Multichannel measuring device with two switches

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Abstract. The paper presents a scheme of a multichannel measuring device with two switches for temperature control on board of the spacecraft. This scheme is based on the multiplicative use of switches, which provides a much more measurements compared to analogues with two separate switches.

1. Introduction

Operational temperature control on board of the spacecraft ensures the possibility of timely and correct response to the occurrence of normal and emergency situations. At elevated temperatures, the electrical parameters of electronic devices deteriorate, and undesirable physical and chemical processes in the materials and structures of components are accelerated, which can lead to the failure of an electronic product.

The thermal regime of electronic components is one of the determining factors for their performance. Many years of experience in testing electronic equipment in the space industry have shown that the most failures are associated with thermal effects on the equipment [1]. Various temperature deviations can be associated with the presence of certain internal defects (for example, short circuit, poor-quality connection, lack of contacts or breaks, inconsistency of technical parameters). However, according to experts, more than half of the failures and malfunctions in the operations of spacecraft onboard equipment are caused by the unfavorable effects of space factors (flows of high-energy electrons and ions, cold and hot cosmic plasma, solar electromagnetic radiation, meteoric matter and other factors) [2].

For temperature control, contact sensors located on the printed circuit board are used, namely, thermistors, temperature resistance detectors, thermocouples, resistance-diode and other built-in structures [3-7]. When working in extreme, hard-to-reach and aggressive environments, in particular, in outer space, the number of wires and elements of the measuring device should be minimal. Previously, we proposed several constructions for measuring the temperature on board of spacecraft, which make it possible to obtain fairly accurate values of overheating and determine their location [8-11].

In this paper, we propose a multichannel measuring device with two switches. Its peculiarity consists in the possibility of a significantly large number of measurements in comparison with two separate switches.
2. The scheme of measuring device
The proposed scheme of the measuring device is presented in Figure 1. The following notation is used in the diagram: $E$ is the direct current (DC) source; $A$ is the ammeter; $D_{ij}$ ($i=1,m, j=1,n$) are diodes; $R_{ij}$ are thermistors with resistance depending on local temperature; $K_1, K_2$ are switches with lockable contacts $K_{1,i}, K_{2,i}$.

![Figure 1. Multichannel measuring device.](image)

The circuit consists of $m$ identical blocks. Each $i$-th block ($i=1,m$) contains $n$ parallel branches $P_{ij}$ with numbers $j=1,n$; each of them contains a diode $D_{ij}$ as a load and the resistor $R_{ij}$; the second end is connected to the $j$-th ends of the remaining blocks connected by the contact $K_{2,j}$.

The device operates as follows. Switch $K_1$ closes to one of $m$ blocks with number $i$, while switch $K_2$ closes to one of $n$ channels with number $j$ at the output of the circuit. The current from the DC voltage source $E$ passes through the ammeter $A$, enters one of the $m$ blocks and goes along the branch $P_{ij}$ in the direction of the open diode $D_{ij}$ closed to the switch $K_2$. In all other branches of $P_{rs}$, where $r\neq j$ or $s\neq j$, the current direction corresponds to the closed diode $D_{rs}$, and makes a negligible contribution to the total current through the ammeter.

Thus, we get a closed circuit, which allows one to measure the resistance of the thermistor $R_{ij}$. After that, the temperature of the thermistor is determined by its nameplate temperature dependence $T=F(R)$.

To increase the accuracy of determining the resistance in the case of a large number of branches and diodes, a system of linear algebraic equations of nodal potentials is constructed and the sought resistance values are increased by iterative method for solving this system [12].

The number of possible measurements represented by this switching device is $m\cdot n$. Previously used devices with two separate switches provide the number of measurements $m+n$. At $m \approx 30$ and $n \approx 30$, two switches provided $m+n \approx 60$ measurements. This proposed switching device allows $m\cdot n \approx 900$ measurements which corresponds to 30 separate switches.

Consider the results of an experiment demonstrating the performance of the proposed multiplicative switch.
Figure 2. Multi-channel measuring device 3×3.

The figure uses the notation from previous description with \( i = \overline{1,3}, \ j = \overline{1,3} \). Here switch \( K_1 \) is closed to contact \( K_{1.1} \); switch \( K_2 \) is closed to contact \( K_{2.1} \). With this configuration of the circuit, the ammeter \( A \) will show the current in the circuit \( P_{1,1} \), which will allow calculating the resistance of the thermistor \( R_{1,1} \) and obtaining the temperature value on it.

For the experiment, the voltage of the DC supply was taken \( E = 27 \ V \) (onboard voltage). Instead of thermistors, resistors were used in the experiment. Measured resistance of resistors is \( R_{i,j} = 3.6 \ k\Omega \).

Silicon diodes HER203 were selected for the experiment. Ammeter \( A \) showed the current strength \( I_{1,1} = 7.35 \ mA \), the voltage across the resistor \( R_{1,1} \) was \( U_{1,1} = 26.57 \ V \). Thus, according to Ohm's law, the resistance of the resistor \( R_{1,1} = 3.61 \ k\Omega \) (with a measured 3.6 kOhm) can be found. The voltage across the rest of the resistors turned out to be zero, which indicates that the diodes used do not allow perceptible reverse currents.

3. Conclusion

The temperature measurement circuit described in this work are of significant interest for solving the problem of operational control of thermal conditions of on-board electronic equipment.

In the experiment considered in this work, it was shown that for a small number of circuit branches, the reverse currents passing through the diodes are not perceptible (they are not recorded by measuring instruments). Therefore, in this case, the resistance of the thermistor is determined quite accurately. However, with a large number of the measuring circuit branches and perceptible reverse currents of the diode, a system of linear algebraic equations of nodal potentials is constructed and the desired resistance values are obtained by an iterative method from the solution of this system.
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