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Method for Determining the Measurement Error of Humidity Sensors

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ABSTRACT: In this article, a technique is given for assessing the additional measurement error of an optoelectronic air humidity sensor, an analysis of the errors in measuring humidity from changes in temperatureand supply voltage and external radiation are made.

KEY WORDS: Air humidity, additional error, error from temperature changes, error from changes in supply voltage, error from changes in external radiation.

I.INTRODUCTION

Let us consider a method for evaluating an additional error using the example of an optoelectronic air humidity sensor.

As you know, the temperature and humidity conditions of the environment in silk-weaving production premises change over time, i.e.air temperature and humidity can even exceed the established values for these rooms, which will lead to disruption of the technological process [2].

In the processes of twisting silk threads and silk weaving, up to several thousand thread breaks occur. The elimination of such a mass of cliffs takes a significant amount of time for the majority of workers [3].

Maintaining the parameters of the air environment (temperature, humidity) at the required level contributes to the normal course of technological processes of twisting threads and weaving [2].

It is also known, like any measurement, measurement of air humidity, accompanied by the introduction of errors in the measurement result.As you know, there are basic and additional errors [1].

In this paper, the question of determining the additional error from changes in temperature, supply voltage and external radiation is considered.

It is possible to estimate these errors theoretically, but this requires the involvement of a rather complex mathematical apparatus. Therefore, a graphical-analytical method for calculating errors from these three factors is proposed here.

To calculate the measurement error from temperature changes, it is necessary to remove the current-voltage characteristic (VAC), the power characteristic of the emitting diodes and the static characteristic of the photoresistor at normal (200C) and limiting temperatures (for example, at 400C).

Figure 1 shows approximate characteristics:

a) current-voltage characteristic;
b) power characteristic of emitting diodes;
c) static characteristics of the emitting LED and photoresistor.

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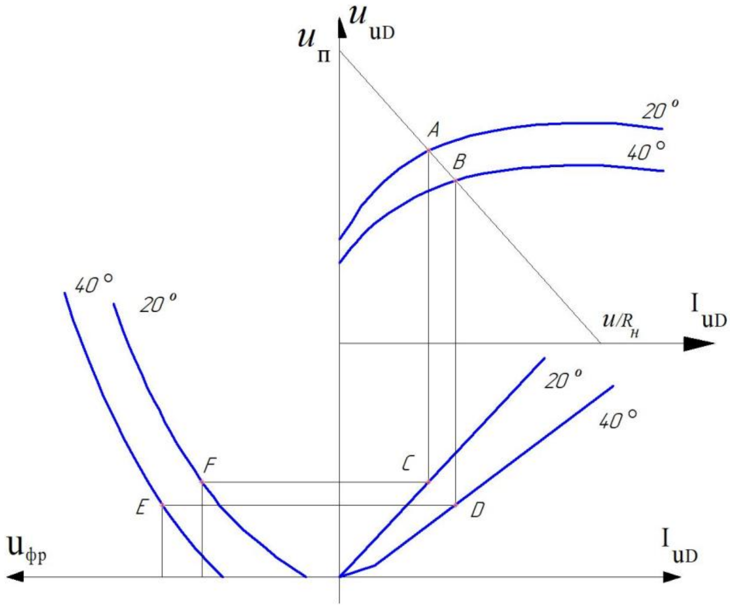

Fig. 1. Volt-ampere (a), power (b) and static (c) characteristics of the emitting diode and photoresistor.

In Fig. 1.a, a load line is drawn, which intersects with the voltage axis at a point whose value is equal to the supply voltage U_p, and with the current axis - at a point with a current value equal to U_p / R_n.This line intersects with the current-voltage characteristic of the emitting diode at points A and B. Through the points we draw straight lines parallel to the ordinate axes, until they intersect with the power characteristics of the emitting diode (points C and D).Then we draw straight lines from these points until they intersect with the static characteristics of the photoresistor (points E and F).If now from these points we draw straight lines perpendicular to the stress axis, then we can determine the change in the photosignal ΔU_ph as a result of the temperature change. The error determined in this case is the absolute error.

In this way, it is possible to determine the absolute errors of photosignals for both channels $\Delta U_{\Phi\Pi_{из.t^0}}$ and $\Delta U_{\Phi\Pi_{оп.t^0}}$.

The relative error in measuring humidity from temperature changes is determined by the formula:

$$\delta = \frac{W_{д} - W_{из}}{W_{д}} \qquad (1)$$

where:

W_д - actual value of humidity;
W_from - measured value of humidity.

In turn, these values are defined as:

$$\Delta W_{д} = к\frac{U_{\Phi\Pi} - aU_{\Phi\Pi_{оп}}}{U_{\Phi\Pi_{оп}}} \qquad (2)$$

$$W_{из} = к \cdot \frac{U_{\Phi\Pi_{из}} + \Delta U_{\Phi\Pi_{из.t^0}} - a(U_{\Phi\Pi_{оп}} + \Delta U_{\Phi\Pi_{оп.t^0}})}{U_{\Phi\Pi_{оп}} + \Delta U_{\Phi\Pi_{оп.t^0}}} \qquad (3)$$

Substituting (2) and (3) into formula (1) we get:

$$\delta = 1 - \frac{U_{из}U_{оп} + \Delta U_{из}U_{оп} - a \cdot U_{оп}^2 - a\Delta U_{оп}^2}{U_{из}U_{оп} - \Delta U_{из}^2 - aU_{оп}^2 - a \cdot \Delta U_{оп}^2} \qquad (4)$$

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Now, substituting the calculated values$\Delta U_{\Phi\Pi_{из.t^0}}$ and $\Delta U_{\Phi\Pi_{on.t^0}}$ into the formula, we can calculate the relative error$\delta_{t^0}$from temperature changes.

The error due to changes in the supply voltage can be calculated as follows.

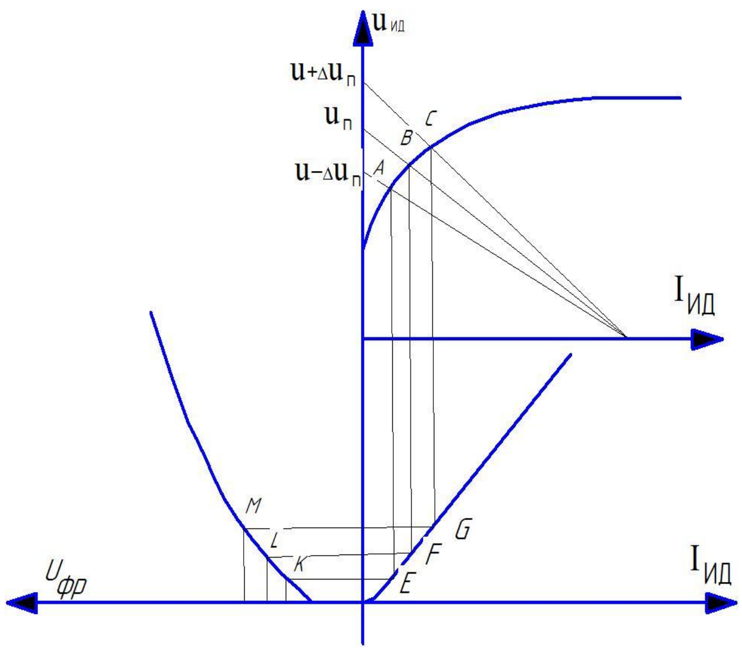

Fig. 2. Volt-ampere (a), power (b) and static (c) characteristics of the emitting diode and photoresistor.

On the voltage axis (Fig. 2) we mark the points U_p + ΔU_p and U_p – ΔU_p, where ΔU_p is the instability of the power supply voltage.Through these points and point U_п / R_н we draw additional load lines.From the points of intersection A, B and C, we omit the straight lines parallel to the abscissa axis until they intersect with the power characteristic of the emitting diode (points E, F and G). Further, from these points we draw straight lines until they intersect with the static characteristic of the photoresistor (points K, L and M).From the two obtained errors ΔU_п we choose the larger one.Using this technique, the absolute errors$\Delta U_{из.U_n}$and $\Delta U_{on.U_n}$ for both channels are determined and then the relative error $\delta_{U_n}$of moisture measurement from the instability of the supply voltage is calculated using the formula (4).

To determine the error due to the presence of external radiation, let us refer to Fig. 3.

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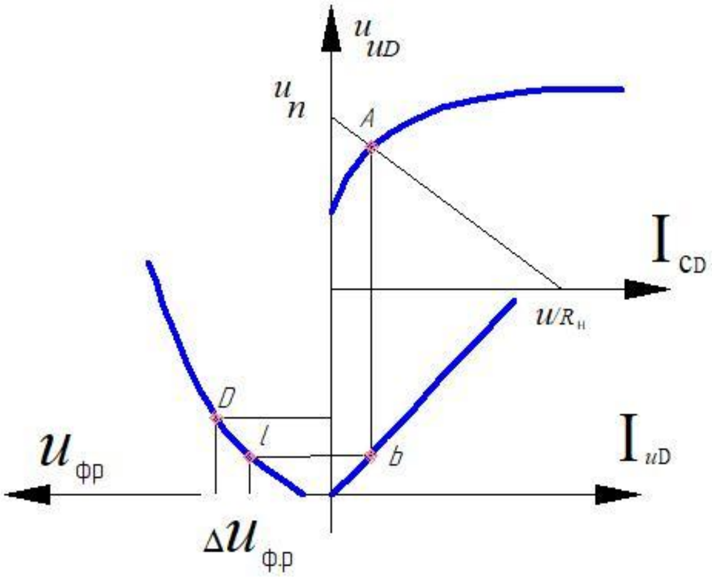

Fig. 3.Volt-ampere (a), power (b) and static (c) characteristics of the emitting diode and photoresistor.

In this figure, point C is found on the static characteristic of the photoresistor and point D in the presence of external radiation. From the graph it is now easy to determine the absolute error $\Delta U_{\Phi P}$ due to external radiation.Determining $\Delta U_{\Phi_{из.р}}$ and $\Delta U_{\Phi_{оп.р}}$for each channel and substituting them into formula (4), you can calculate the relative error in measuring humidity from the presence of external radiation.

Assuming that each source of error occurs randomly in time and is independent of the others, the resulting error in moisture measurement can be determined based on the formula:

$$\delta = \sqrt{\delta_{uu}^2 + \delta_{\phi n}^2 + \delta_D^2 + \delta_{uc}^2} \qquad (5)$$

where:

δ_{uu} −error of radiation sources;
$\delta_{\phi n}$ −photodetector error;
δ_D −additional errors;
δ_{uc} − is the error of the measuring circuit.

This expression makes it possible to determine the value of the root-mean-square error.
The entropy error of an optoelectronic humidity sensor is defined as:

$$\Delta_э = K_э\delta = 2{,}07 \cdot \delta \qquad (6)$$

where: K = 2.07 - entropy error coefficient.

Thus, as a result of the application of this research method, analytical expressions were obtained to assess the error of the device.

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