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МИНИСТЕРСТВО ВЫСШЕГО ОБРАЗОВАНИЯ, НАУКИ И ИННОВАЦИЙ РЕСПУБЛИКИ УЗБЕКИСТАН
АНДИЖАНСКИЙ МАШИНОСТРОИТЕЛНЫЙ ИНСТИТУТ

НАУЧНО-ТЕХНИЧЕСКИЙ ЖУРНАЛ
МАШИНОСТРОЕНИЕ

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MINISTRY OF HIGHER EDUCATION, SCIENCE AND INNOVATIONS REPUBLIC OF UZBEKISTAN
ANDIJAN MACHINE-BUILDING INSTITUTE

SCIENTIFIC AND TECHNICAL JOURNAL
MACHINE BUILDING

O‘zbekiston Respublikasi Vazirlar mahkamasi huzuridagi Oliy attestatsiya komissiyasi (OAK) Rayosatining 2021-yil 30-dekabrdagi 310/10-son qarori bilan Andijon mashinasozlik institutining “Mashinasozlik” ilmiy-texnika jurnali “TEXNIKA” va “IQTISODIYOT” fanlari bo‘yicha falsafa doktori (PhD) va fan doktori (DSc) ilmiy darajasiga talabgorlarning dissertatsiya ishlari yuzasidan asosiy ilmiy natijalarini chop etish tavsiya etilgan ilmiy nashrlar ro‘yxatiga kiritilgan.

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"Mashinasozlik" ilmiy-texnika jurnali O'zbekiston Respublikasi Axborot va ommaviy kommunikatsiyalar agentligining 2020 yil 28- fevraldagi 04-53-raqamli guvohnomasiga binoan chop etiladi.

УДК:628.34.001.57

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DETERMINATION OF STATIC CHARACTERISTICS OF OPTOELECTRONIC DISCRETE DISPLACEMENT TRANSDUCERS WITH HOLLOW AND FIBER FIBER

ОПРЕДЕЛЕНИЕ СТАТИЧЕСКИЕ ХАРАКТЕРИСТИК ОПТОЭЛЕКТРОННЫХ ДИСКРЕТНЫХ ПРЕОБРАЗОВАТЕЛЕЙ ПЕРЕМЕЩЕНИЙ С ПОЛЫМИ И ВОЛОКОННЫМИ СВЕТОВОДАМИ

G‘OVAK VA TOLALI YORUG‘LIK O‘TKAZGICHLI OPTOELEKTRON DISKRET SILJISH O‘ZGARTIRGICHLARINING STATIK TAVSIFLARINI ANIQLASH.

Annotation.

In this article, optoelectronic discrete converters (ODC) of any type, longitudinal or transverse displacements of an external modulating body (EMD) are converted into a change in the parameters of the light flux $\mathbf{\Phi_0}$ in the corresponding light guides from lumped radiation sources (LRS) or a distributed radiation source (DRS). Further, the light fluxes $\mathbf{\Phi_0}$ falling on the corresponding radiation receiver (RR) change their parameters and the output voltages $\mathbf{U_{вых}}$ in the measuring circuits change.

Аннотация.

В данной статье оптоэлектронные дискретные преобразователи (ОДПВ) любого типа продольные или поперечные перемещения внешнего модулирующего тела (ВМТ) преобразуются в изменение параметров светового потока $\mathbf{\Phi_0}$ в соответствующих световодах от сосредоточенными источниками излучений (СИИ) или распределенного источника излучения (РИИ). Далее световые потоки $\mathbf{\Phi_0}$ падая на соответствующие приемник излучения (ПИ) изменяют их параметры и изменяются выходные напряжения $\mathbf{U_{вых}}$ в измерительных схемах.

Annotatsiya.

Ushbu maqolada, har qanday turdagi optoelektronik diskret konvertorlar (OEDT), tashqi modulyatsiya qiluvchi tananing (MQT) bo‘ylama yoki ko‘ndalang siljishlari nurlanish manbalaridan (SNM) mos keladigan yorug‘lik yo‘riqnomalarida $\mathbf{\Phi_0}$ yorug‘lik oqimi parametrlarining o‘zgarishiga aylantiriladi.) yoki taqsimlangan nurlanish manbai (TNM). Bundan tashqari, mos keladigan nurlanish qabul qilgichga (NQQ) tushadigan $\mathbf{\Phi_0}$ yorug‘lik oqimlari o‘z parametrlarini o‘zgartiradi va o‘lchash davrlarida $\mathbf{U_{вых}}$ chiqish kuchlanishlari o‘zgaradi.

Key words: *radiation source, radiation receiver, measuring circuit, optical fiber, optical fibers, operational amplifiers.*

Ключевые слова: *источника излучения, приемника излучения, измерительной схемы, световод, волоконные световоды, операционные усилители.*

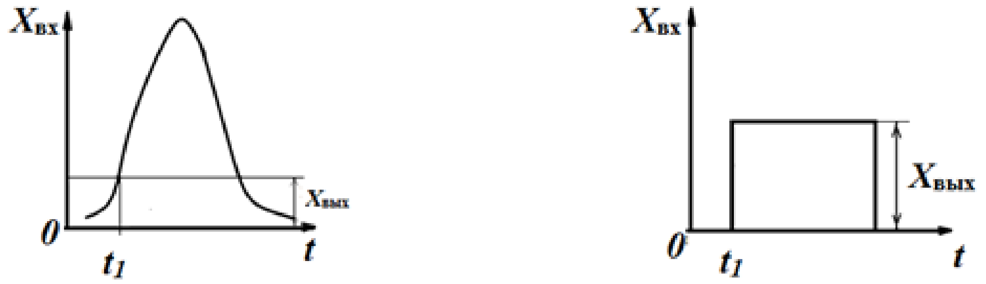
Kalit so'zlar: *nurlanish manbai, nurlanishni qabul qiluvchi, o'lchash sxemasi, optik tola, optik tolalar, operatsion kuchaytirgichlar.*

Introduction

The static characteristic of the ODC is the dependence in the steady state between the values of the input $X_{вх}$ and output $X_{вых}$ signals. A feature of the ODC designs is the presence of the following main elements: radiation source (RS); radiation receiver (RR); light guide (hollow or fiber) (LG); a measuring circuit (MC) with an output signal generator, which, depending on the principle of constructing the ODC, are connected in a certain way to perform the necessary conversion function. Based on the foregoing, it can be stated that the static characteristic of any ODC is determined by the parameters of all these elements, and in the future, the analysis of the static characteristics of the ODC will be carried out both taking into account their mathematical models and the type of measuring circuits [1-4, 7-10].

Methods

In the relay-type ODC, the intermediate continuous signal (Fig. 1, a) is converted into a discrete output signal (Fig. 1, b).



a) b)

Fig.1. Discrete signals of relay type.

In the pulse type ODC, the input signals are converted into a sequence of pulses:

a) b)

Fig.2. Discrete signals of impulse type.

In ODC, an analog-to-digital type signal is converted into a digital output signal based on geometric coding.

Thus, the static characteristic of the ODC is determined by the sequential conversion of the input value into a continuous signal, followed by the conversion into the corresponding discrete signal. For the formation of the static characteristic of the ODC, a significant role is played by measuring circuits in the form of dividing or bridge circuits [4], in the arms of which various radiation receivers are included: photoresistors, photodiodes, and others. For example, in the bridge measuring circuit in Fig. 3c, one of the main arms is a photoresistor with resistance $R_{фр1}$, and a compensation photoresistor $R_{фр2}$ is usually included in the other arm (adjacent) to compensate for various external non-informative influences (for example, changes in ambient temperature, background illumination and other). The other arms of the bridge measuring circuit include constant electrical resistances R_3 and R_4.

To obtain a standard output signal in the measured range in the form of an electric current from *0* to *5* mA or in the form of an electric voltage from *0* to *2* V, the output of the bridge circuit is connected to the input of the operational amplifier OA [5-6, 11].

To calculate the output voltage $\boldsymbol{U_{вых}}$ of the bridge circuit (Fig. 3, c), the following formula is used

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} \frac{\boldsymbol{R}_{\text{фр1}}\boldsymbol{R_4} + \boldsymbol{R}_{\text{фр2}}\boldsymbol{R_3}}{[\boldsymbol{R}_{\text{фр1}} + \boldsymbol{R}_{\text{фр2}}](\boldsymbol{R_3} + \boldsymbol{R_4})}, \quad (1)$$

where: $\boldsymbol{U_M}$ is the supply voltage of the bridge circuit.

In the initial state, the measuring circuit is in equilibrium ***($U_{вых}$=0)***, since $\boldsymbol{R}_{\text{фр1}} = \boldsymbol{R}_{\text{фр2}} = \boldsymbol{R}_{\text{фр3}} = \boldsymbol{R}_{\text{фр4}}$. When the external modulating body is moved, the light flux is redistributed, which leads to a change in the value of $\boldsymbol{R}_{\text{фр1}}$. If $\boldsymbol{R}_{\text{фр1}}$ changes by the value of $\boldsymbol{R}_{\text{фр1}} \cdot \boldsymbol{\varepsilon_1}$, then formula (1) can be rewritten as:

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} \frac{\boldsymbol{R}_{\text{фр1}}(\boldsymbol{1} + \boldsymbol{\varepsilon_1}) + \boldsymbol{R}_{\text{фр2}}\boldsymbol{R_3}}{[\boldsymbol{R}_{\text{фр1}}(\boldsymbol{1} + \boldsymbol{\varepsilon_1}) + \boldsymbol{R}_{\text{фр2}}](\boldsymbol{R_3} + \boldsymbol{R_4})}, \quad (2)$$

where: $\boldsymbol{\varepsilon_1} = {\Delta\boldsymbol{R}_{\text{фр1}}}/{\boldsymbol{R}_{\text{фр1}}}$ – the relative change in the resistance of the shoulder $\boldsymbol{R}_{\text{фр1}}$;

$$\Delta\boldsymbol{R}_{\text{фр1}} = \boldsymbol{R}_{\text{фр1}}(\boldsymbol{x}) - \boldsymbol{R}_{\text{фр1}}(\boldsymbol{x} = \boldsymbol{0})$$

The resistance values $\boldsymbol{R}_{\text{фр1}}(\boldsymbol{x})$ are determined by the characteristic $\boldsymbol{R}_{\text{фр1}} = \boldsymbol{f}[\Phi_{\boldsymbol{0}}(\boldsymbol{x})]$ for specific ODC designs, taking into account changes in $\Phi_{\boldsymbol{0}}(\boldsymbol{x})$ when moving the external modulating body.

Expression (2) can be transformed by dividing successively by $\boldsymbol{R}_{\text{фр2}}$ and $\boldsymbol{R_4}$

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} \frac{\boldsymbol{K\varepsilon_1}}{(\boldsymbol{K} + \boldsymbol{1})(\boldsymbol{K} + \boldsymbol{1} + \boldsymbol{K\varepsilon_1})}, \quad (3)$$

where: $\boldsymbol{K} = {\boldsymbol{R}_{\text{фр1}}}/{\boldsymbol{R}_{\text{фр2}}} = {\boldsymbol{R_3}}/{\boldsymbol{R_4}}$ – the symmetry coefficient of the bridge measuring circuit.

With relatively small changes in the resistance $\boldsymbol{R}_{\text{фр1}}(\boldsymbol{\varepsilon_1} \ll \boldsymbol{1})$, the expression for the static characteristic can be represented as

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} \frac{\boldsymbol{K\varepsilon_1}}{(\boldsymbol{K} + \boldsymbol{1})^2} \quad (4)$$

Similarly, for a dividing circuit (Fig. 1, a), the output voltage $\boldsymbol{U}_{\text{вых}}$, if $\boldsymbol{R_1}$ is the resistance of the radiation receiver (photoresistor or photodiode) is equal to:

$$\boldsymbol{U}_{\text{вых}} = \frac{\boldsymbol{U}_{\text{М}} \cdot \boldsymbol{K\varepsilon_1}}{\boldsymbol{R_1} + \boldsymbol{R_2}} \quad (5)$$

When changing $\Phi_{\boldsymbol{0}}(\boldsymbol{x})$, the resistance of the radiation receiver will change by $\boldsymbol{R_1\varepsilon_1}$ and become equal to $\boldsymbol{R_1}(\boldsymbol{1} + \boldsymbol{\varepsilon_1})$, which leads to a change in $\boldsymbol{U}_{\text{вых}}$

$$\boldsymbol{U}_{\text{вых}} = \frac{\boldsymbol{U}_{\text{М}}}{\boldsymbol{R_1}(\boldsymbol{1} + \boldsymbol{\varepsilon_1}) + \boldsymbol{R_2}}\boldsymbol{R_1}(\boldsymbol{1} + \boldsymbol{\varepsilon_1}) - \frac{\boldsymbol{U}_{\text{М}} \cdot \boldsymbol{R_1}}{\boldsymbol{R_1} + \boldsymbol{R_2}} \quad (6)$$

or

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} \frac{\boldsymbol{k\varepsilon_1}}{(\boldsymbol{k} + \boldsymbol{1})(\boldsymbol{k} + \boldsymbol{1} + \boldsymbol{k\varepsilon_1})}, \quad (7)$$

which is similar to expression (3), that is, the formulas for the bridge and dividing circuits are the same.

If two radiation receivers are included in the arms of the dividing or bridge circuits with a differential design of the ODPC, then under the influence of the input value $\boldsymbol{x_{вх}}$, the resistance of one arm, for example $\boldsymbol{R_1}$, will increase and become equal to $\boldsymbol{R_1}(\boldsymbol{1} + \boldsymbol{\varepsilon_1})$ and the resistance of the arm $\boldsymbol{R_2}$ will decrease and will be equal to $\boldsymbol{R_2(1+\varepsilon_2)}$, then the output voltage formula will take the form (Fig. 3, c):

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} \frac{\boldsymbol{k}}{(\boldsymbol{k}+\mathbf{1})} \cdot \frac{\boldsymbol{\varepsilon_1} + \boldsymbol{\varepsilon_2}}{\boldsymbol{k} + \mathbf{1} + \boldsymbol{k\varepsilon_1} - \boldsymbol{\varepsilon_2}}, \quad (8)$$

at $\boldsymbol{k} \approx \mathbf{1}; \boldsymbol{\varepsilon_1} \ll \mathbf{1}$ и $\boldsymbol{\varepsilon_2} \ll \mathbf{1}$ can be written

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} \frac{\boldsymbol{k}}{(\boldsymbol{k}+\mathbf{1})^2} \cdot (\boldsymbol{\varepsilon_1} + \boldsymbol{\varepsilon_2}) \quad (9)$$

Results and Discussion

An analysis of the characteristics of bridge circuits shows that from the point of view of nonlinearity, circuits with two and four radiation receivers in the arms of the circuits are most preferable (Fig. 3, d).

Due to the fact that the ODC under consideration are used in devices with built-in microprocessors, to match the ODC output with the microprocessor, it is necessary to pre-process the output signal: amplification, output voltage conversion, noise suppression, etc. [12, 13, 15, 18-20].

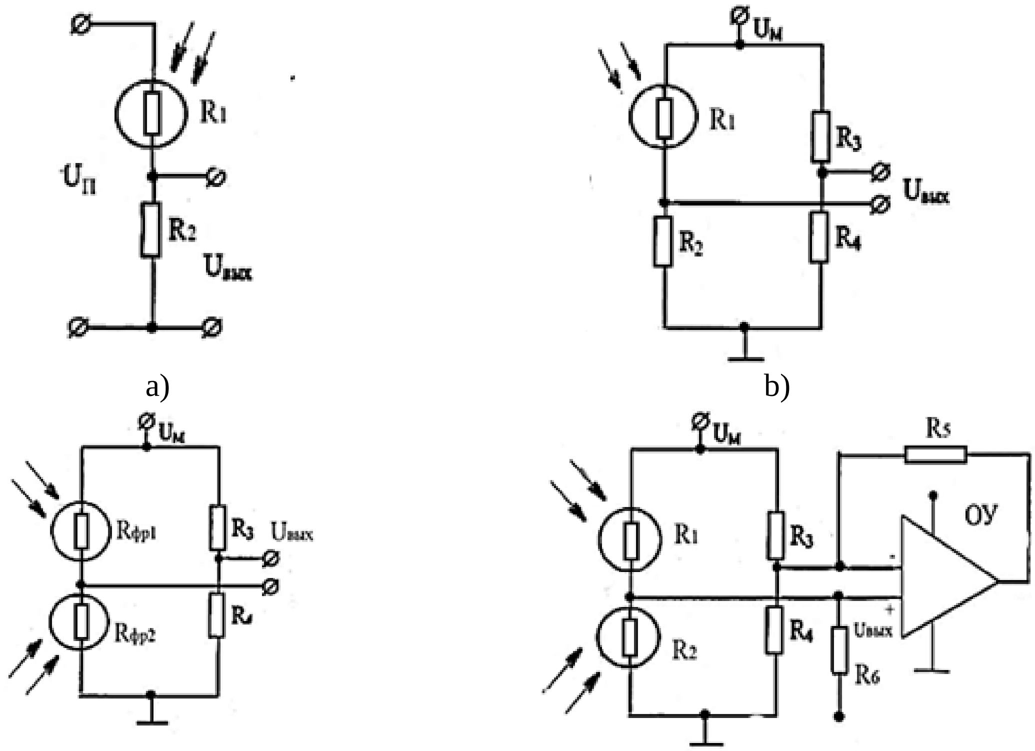
One of the most important elements of the pre-processor processing of ODC signals is the operational amplifiers of the op amp (Fig. 3, d). At the same time, with the help of operational amplifiers, the sensitivity of the static characteristics of the ODC is effectively increased and further converted into a discrete form.

For further calculations, it is necessary to determine the relative values of e1 Depending on the change in the total luminous flux $\boldsymbol{\Phi_0(x)}$, incident on the transducer radiation receiver [14, 16-17, 20].

Let us analyze the dividing measuring circuit shown in Fig. 4, which is similar to the circuit in Fig. 3, a and can be considered as a chain consisting of resistors $\boldsymbol{R_2}$ *and* $\boldsymbol{R}_{\text{фр}\mathbf{1}}$, connected in series, to which the supply voltage $\boldsymbol{U_M}$ is supplied as to the entire bridge circuit. In this case, the voltage $\boldsymbol{U_{вых}}$ on the resistance $\boldsymbol{R}_{\text{фр}\mathbf{1}}$ can be found from the expression:

$$\boldsymbol{U}_{\text{вых}} = \boldsymbol{U}_{\text{М}} - \boldsymbol{I}_{\text{ц}} * \boldsymbol{R}_{\text{фр}\mathbf{1}} = \boldsymbol{R_3} * \boldsymbol{I}_{\text{ц}}, \quad (10)$$

where: $\boldsymbol{U_м}$ - voltage applied to the divider, $\boldsymbol{I_Ц}$ - current in the divider circuit.



v) g)

Fig.3. Measuring schemes of ODC: a - dividing; b, c, d - bridge.

Since the value of the photocurrent $\boldsymbol{I_\phi}$ is a function of the light flux $\Phi_\mathbf{0}(\boldsymbol{x})$**,** incident on the radiation detector and for small values of the light flux this dependence is linear, we can write

$$\boldsymbol{I}_\text{ф} = \boldsymbol{S}_{\text{фр}\mathbf{1}} * \Phi_\mathbf{0}(\boldsymbol{x}), \tag{11}$$

where: $\boldsymbol{S}_{\text{фр}\mathbf{1}}$ - integrated sensitivity $\boldsymbol{R}_{\text{фр}\mathbf{1}}$.

Since the value of the dark current of the radiation receiver $\boldsymbol{I}_\mathbf{T}$ is small compared to $\boldsymbol{I}_\mathbf{ф}$, we can write:

$$\boldsymbol{I}_\text{т} = \boldsymbol{I}_\text{ф} \tag{12}$$

taking into account the latter, we can write:

$$\frac{\boldsymbol{U}_\text{М} - \boldsymbol{I}_\text{ф}\boldsymbol{R}_\mathbf{3}}{\boldsymbol{I}_\text{ф}} = \boldsymbol{R}_{\text{фр}\mathbf{1}} \tag{13}$$

or

$$\frac{\boldsymbol{U}_\text{М}}{\boldsymbol{I}_\text{ф}} - \boldsymbol{R}_\mathbf{3} = \boldsymbol{R}_{\text{фр}\mathbf{3}} \tag{14}$$

Substituting the values $\boldsymbol{I}_\text{ф}$ at $\boldsymbol{x}$=$\boldsymbol{X_{мин}}$ we find the following

$$\frac{\boldsymbol{U}_\text{М}}{\Phi_\mathbf{0}(\boldsymbol{X}_\text{мин})} - \boldsymbol{R}_\mathbf{3} = \boldsymbol{R}_{\text{фр}\mathbf{1}}(\boldsymbol{X}_\text{мин}) \tag{15}$$

at $\boldsymbol{x}$=$\boldsymbol{X}$,

$$\frac{\boldsymbol{U}_\text{М}}{\Phi_\mathbf{0}(\text{X})} - \boldsymbol{R}_\mathbf{3} = \boldsymbol{R}_{\text{фр}\mathbf{1}}(\text{X}) \tag{16}$$

From here we can write an expression for $\Delta\boldsymbol{R}_{\text{фр}\mathbf{1}}$:

$$\Delta\boldsymbol{R}_{\text{фр}\mathbf{1}} = \boldsymbol{R}_{\text{фр}\mathbf{1}}(\boldsymbol{X}_\text{мин}) - \boldsymbol{R}_{\text{фр}\mathbf{1}}(\text{X}) = {}^{\boldsymbol{U_m}}\!/\!_{\boldsymbol{S}_{\text{фр}\mathbf{1}}} * \left[{}^{\mathbf{1}}\!/\!_{\Phi_\mathbf{0}(\boldsymbol{X}_\text{мин})} - {}^{\mathbf{1}}\!/\!_{\Phi_\mathbf{0}(\text{X})}\right], \tag{17}$$

and

$$\boldsymbol{\varepsilon}_\mathbf{1} = \Delta\boldsymbol{R}_{\text{фр}\mathbf{1}} - \boldsymbol{R}_{\text{фр}\mathbf{1}}(\boldsymbol{X}_\text{мин}) = {}^{\mathbf{1} - \Phi_\mathbf{0}(\boldsymbol{X}_\text{мин})}\!/\!_{\Phi_\mathbf{0}(\text{X})} * {}^{\mathbf{1}}\!/\!_{\left\{\mathbf{1} - \boldsymbol{S}_\mathbf{1} * \Phi_\mathbf{0}(\boldsymbol{X}_\text{мин}) * {}^{\boldsymbol{R}_\mathbf{3}}\!/\!_{\boldsymbol{U}_\text{М}}\right\}} \tag{18}$$

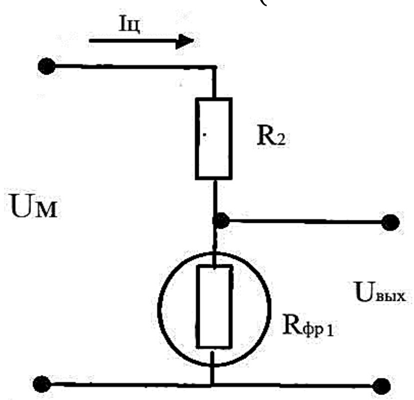


Fig.4. Dividing measuring scheme of ODC.

$$\boldsymbol{U}_\text{вых} = \boldsymbol{U_n}\frac{\boldsymbol{K}}{(\boldsymbol{K}+\mathbf{1})^\mathbf{2}} \cdot \frac{\Delta\boldsymbol{R}_\text{фр}}{\boldsymbol{R}_\text{фр}} \tag{19}$$

$\boldsymbol{K}$ – the symmetry factor of the bridge.

Let us consider the static characteristic of the ODC with CRS and a hollow fiber during the longitudinal movement of the EMD, the physical model of which is shown in Fig. 5 when it is used to control the discrete level of the liquid in the reservoir [5, 6, 8, 9].

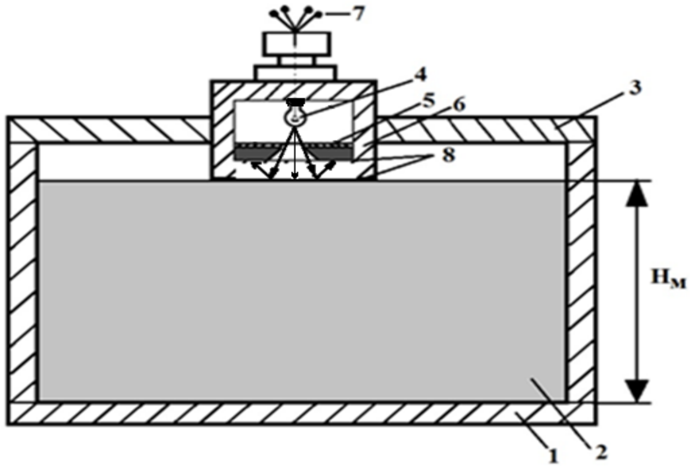


Fig.5. ODC based on a hollow fiber for discrete control of the maximum liquid level. 1 - reservoir; 2 - liquid; 3 – reservoir cover; 4 – radiation source; 5 – radiation receiver; 6 – hollow fiber; 7 - output wires; 8 - protective glass.

Research and calculation according to the formulas $\boldsymbol{\Phi_{\sum}=\Phi_{np1}+\Phi_{omp2}}$ and $(\boldsymbol{x}) = \boldsymbol{S}_{\text{сектора}} - \boldsymbol{S}_{\Delta}$ showed that the graph of the change in the static characteristic $\boldsymbol{\Phi_0=f(H)}$ has the form shown in Fig. 6, a.

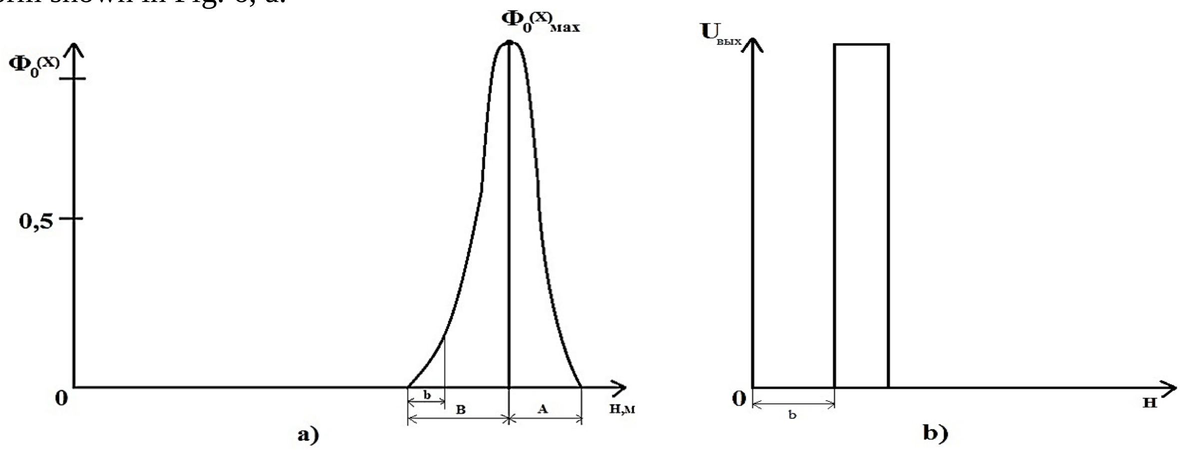


Fig.6. The static characteristic of the ODC (*a*) and its discrete form (*b*) for controlling the maximum liquid level.

Section A (Fig. 6, a) of the static characteristic was $\boldsymbol{4\cdot10^{-3}}$m, and section B was $\boldsymbol{6\cdot10^{-3}}$m. The sensitivity of the transducer based on the ODC is determined from expression (20).

$$К = \frac{\pi D_0^2}{2x_0}\left(1 + \frac{x}{x_0}\right), \qquad (20)$$

An analysis of formula (20) shows that in order to increase the sensitivity of the ODPC based on a hollow fiber, it is necessary to increase $\boldsymbol{D_0}$ and decrease $\boldsymbol{x_0}$.

Conclusion

The static characteristics of optoelectronic discrete converters are determined on the basis of joint consideration, the designs of converters with hollow and fiber light guides and the corresponding measuring circuit with a radiation receiver. It is shown that dividing and bridge measuring circuits are mainly used in optoelectronic discrete displacement transducers.

The static characteristics of relay optoelectronic discrete converters with lumped radiation sources based on hollow and fiber light guides are obtained for longitudinal and transverse displacements of the external modulating body.

References:

1. Kholmatov U. Intelligent discrete systems for monitoring and control of the parameters of technological processes on the basis of fiber and hollow fiber //Monograph.– 2022.–C. – 2022. – С. 5-114

2. Шипулин Ю. Г. и др. Оптоэлектронный преобразователь для автоматических измерений перемещений и размеров //Мир измерений. – 2013. – №. 1. – С. 41-43.

3. Kholmatov U. S. et al. Characteristics of optoelectronic discrete displacement converters with hollow and fiber light guides //E3S Web of Conferences. – EDP Sciences, 2024. – Т. 471. – С. 06015.

4. Алматаев О. Т. и др. Оптоэлектронные преобразователи рефлективного типа для автоматизации жидкостных и газовых поверочных расходомерных установок //Механика. Научные исследования и учебно-методические разработки. – 2014. – №. 8. – С. 27-34.

5. Хамдамов Б. М. и др. Интеллектуальный оптоэлектронный прибор для контроля расхода воды в открытых каналах //Наука. Образование. Техника. – 2015. – №. 2. – С. 72-82.

6. Жумаев О. А. и др. Задачи разработки и проектирования оптоэлектронных преобразо вател ей для газомерных установок //Вестник Курганского государственного университета. – 2015. – №. 3 (37). – С. 113-116.

7. Азимов Р. К. и др. Морфологический метод структурного проектирования оптоэлектронных преобразователей на основе полых и волоконных световодов (ОЭГТВС) //Современные материалы, техника и технологии в машиностроении». III Международная научно-практическая конференция. – 2016. – С. 15-19.

8. Kholmatov U. The possibility of applying the theory of adaptive identification to automate multi-connected objects //The American Journal of Engineering and Technology. – 2022. – Т. 4. – №. 03. – С. 31-38.

9. Холматов У. С. Исследования математической модели волоконно-оптического датчика при продольном и поперечном перемещениях //научно-технический журнал машиностроение. – 2022. – №. 1. – С. 78-85.

10. Kholmatov U. Optimization of mathematical model of optoelectronic discrete displacement converter //scientific and technical journal machine building. – 2022. – №. 2. – С. 74-82.

11. Kholmatov U. Determination of the main characteristics of optoelectronic discrete displacement transducers with hollow and fiber fiber //scientific and technical journal machine building. – 2022. – №. 4. – С. 160-168.

12. Холматов У. С. Определение основных и статические характеристики оптоэлектронных дискретных преобразователей перемещений с полыми и волоконными светов //Научно-технический журнал машиностроение. – 2022. – №. 5. – С. 711-719.

13. Холматов У. С. Определение основных теории адаптивной идентификации для автоматизации многосвязных объектов //Namangan muhandislik texnologiya instituti ILMIY-TEXNIKA JURNALI. – 2022. – №. 1/7. – С. 544-550.

14. Шипулин Ю. Г., Холматов У. С. Интеллектуальные дискретные системы для контроля и управления параметрами технологических процессов на основе волоконных и полых световодов //Монография, Андижан.–2018.–C. – 2018. – С. 1-140.

15. Холматов У. С. Анализ шумовых факторов в волоконных и полых оптических датчиках информационно-измерительных систем //Технология новых материалов: перспективы развития полимерных композиционных материалов, применяемых в машиностроении». Международной научно-практической конференция, Андижан. – 2022. – С. 197-201.

16. Холматов У. С. Статические характеристики оптоэлектронных дискретных преобразователей для автоматического измерения перемещений и размеров //научно-технический журнал машиностроение. – 2023. – №. 2. – С. 190-201.

17. Холматов У. С. Расширение теории адаптивной идентификации применительно к многосвязным объектам //научно-технический журнал машиностроение. – 2023. – №. 1. – С. 376-382.

18. Холматов У. С. Характеристики основных теории адаптивной идентификации для автоматизации многосвязных объектов //International Journal of Education, Social Science & Humanities. – 2024. – Т. 12. – №. 4. – С. 1360-1369.

19. Холматов У. С. Основы характеристики теории адаптивной идентификации для автоматизации многосвязных объектов //International Journal of Education, Social Science & Humanities. – 2024. – Т. 12. – №. 5. – С. 1515-1523.

20. Zhumaev O. A. Et al. Problems of optoelectronic transducers for gas-measuring installations design and development //вестник. – С. 113.