UDC 621.317.72

J.V.Vitruk, Ph.D. (National Aviation University, NTUU "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine)
D.P.Ornatsky, doctor of science (National Aviation University Ukraine)

Automatized airfield meteorological station for temperature measurements.

The structural scheme of the measuring channel for remote measurements of environmental parameters at distances up to several kilometres is proposed. The results of the comparative analysis with the existing technical solutions and the results of the simulation of the proposed measuring channel are presented.

1. Introduction and problem statement

The current stage of development of civil aviation is characterized by an increase in air traffic intensity. The requirements for ensuring flight safety are constantly increasing. Support for a given level of flight safety, as defined by the ICAO International Civil Aviation Organization documents, depends on many factors, among which one of the main is the meteorological conditions that affect flight performance, take-off, and landing of the aircraft.

The weather causes numerous problems for air transport. According to ICAO, over the past 25 years, adverse weather conditions have been officially recognized as the cause of 6 to 20% of aviation incidents. In addition, even in a larger (one and a half times) number of cases, they were an indirect or concomitant cause of such events. Therefore, obtaining accurate and reliable meteorological information is essential for each airport.

Table 1 presents the requirements for the metrological characteristics of the measuring parameters.

Table 1

Meteorological Measurement Channels	Measurement Range	Limits of Permissible Error
Air temperatures	from 45 to + 55 ° C	± (0,1 + 0,005 [t])
Relative humidity of air	is 0,8 100%	± 4% (0,8-90); ± 5% (> 90)
Atmospheric pressure	600 - 1100 GPa	± 0,3 GPa
Air velocity	0.5 - 60 m/s	± (0.4 ± 0.035 V)
Direction of air flow	0-360°	± 3°
Height of clouds	0 - 7500 m	± 10 m
Meteorological optical range	7.5 - 50000 m	from 10% to 20%
Precipitation amounts	0 - 200 mm	± (0,5 + 0,2/M)

Direct proximity to the runway contributes to the increase of the level of all components of the noise spectrum, which increases the requirements for the impedance of the measuring channel.

Requirements for suppression of interferences: the general type - about 140-160 dB, the normal type of order 60-80 dB, at a speed of 8-10 measurements per second, are quite high, which is due to a significant length of the communication line (up to several kilometers).

2. Analysis of the research and publications

[1] presents the implementation of a measuring channel for remote measurement of temperature using the standard measuring instruments of the family 7B (National Instruments (NI)), the feature of which is the direct conversion of the measuring signal into a unified signal format 4..20mA.

The main drawbacks of this solution are a significant error (about 0.5%) due to the accumulation of errors from the three, serially connected, measuring converters that form the measuring channel, the metrological characteristics are given in Table 2. In this case, the factor of suppression of interferences of the general type is provided at 160 dB, thanks to the "isolation" of each module, and the noise of a normal type of order of 60 dB, at a speed of 9 measurements per second, which may prove to be inadequate since the amplitude of the interference can reach several hundred milivolts.

Table 2

Measuring transducer	Basic error	Nonlinearity error	Input range	Output signal range
Resistance-voltage 7B-34	0,15%	0,05%	Pt100, -100°C..+100°C	1-5 V
Voltage-current– 7B-39	0,1%	0,02%	1-5 V	4-20 mA
Current voltage – 7B-32	0,1%	0,02%	4-20 mA	1-5 V

The resident portion of the measuring channel consists of 7V-34 and 7V-39 converters, which require power supply from a separate 24 V DC unit.

[2] presents the implementation of a measuring channel for remote measurement of temperature with platinum resistance thermometers in the range of -100 ° C .. + 100 ° C, using unified measuring converters of the family 6B, the feature of which is the use of digital signals for the transmission of measuring information. The system provides sufficiently high metrological characteristics: the basic error is 0.02 ° C (typical value), the maximum error of 0.15 ° C, which satisfies the requirements, but does not provide transmission over a distance of more than 1200 meters, both with and without the use of modems , besides this ratio of suppression of interferences of the general and normal type is similar to the family of 7V, and power supply also needs a separate network.

3. Formation of purpose (task setting)

The purpose of this work is to create a measuring channel for remote measurement of output signals of resistance thermometers with improved technical and economic indicators.

4. Presentation of the main material

The authors propose a structural scheme of the measuring channel (Fig. 1), the feature of which is the use of narrowband PWM and effective linearization of the sensor transformation function, which allows for the continuous correction of the systematic component of the error of the entire measuring channel by two points.

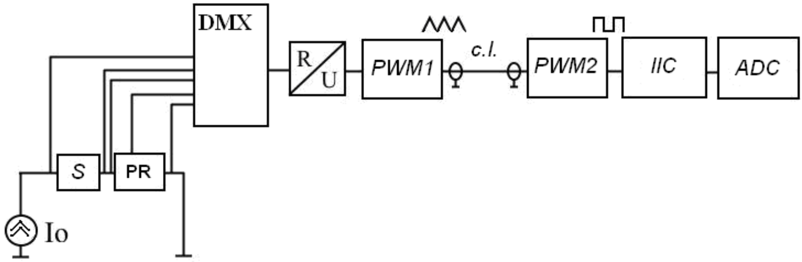

Fig.1 The block diagram of the measuring channel

The resident part of the measuring channel consists of: sensor - S (platinum resistance thermometer Pt100), I0 - source of current sensor initialization, PR- precision resistors, DMX - dual multiplexer with differential inputs and outputs, R/U - measuring transducer of resistance to voltage, PWM1 is a pulse-width modulator that has an output stage (common collector) that modulates the current in a two-wire communication line (c.l.) (On which the power supply is also transmitted) in accordance with a modulating function that has the form of an asymmetric triangular voltage, the coefficient of asymmetry of which is an informative parameter.

Reception part contains: demodulator of pulse-width signals - PWM2, iterative integrating converter - IIC, analog-to-digital converter - ADC. PWM2 consists of a serially coupled differentiator and a comparator. The output of the latter is controlled by an electronic switch, which connects the IIC input to the outputs of the source of the bipolar exemplary voltage. Thus, at the output of the IIC, a recovered input signal is formed.

The method of "positive" feedback today is widely used to correct the error of nonlinearity of platinum resistance thermometers due to its ease of implementation and high efficiency. But known implementations such as XTR-103 (Burr-Brown) and [3] have the following metrological limitations: in the first case, they are due to the fact that for the correction of the error of non-linearity, two identical controlled source of current of the sensor initialization current are used (that makes sense only when voltage limits are used), in the second case a circuit with a resistive summator of currents is used, which reduces the efficiency of the correction. Fig. 2 shows the functional diagram of the measuring transducer of the resistance increase of the sensor in the voltage, which is devoid of the above-mentioned shortcomings. Differential output signal Uout is formed by two identical instrumentation amplifiers (IA-1, IA-2). The linearization of the transformation function of the platinum resistance thermometer Rs(t°C) occurs by modulating the current of initialization of the sensor by the output voltage of the converter (Uout) using an inverting adder on the OA1 operational amplifier and the corresponding choice of the "positive" feedback R* resistor.

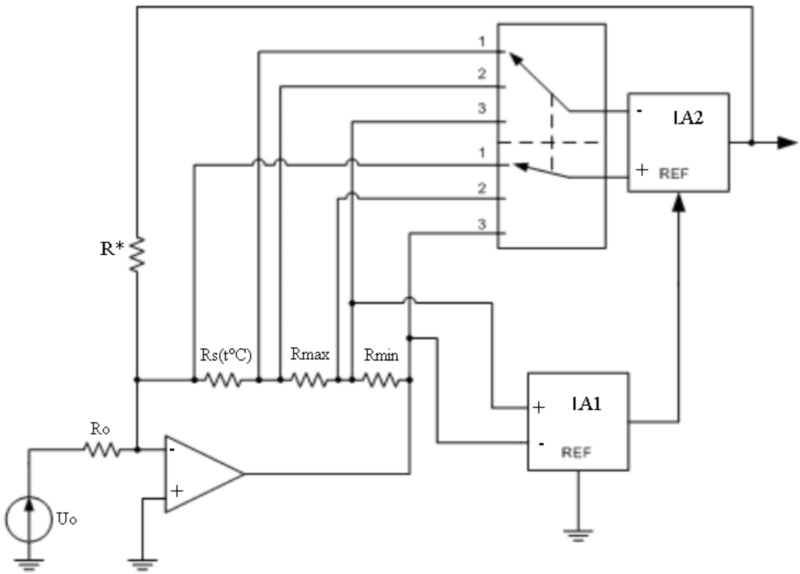

Fig.2 Functional diagram of the measuring transducer of the gain of the resistance in the voltage

By implementing the method of model measures, correction of the systematic components of the error of the measuring channel is carried out. To do this, using the DMX multiplexer, the voltage drop or the Rs(t°C) sensor, or the Rmax that corresponds to the resistance value of the sensor at maximum temperature, or Rmin, corresponding to the resistance value at the minimum temperature, is connected to the input of the instrumentation amplifier IA-2 .Since the transformation function of the measurement transformation will be linear in relation to the temperature, the output voltage can be calibrated directly in units of temperature measurement, that is, in degrees Celsius (° C).A computer electronic model was constructed in the Electronic Workbench environment and the results of its work are presented in Table 3 in the range -50 ° C ... +100 ° C.

Table 3

t,°C	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100
$R_S(t)$, Ohm	80,31	84,27	88,22	92,16	96,09	100	103,9	107,79	111,67	115,54	119,4	123,24	127,07	130,89	134,7	138,5
U_{OUT}, mV	-195,43	-156,36	-117,27	-78,16	-39,04	0,002	39,06	78,133	117,22	156,33	195,45	234,48	273,52	312,58	351,66	390,74

On the basis of the obtained data, a class of accuracy of the measuring transducer temperature-voltage was determined. For this purpose, using the method of least squares, coefficients of the transformation function in the form of linear regression were obtained. In our case, the number of measurements is m = 16, the coefficient a = -0,013 and b = 3.9078. The sum of the squares of deviations is 0.015. The ideal value of these coefficients a* = 0 and b* = 3.9083.

Then the additive given error δ will be equal to:

$$\delta = \frac{a - a^*}{U_{OUT\max} - U_{OUT\min}} \cong \frac{-0.013}{600} \cdot 100\% = -0.002\%$$

Multiplicative error:

$$\gamma = \left(\frac{b}{b^*} - 1 \right) \cdot 100\% = \left(\frac{3.9078}{3.9083} - 1 \right) \cdot 100\% \cong -0.01\%$$

The mean square value of the reduced random component of the error σ:

$$\sigma = \frac{\sqrt{\frac{\sigma_b^2}{m-1}}}{U_{OUT\max} - U_{OUT\min}} \cdot 100\% \cong 0.005\%$$

To perform more accurate calculations a mathematical-software model was developed in the environment of Mathcad. According to the results of this model, the optimum value of the transfer coefficient of the measuring amplifier A_{IA} = 9.87426 and R* = 25509 Ohm was obtained. At the same time, the maximum error at the end of the scale was $1.7 \bullet 10^{-4}$%, which is seven times less than in the method proposed in [3].

5. Conclusions

It was proposed to use narrowband PWM to transmit measuring information over a long distance (up to several kilometers), which allowed obtaining high linearity and blocking the security of the entire measuring channel, and as a result the possibility of its correction by two points.

In order to minimize the methodological error, computer simulations in Mathcad environment were calculated for A_{IA} and R*, at which the error decreased by 7 times compared with known methods.

References

1. Modular, Compact Process Control Signal Conditioners 7B Series, Analog Devices.

2. Distributed Signal Conditioning and I/O Modueles 6B Series, National Instruments.

3. Rathlev J. Линеаризующая схема для платинового термометра, журнал «Экспресс-информация» серия «Контрольно-измерительная техника», ВНИНТИ, випуск №2, - 1978, ст.13-16.