janet Dzator	

Computational Modelling of the Role of Leadership Style for Its Context-Sensitive Control Over Multilevel Organisational Learning 223
 Gülay Canbaloglu, Jan Treur, and Anna Wiewiora

Enumeration of LCD and Self-dual Double Circulant Codes Over $\mathbb{F}_q[v]/\langle v^2 - 1 \rangle$ 241
 Shikha Yadav and Om Prakash

Autonomous Dysfunction and the Phenomenon of Early Aging of Regulatory Systems 251
 Irina Kurnikova, Shirin Gulova, Ramchandra Sargar, and Nikolay Kisliy

Principles for Assurance on Corporate Governance of ICT 257
 Petrus M. J. Delpont and Rossouw Von Solms

The Role of Telecommunication Technology During COVID-19 Pandemic in Indonesia 275
 Vina Fujiyanti, Syifaul Fuada, and Nadia Tiara Antik Sari

Online Purchase Over Pandemic Covid-19: Its Growth and Future in Malaysia 285
 Tang Mui Joo and Chan Eang Teng

MAGNeto: An Efficient Deep Learning Method for the Extractive Tags Summarization Problem 297
 Hieu Trong Phung, Anh Tuan Vu, Tung Dinh Nguyen, Lam Thanh Do, Giang Nam Ngo, Trung Thanh Tran, and Ngoc C. Lê

Design and Development of a Mobile Outdoor AR Application for On-Site Visualization of Wind Turbines 311
 Simon Burkard and Frank Fuchs-Kittowski

An Incorporated Solution to Support Elder People in Staying in Their Familiar Surroundings 323
 Dominic Mircea Kristaly and Sorin-Aurel Moraru

Analysis of Indoor Localization Using Beacons for the Visually Impaired: A Systematic Literature Review 339
 Juan Surco-Anacleto and Michael Cabanillas-Carbonell

Information and Communication Technologies for Employability in Times of COVID-19, a Systematic Literature Review 349
 Jesus Palacios-Loayza, Carlos Ayala-Inca, and Michael Cabanillas-Carbonell

The Acceptance and Challenges of Online Learning over Covid-19 Pandemic 359
 Eang Teng Chan and Mui Joo Tang

Learn to Ask What You Don't Know 369
 Binay Dahal, Sing Choi, and Kazem Taghva

Location-Based Service Discovery for Mobile-Edge Computing Using DNS 379
 Kurt Horvath, Helmut Wöllik, Uran Christoph, and Valentin Egger

Promoting Viable Supply Chain Management (SCM) in the Nigeria Agro-Allied Industry Using Internet of Things 389
 Makinde Oluwafemi Ajayi and Opeyeolu Timothy Laseinde

Recovery System of Work Performance by Using Indoor Environmental Changes Based on EEG-Movement Feature Space 401
 Hinata Serizawa and Yoshihisa Fukuhara

Moroccan Sign Language Video Recognition with Deep Learning 415
 Abdelbasset Boukdir, Mohamed Benaddy, Othmane El Meslouhi, Mustapha Kardouchi, and Moulay Akhloufi

Home Automation System and Quality of Life in Low-Income Households: A Systematic Review of the Literature from 2010 to 2021 423
 Jenifer Diana Bustamante-Gonzales, Hugo Eladio Chumpitaz-Caycho, and Franklin Cordova-Buiza

Detecting Termites in Wood Structure Using Internet of Things Approach 431
 Nur Zaimah Ahmad, Lutfil Hadi Zaifri, Bazilah A. Talip, and Aznida Abu Bakar Sajak

Performance Evaluation of Boosted 2-Stream TCRNet 443
 Shah Hassan, Md Jibanul Haque Jiban, and Abhijit Mahalanobis

Design of a Cascaded Single-Phase Multilevel Inverter for Photovoltaic Applications 451
 Darío Fernando Yépez Ponce, Héctor Mauricio Yépez Ponce, and William Manuel Montalvo López

An IoT Architecture to Enhance Monitoring and Predictive Maintenance for Cultural Heritage Buildings 461
 Mario Casillo, Massimo De Santo, Marco Lombardi, Rosalba Mosca, Domenico Santaniello, and Carmine Valentino

A BIM-Based Approach for Decision Support System in Smart Buildings 471
 Francesco Colace, Caterina Gabriella Guida, Brij Gupta, Angelo Lorusso, Francesco Marongiu, and Domenico Santaniello

Deficiencies of Computational Image Recognition in Comparison to Human Counterpart 483
 Vladimir Vinnikov and Ekaterina Pshehotskaya

Electronic Health Record’s Security and Access Control Using Blockchain and IPFS 493
 Md. Yeasin Ali, Suhaib Ahmed, Muhammad Iqbal Hossain, A. B. M. Alim Al Islam, and Jannatun Noor

Implementing Butterfly Key Expansion Using Post-Quantum Algorithms 507
 Ahmad Salman and Zachary Blankinship

Perceived Readiness of Information and Communication Technology Policy in Supporting Mobile Learning in Times of COVID-19 at South African Schools 517
 Baldreck Chipangura

Application of Random Forest Model in the Prediction of River Water Quality 525
 Turuganti Venkateswarlu and Jagadeesh Anmala

Supervised Learning-Based PV Output Current Modeling: A South Africa Case Study 537
 Ely Ondo Ekogha and Pius A. Owolawi

Use of Social Networks by Russian Politicians 547
 Olga Gris and Anna Sosnovskaya

Design and Implementation of Verifiable Blockchain-Based e-voting System 557
 Seiwoong Choi, HeeSeok Choi, and Kwang Sik Chung

DevOps Best Practices in Highly Regulated Industry 567
 Ruth G. Lennon

Citizens’ Use of Social Media: A Thematic Analysis on Digital Co-Production in Disaster Management 587
 Vicente A. Pitogo and Jesterlyn Q. Timosan

Robot Welding Path Planning and Application Based on Graphical Computing 597
 Jingjing Lou, Xujiang Yu, Yongfei Chen, Zhubing Sun, and Pengfei Zheng

The Interpolation-Vandermonde Method for Numerical Solutions of Weakly Singular Volterra Integral Equations of the Second Kind 607
 E. S. Shoukralla, B. M. Ahmed, Ahmed Saeed, and M. Sayed

Adoption of Cloud-Based Communicable Disease Surveillance in Taiwan: Chief Information Officers’ Perspectives of Hospitals 615
 Pi-Jung Hsieh and Hui-Min Lai

Design and Evaluation of a Novel and Modular Educational Robot Platform Based on Technology Acceptance Model 633
 Avraam Chatzopoulos, Konstantinos Kalovrektis, Apostolis Xenakis, Elefterios Chondrogiannis, Michail Papoutsidakis, Michail Kalogiannakis, and Sarantos Psycharis

Assessing the Effects of Landmarks and Routes on Neuro-Cognitive Load Using Virtual Environment 645
 Usman Alhaji Abdurrahman, Lirong Zheng, and Usman Haruna

On the Transposition of Translator Functions in a Digital Communicative Environment 657
 Lyudmila Kushnina, Elena Alikina, Irina Perlova, Kristina Permiakova, and Marina Khudaiberdina

Factors Affecting Intelligent Enterprise Resource Planning System Migrations: The South African Customer’s Perspective 665
 Precious Mushayi and Thembekile Mayayise

Analysis of an Efficient ZnO/GeTe Solar Cell Using SCAPS-1D 677
 Mostafa M. Salah, A. Zekry, Mohamed Abouelatta, Ahmed Shaker, Mohamed Mousa, and Ahmed Saeed

Looping Through Color Space: A Simple Augmentation Method to Improve Biased Object Detection 687
 Pascal Lampert, Janis Jung, Andreas Hubert, and Konrad Doll

Detection of Retinopathy of Prematurity Stages Utilizing Deep Neural Networks 699
 Nazar Salih, Mohamed Ksantini, Nebras Hussein, Donia Ben Halima, Ali Abdul Razzaq, and Sohaib A. Mahmood

Iterative Approach for Reduction of Index-2 Periodic Models Using Generalized Inverse Procedure 707
 Atia Afroz, Mohammad-Sahadet Hossain, Musannan Hossain, and Mashrur Wasek

Smart Village Crop Planning: Enhancing Farmer’s Decision-Making Culture with Data-Driven Predictive Model 717
 Ariza Nordin and Faizah Ahmad Faizar

Closed-Domain Multiple-Choice Question Answering System for Science Questions 729
 Kedar P. Vaidya, Sanya A. Chetwani, and Mansi A. Radke

Quality Management Within and Visiting e-cultural Tourist Destinations: Case Study Rural Parish of San Miguelito 743
Alicia Porras-Angulo, Alba Hernández-Freire, Johana Porras-Quispe, and Adriana Cuesta-Chiriboga

Use of GeoGebra in Learning to Solve the Problem of Calculating the Root of a Nonlinear Equation 753
Judith Keren Jiménez-Vilcherrez, Felicita Marcela Velásquez-Fernández, Araceli Margarita Acevedo-Ruiz, Ricardo Velezmoro-León, and Robert Ipanaqué-Chero

Usability Evaluation Using Unmoderated Remote Usability Testing on Angkasa LMS Website Case Study 761
Veronikha Effendy, Dana Sulistiyo Kusumo, Nungki Selviandro, and Kusuma Ayu Laksitowening

Distributed Deep Reinforcement Learning for Resource Allocation in Digital Twin Networks 771
Jie Luo, Jie Zeng, Ying Han, and Xin Su

The COVID-Enforced Adoption of Technology for Reluctant Entrepreneurial Businesses: A Systematic Literature Review 783
Gareth Mclean and Adriana A. Steyn

Integrated Remote Primary Care Infrastructure: A Framework for Adoption and Scaling of Remote Patient Management Tools and Systems 797
Barimwotubiri Ruyobeza, Sara S. Grobbelaar, and Adele Botha

A Comprehensive Virtual Classroom Dashboard 819
Amber Kimberling and Sampson Akwafuo

Freddy Render: A Horizontally Scaled Blender-Based Solution for 3D Graphics Rendering 829
Mike Peralta and Sampson Akwafuo

Medical X-Ray Image Classification Employing DCGAN and CNN Transfer Learning Techniques 839
Md. Asif Talukdar, Ayesha Siddika, Ahasanul Haque Abir, Mohammed Ziad Hassan, and Muhammad Iqbal Hossain

A Survey on Counterfeits in the Information and Communications Technology (ICT) Supply Chain 849
Samar Saleh, Rong Lei, Weihong Guo, and Elsayed A. Elsayed

Banking Credit Risk Analysis using Artificial Neural Network 871
Charles Maruma, Chunling Tu, and Claude Nawej

Implementation, Analysis, and Emulation of Electric Vehicle Powertrain System with Sensorless Field Controlled PMSM Drive 879
Monika Verma, Mini Sreejeth, and Madhusudan Singh

Verification of the Effectiveness of Learning Materials that Support Self-regulation for Learning Considering Differences in Career Resilience: Acquiring Knowledge of Level 3 Automated Driving Vehicles 889
Maki Arame, Junko Handa, Yoshiko Goda, Masashi Toda, Ryuichi Matsuba, Huiping Zhou, Makoto Itoh, and Satoshi Kitazaki

ICT-Enabled Vehicle Theft Detection and Recovery System 901
Kamlesh Kumawat and Vijay Singh Rathore

Determination of Antibiotic Resistance Level in *Klebsiella* using Machine Learning Models 913
Snehal Gupta, Sreemoyee Chatterjee, Amita Sharma, Marina Popolizio, Vincenzo Di Lecce, Mariantonietta Succi, Patrizio Tremonte, Rita Dario, and Vijay Singh Rathore

Author Index 925

Accuracy of Potentiometric Methods for Measuring Ion Activity in Solutions



O. M. Vasilevskiy , 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

O. M. Vasilevskiy (✉) · V. M. Sevastianov · K. V. Ovchynnykov
Vinnytsya National Technical University, 95 Khmelnytskoye Shose, Vinnytsya 21021, Ukraine
e-mail: o.vasilevskiy@gmail.com

V. M. Didych
National Pirogov Memorial Medical University, Vinnytsya 21000, Ukraine

S. A. Burlaka
Vinnytsya National Agrarian University, 3, Solnyschna St, Vinnytsya 21008, Ukraine

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:

$$N_{ADC} = (U'_0 - \alpha(273.15 + t)n_a^{-1} pX_i)k(U_{ref})^{-1}2^m, \quad (1)$$

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 $198.4 \times 10^{-3}/^{\circ}C$; t —is the temperature of the environment being analyzed ($^{\circ}C$); 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:

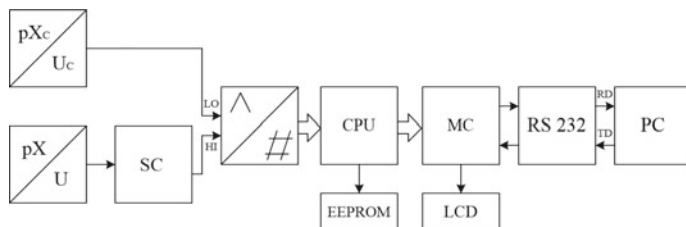


Fig. 1 Structural diagram digital potentiometric transducer of ions activity, built on the principle of ADC of serial approximation

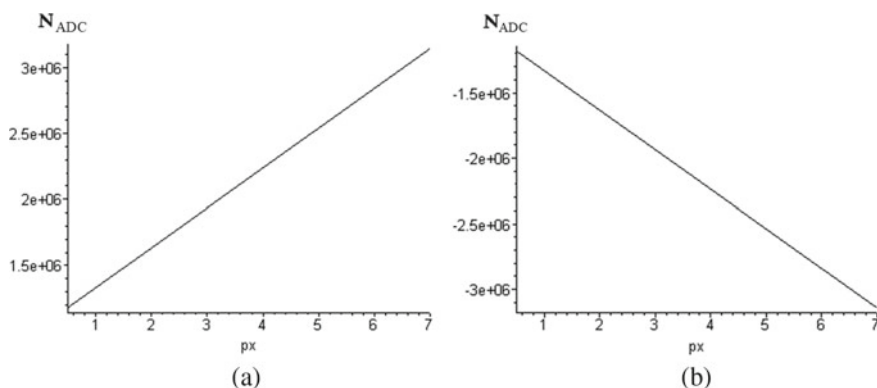


Fig. 2 Characteristics of ions activity change while realization of the digital transducer, built according to the principle of the analog-to-digital conversion of the successive approximation: **a** while measuring of negatively changed ions; **b** while measuring of positively changed ions

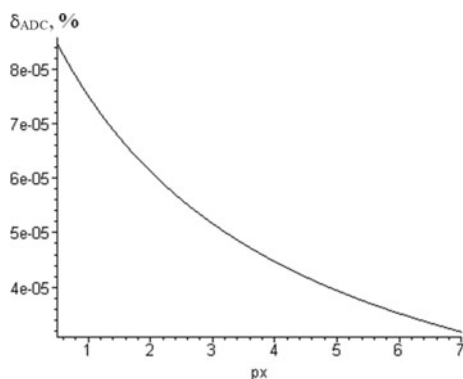
$$\delta_{\text{ADC}} = U_{\text{ref}}(U'_0 - \alpha(273.15 + t)n_a^{-1}pX_i)^{-1}[k2^m]^{-1}100\%. \quad (2)$$

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

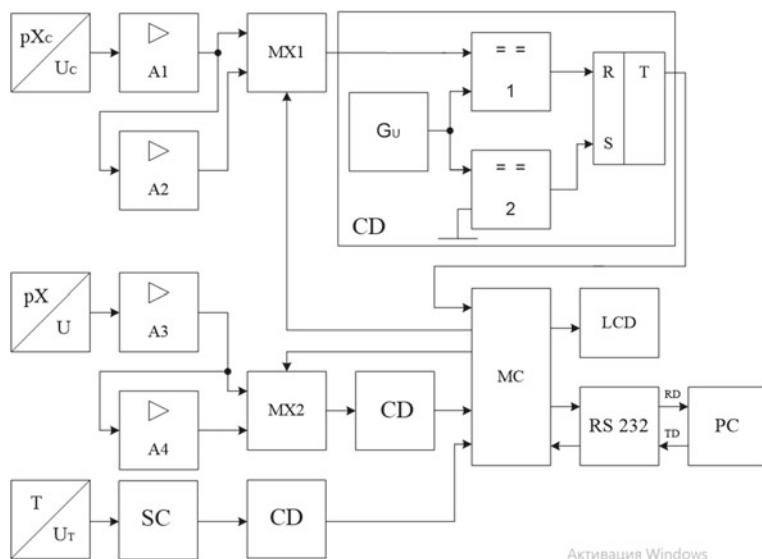


Fig. 4 Structural diagram of digital transducer of ions activity, built on the principle of time-pulse conversion

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 thermoresistor 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 multiplexers. 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:

$$N_{UT} = k(U'_0 - \alpha(273, 15 + t)n_a^{-1}pX_i)Kf_0 \quad (3)$$

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:

$$\delta_{UT} = [k(U'_0 - \alpha(273.15 + t)n_a^{-1}pX_i)Kf_0]^{-1}100\%. \quad (4)$$

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

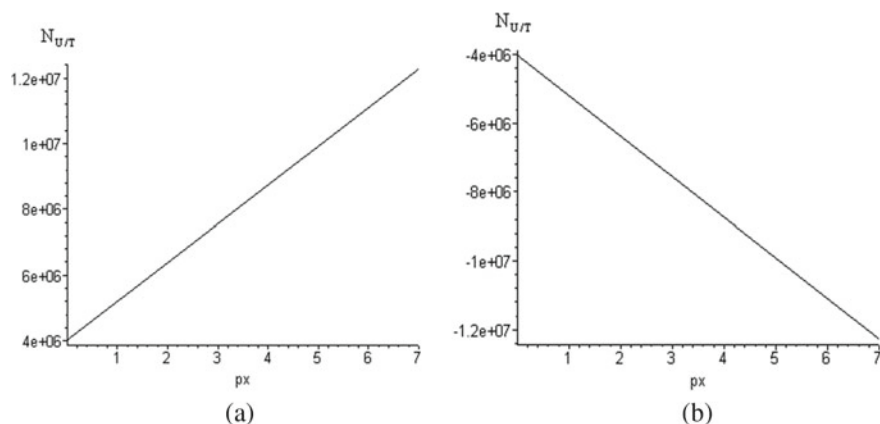
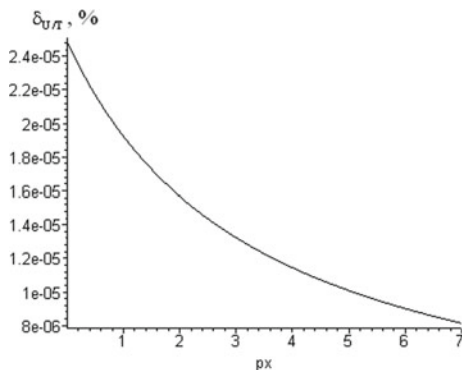


Fig. 5 Static characteristics of digital transducer of ions activity, built on the principle of time-pulse conversion: **a** while measuring negatively charged ions; **b** while measuring positively charged ions

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

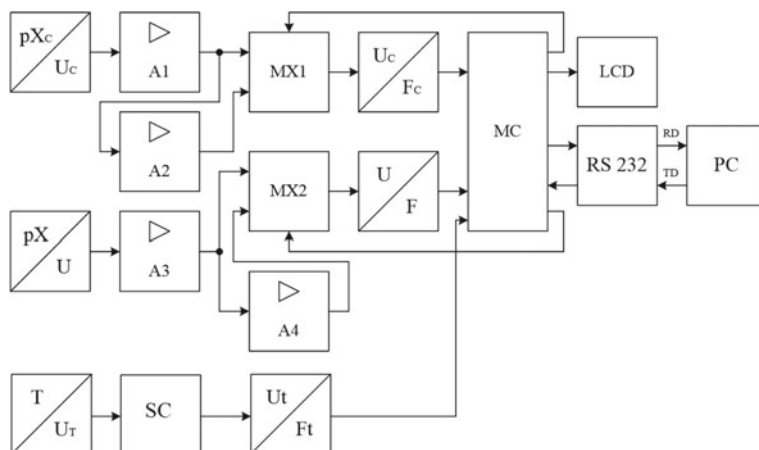


Fig. 7 Structural diagram of the digital transducer of ions activity, built on the base of voltage into frequency converters

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:

$$N_{U/F} = U_{\max} f_0 \tau [(U'_0 - \alpha(273, 15 + t)n_a^{-1} pX_i)k]^{-1} \quad (5)$$

where U_{\max} —is the value of the reference voltage of UFC (10 V); $\tau = RS$ —constant of UFC time, used for setting the full-scale output frequency of the quartz-crystal resonator of the microcontroller ($R = 1 \text{ k}\Omega$, $C = 47 \text{ mF}$); 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

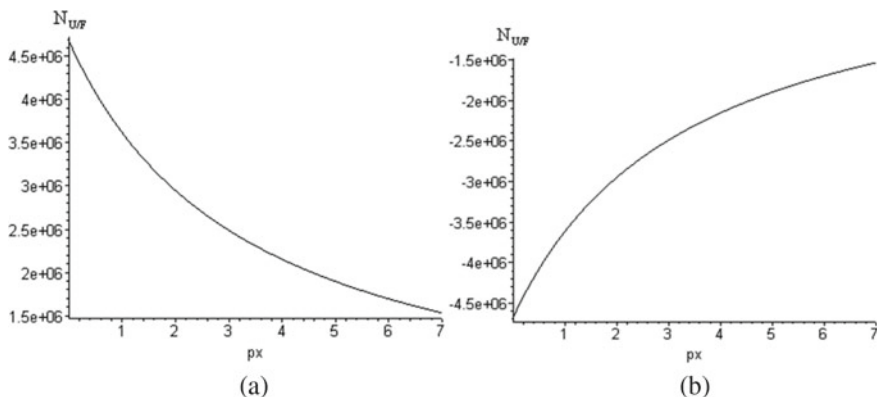


Fig. 8 Static characteristics of the measuring channel of ions activity, built on the principle of voltage into frequency conversion: **a** while measuring negatively charged ions; **b** while measuring positively charged ions

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

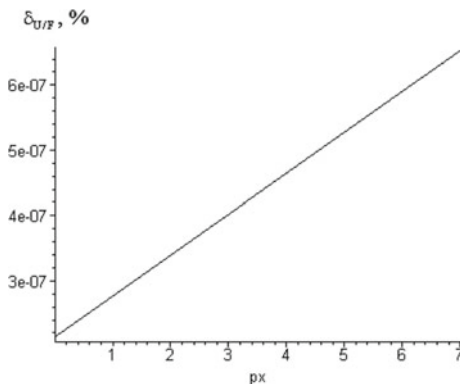
Error of the digital transducer of ions activity, built on the base of voltage into frequency converter with the account of the conversion Eq. (5) is described by the expression:

$$\delta_{U/F} = k(U'_0 - \alpha(273.15 + t)n_a^{-1}pX_i)[U_{max}\tau f_0]^{-1}100\%. \tag{6}$$

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). Linearizing 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 nonlinearity 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. Vasilevskiy 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. Vasilevskiy 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)