**Experimental Analysis of Normalising Converters**

Olim Alimnazarov1, a), Xurshida Mengatova2, Zaynura Xayitmuratova2

*1Termiz State Pedagogical Institute, Surkhandarya, Uzbekistan*

*2Termiz State University of Engineering and Agrotechnologies, Surkhandarya, Uzbekistan*

*a)Corresponding author: olimbekalimnazarov12@gmail.com*

**Abstract:** In this article, the results of applying the parameters of normalizing converters in practical processes are presented. During the research, the output signals of normalizing converters for input signals in the ranges of 0…5 mA, 4…20 mA, and 0…10 V were analysed. Their interrelation, linearity, and resistance to electromagnetic interference were analysed. The experiments were conducted in two directions. In the first direction, the linearity and stability of two output signals obtained from three input signals in the ranges of 0…10 V, 0…5 mA, and 4…20 mA were studied. In the second direction, the process of branching the input current in the range of 0…5 mA into output signals through four normalising converters was analysed. In addition, the process of branching the input voltage in the range of 0…10 V into output signals through four normalising converters was also studied. According to the results, the normalising converters make it possible to ensure the stability of input signals against electromagnetic interference and maintain their linearity. This makes it possible to apply the experimental results in practical processes.

**Keywords:** normalising converter, stability, channel, experimental analysis, input and output signals.

**INTRODUCTION**

It is known that normalising converters ensure the interrelation between the signals from primary sensors and those entering secondary equipment. Normalising converters ensure the stability of transmission parameters by standartising the signals generated by primary sensors [1]. In this case, they are distinguished by their ability to maintain the linearity of signals from primary sensors up to 98 %. In this process, the normalising converters maintain stability against electromagnetic interference and ensure linearity [2, 3]. This, of course, requires the development of protection modules for the input signals within the output range. Through this, the experimental results demonstrate the the stability of normalising converters in the transmission process and against electromagnetic interference. Studies show that optimized normalising converters reduce nonlinearity errors. This ensures the overall accuracy of laboratory measurements [4, 5]. Normalising converters with intelligent calibration algorithms standardise the system’s input and output signals. This make it possible to linearise it in accordance with the process. In this process, normalising converters perform the function of reducing mutual interferences in complex measurement processes within multichannel sensor systems. In intelligent sensor systems, microcontrollers and real-time calibration modules are used. This ensures the stability of input and output signal normalisation in multichannel sensor systems [6, 7]. In microelectronic amplifiers, the parameters of stability against electromagnetic interference are modelled. Its results expand the accuracy and dynamic range of output signals in measurement systems. Normalising converters are analysed though input signal algorithms. In this case, normalising converters with low power consumption and low sensitivity to electromagnetic interference are used in microelectromechanical systems [8, 9]. This process makes it possible to analyse input and output signals in real-time though an intelligent normalising converters module within a protective environment. In addition, the normalisation of input signals makes it possible to ensure the linearity of input signals [10, 11]. The experimental analysis of normalising converters makes it possible not only to improve their linearity and stability but also to parameters of sensor systems.

**METHODS**

In this study, an experimental analysis of normalising converters was carried out. In our experiment, the parameters of normalising converters that convert primary sensor input signals into various physical quantities were analysed. In this case, the experiment considers normalising converters that convert input signals in the ranges of 0…10 V, and 4…20 mA into output ranges of 4…20 mA and 0…10 V.

In this process, our experiments were conducted in two directions. In the first direction, a voltage signal is supplied through the first input source of the multichannel system, while current signals are supplied through the second and third sources. Each of the output current signals from these normalising converters is converted into input signals of the same type and value when entering the measuring devise (MD). As a result, the measuring devise (MD) generates two different quantities of voltage and current signals from the three input signals. Through this, the interrelation among various elements within the system is achieved by the normalising converters. Another important function of normalising converters is to ensure the protective environment of the controller, which serves as the central element of the measurement system.

Fig. 1 shows a system with three input channels and two output channels. In this setup, a 0…10 V voltage from the first input source, a 0…5 mA current from the second source, and a 4…20 mA current from the third source are sequentially supplied to three normalising converters. Though the normalising converters, all input signals are converted into 4…20 mA current signals of the same type and value. Here, the measuring device (MD) collects and analyses the three standardised input signals, converting them into two output current signals of the same type and value 4…20 mA. Through the normalising converters, the input signals are converted into the ranges of 4…20 mA and 0…1 V. in this way, the input signals from three different sources are standardized to the 4…20 mA range through the measuring device (MD). In this case, the measuring device (MD) produces two output signals a 0…10 V voltage and a 4…20 mA current from the three input signals.

**SS1**

**SS2**

**SS3**

**NC1**

**NC2**

**NC3**

0…10 V

0…5 mA

4…20 mA

4…20 mA

4…20 mA

4…20 mA

4…20 mA

4…20 mA

4…20 mA

0…1 V

**MD**

**SC1**

**SC2**

**NC1**

**NC2**

**FIGURE 1.** Source of a system with three input channels and two output channels

*Here: SS-signal sources (sensors); SC-signal consumers (measurement or control devices); NC-normalising converters; MD-measurement and control system.*

In the second direction, a single input current signal is branched into four outputs, consisting of three current signals and one voltage signal. In addition, experiments were conducted using a system where a single input voltage signal is branched into four outputs, consisting of three current signals and one voltage signal. A separate normalising converter was connected to each branch. Their output signals were recorded through a voltmeter and an ammeter. This method makes it possible to transmit primary sensor signals stably to several control or measuring devices.

In Fig. 2, an input current of 0…5 mA from the signal source is transmitted in parallel to all converters. In this case, the outputs of three networks are converted into current signals within the 4…20 mA range, and one network is converted into a voltage signal within the 0…10 V range.

0…5 mA

4…20 mA

4…20 mA

4…20 mA

0…10 V

**SS**

**NC1**

**NC2**

**NC3**

**NC4**

**SC1**

**SC2**

**SC3**

**SC4**

**FIGURE 2.** Source of a system in which a single input current signal is branched into three output   
current and one voltage signals

In Fig. 3, an input voltage signal of 0…10 V from the signal source is applied. This input voltage signal is transmitted in parallel to four networks. In this case, the outputs of three networks are converted into 4…20 mA current signals, while one network remains unchanged within its 0…10 V range. In this circuit, a single voltage signal is sent in parallel to all converters. The signal type of one network within them remains unchanged.

0…5 mA

4…20 mA

4…20 mA

4…20 mA

0…10 V

**SS**

**NC2**

**NC3**

**NC4**

**SC1**

**SC2**

**SC3**

**NC1**

**SC4**

**FIGURE 3.** Source of a system in which a single input voltage signal is branched into three output   
current and one voltage signals

During the experiment, the connection was made to the function generator through normalising converters as shown in Fig. 4. Input current and voltage signals of various magnitudes were applied. Its normalized values were recorded as output signals through the readings of the voltmeter and ammeter. In this case, the graph of the linear relationship between the input and output signals is plotted using a constant voltage.

FG

CHANNEL1

V

A

1

2

3

4

+

-

NC

**FIGURE 4.** Schematic diagram of the experiment

*Here: V-voltmeter measuring alternating voltage; A-ammeter measuring direct current; FG-function generator*

**RESULTS AND DISCUSSIONS**

In the course of the study, an experimental analysis of the linearity and stability parameters of the output signals of normalising converters was carried out.

The experiment was conducted in two directions. First direction. A voltage of 0…10 V was applied from the first input source of the three input channels shown in Fig. 1. A 0…5 mA current signal from the second source and a 4…20 mA current signal from the third source were sequentially transmitted to three normalising converters. All inputs were converted into current signals within the 4…20 mA range through the normalising converters. The measuring and converting device transformed the three normalized input signals into two output current signals within the 4…20 mA range. The input signals were converted into the 4…20 mA and 0…1 V ranges through the normalising converters. In this case, the measuring and converting device produced two types of output signals from the three input signals: 0…1 V voltage and 4…20 mA current. According to its graphical analysis, the linearity of the output signals within the 4…20 mA and 0…10 V ranges was ensured through the input in the 0…10 V range (Fig. 5).

**mA**

20.0

17.5

15.0

12.5

10.0

7.5

5.0

2.5

0

0 2 4 6 8 10

**Output current (4…20 mA)**

**Output voltage (0…1 V)**

**V**

**FIGURE 5.** Graph of the linear relationship between the 0…10 V input and the signals within the   
4…20 mA and 0…10 V ranges

This made it possible to ensure the protective environment of the controller, which is the central element of the measuring system. In this process, the normalising converters not only standardised the signals but also provided a protective environment.

Second direction. A 0…5 mA current signal from the signal source shown in Fig. 2 was transmitted in parallel to all converters as the input. In this case, the outputs of three networks were converted into current signals within the 4…20 mA range. Only one network was converted into a voltage signal within the 0…10 V range. According to its graphical analysis, the input current signal within the 0…5 mA range was converted into a 4…20 mA current signal through three networks. Through one network, it was converted into an output voltage signal within the 0…10 V range (Fig. 6).

**mA**

20.0

17.5

15.0

12.5

10.0

7.5

5.0

2.5

0

0 2 4 6 8 10

**V**

**Networks (NC1, NC2, NC3): 4…20 mA**

**Network (NC4): 0…10 V**

**FIGURE 6.** Graph of the conversion of the 0…5 mA input signal into the output 4…20 mA and 0…10 V voltage signals

In Fig. 3, an input voltage signal of 0…10 V was applied from the signal source. This input voltage signal is transmitted in parallel to four networks. In this case, the outputs of three networks were converted into 4…20 mA current signals. One network retained the voltage signal unchanged within the 0…10 V range. In this circuit, a single voltage signal was sent in parallel to all converters. The signal type of one of the networks remained unchanged. According to its graphical analysis, the input voltage signal within the 0…10 V range was converted accordingly. Through three networks, it was linearly converted into output signals within the 4…20 mA and 0…10 V range (Fig. 7).

**mA**

20.0

17.5

15.0

12.5

10.0

7.5

5.0

2.5

0

0 2 4 6 8 10

**V**

**Networks (NC1, NC2, NC3): 4…20 mA**

**Network (NC4): 0…10 V**

**FIGURE 7.** Graph of the conversion of the 0…10 V input signal into the output 4…20 mA and 0…10 V signals

A separate normalising converter was connected for each network. Their output signals were recorded using a voltmeter and an ammeter. Linearity and stability of the signals were ensured even in the branched systems. This process enabled the transmission of signals from multiple sensors in real-time within multichannel systems.

Overall, the conducted experiments demonstrated that the normalising converters ensured high linearity between the input and output physical quantities. Furthermore, they standardised signals in multichannel systems and ensured a protective environment for the controller, which is the central element of the system.

**CONCLUSION**

In this study, an experimental analysis of the linearity and stability parameters of normalising converter’s outputs was carried out. The experiments were conducted in two directions. According to the results, three inputs in the ranges of 0…10 V, 0…5 mA, and 4…20 mA were converted into two outputs in the ranges of 4…20 mA and 0…10 V through normalising converters. This conversion process ensures stability in measurement systems.

In the second direction of the study, the process of transmitting inputs to four converters through parallel networks in real-time mode was analysed. In this case, the input signal in the 0…10 V range was converted into a current signal in the 4…20 mA range across three networks. Only in one network was the voltage left unchanged, demonstrating the system’s adaptability. In the next stage, a 0…10 V voltage signal was applied as the input. This input voltage signal is transmitted in parallel to four networks. In this case, the outputs in three networks were converted into 4…20 mA current signals, while in only one network the signal remained unchanged in the 0…10 V range.

Overall, the conducted experiments demonstrated the linearity and stability of multichannel input and output signals of the normalising converters. In addition, it ensured the protective environment of the controller, which serves as the central element of the system.

**REFERENCES**

1. Brkić, M., Radić, J., Babković, K., & Damnjanović, M. (2024). Integrated Precision High-Frequency Signal Conditioner for Variable Impedance Sensors. *Sensors*, 24(20), 6501. <https://doi.org/10.3390/s24206501>
2. Safari, L., Barile, G., Stornelli, V., & Ferri, G. (2022). A Review on VCII Applications in Signal Conditioning for Sensors and Bioelectrical Signals: New Opportunities. *Sensors*, 22(9), 3578. <https://doi.org/10.3390/s22093578>
3. Staffa, A., Palmieri, M., Morettini, G., Zucca, G., Crocetti, F., & Cianetti, F. (2023). Development and Validation of a Low-Cost Device for Real-Time Detection of Fatigue Damage of Structures Subjected to Vibrations. *Sensors*, 23(11), 5143. <https://doi.org/10.3390/s23115143>
4. Kim, Ji-Yun, and Je-Heon Han. 2023. "Optimal Transducer Placement for Deep Learning-Based Non-Destructive Evaluation" *Sensors* 23, no. 3: 1349. <https://doi.org/10.3390/s23031349>
5. Scarsella, M., Barile, G., Stornelli, V., Safari, L., & Ferri, G. (2023). A Survey on Current-Mode Interfaces for Bio Signals and Sensors. *Sensors*, 23(6), 3194. <https://doi.org/10.3390/s23063194>
6. Carneiro, M., Oliveira, V., Oliveira, F., Teixeira, M., & Pinto, M. (2022). Simulation Analysis of Signal Conditioning Circuits for Plants’ Electrical Signals. *Technologies*, 10(6), 121. <https://doi.org/10.3390/technologies10060121>
7. Thakur, D., Sharma, K., Kapila, S., & Sharma, R. (2021). Ultra-low power signal conditioning system for effective biopotential signal recording. *Jounal of Micromechanics and Microengineering,* 31(12), <https://doi.org/10.1088/1361-6439/ac3465>
8. Ali, G., & Mohd-Yasin, F. (2024). Comprehensive Noise Modeling of Piezoelectric Charge Accelerometer with Signal Conditioning Circuit. *Micromachines*, 15(2), 283. <https://doi.org/10.3390/mi15020283>
9. Puentes-Conde, G. M., Sifuentes, E., Molina, J., Enríquez-Aguilera, F., Bravo, G., & Enríquez, G. N. (2025). Direct Interface Circuits for Resistive, Capacitive, and Inductive Sensors: A Review. *Electronics*, 14(12), 2393. <https://doi.org/10.3390/electronics14122393>
10. Al-Rawashdeh, A. Y., Younes, T. M., Dalabeeh, A., Al\_Issa, H., Qawaqzeh, M., Miroshnyk, O., Kondratiev, A., Kučera, P., Píštěk, V., & Stepenko, S. (2023). Experimental Investigation of Microcontroller-Based Acoustic Temperature Transducer Systems. *Sensors*, 23(2), 884. <https://doi.org/10.3390/s23020884>
11. Deng, Z., Lian, Z., Ye, J., Qin, K., Wang, Y., Li, F., & Meng, X. (2025). Design of Low-Frequency Extended Signal Conditioning Circuit for Coal Mine Geophone. *Sensors*, 25(19), 5946. <https://doi.org/10.3390/s25195946>