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Electrothermal Models of Structural Elements of Radioelectronic Device

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Abstract—The paper considers basic features of thermal processes in structural modules of radioelectronic device (cell, microassembly) and elements of their electronic structure. The efficiency factors of modules and the indicators of energy performance of resistors, capacitors, and inductors were analyzed on the basis of models of equivalent two-pole networks. The mathematical model of microassembly thermal field was proposed and the analytical equation for determining temperatures of all its elements was derived.

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PROBLEM STATEMENT

The operation of radioelectronic device (RED) results in the creation of a set of related physical quantities representing output characteristics $\mathbf{Y}_m$ of vector $\mathbf{Y} = [\mathbf{Y}_1, \ldots, \mathbf{Y}_m, \ldots, \mathbf{Y}_t]$, where "T" is the transpose operator [1]. Components of vector $\mathbf{Y}$ are the output signals of video path or audio frequency channels, amplitudes of vibrations of RED unit on vibration isolators, and temperatures of electronic structure elements (ESE).

The internal physicochemical processes occurring in RED and represented by vector $\mathbf{P} = [\mathbf{P}_1, \ldots, \mathbf{P}_j, \ldots, \mathbf{P}_q]^{\mathrm{T}}$ produce a significant impact on the RED performance. These internal processes can be divided into two groups: group $\mathbf{P}_1$ includes the main processes and group P_2 consists of derivative processes caused by the action of the main ones.

Processes $\mathbf{P}_1$ include the following ones: amplification, generation, transmission and reception of radio and information signals; signal conversion (digital-to-analog, analog-to-digital, frequency conversion, and conversion in terms of phase); withdrawal of mechanical energy from the structural modules of RED by using vibration isolators; origination of mechanical stresses in structural design elements during deformations; and heat mass exchange. General energy consumption for the specified processes within the entire RED amounts to 10–25%.

Nonideality of processes in the first group leads to the appearance of processes of group $\mathbf{P}_2$. The general characteristic of $\mathbf{P}_1$ imperfection is the efficiency factor $\eta < 1$. Group $\mathbf{P}_2$ includes the following processes: release of heat in resistive films and junction regions of diodes and transistors; reverse current in the specified regions; internal scattering of energy in structural elements; electrolytic processes in capacitors; and the time variation of properties of construction materials due to their aging.

Energy consumption in processes of the second group amounts to 75–90% of the total consumption in the entire RED. Hence, it is expedient to analyze the degree of energy perfection of both radioelectronic devices as a whole and individual elements of their electronic structure.

The occurrence of thermal processes can cause failures of apparatuses in service. The statistics indicates that the share of RED failures caused by thermal factors can reach 45–50% of their total number. As a rule, the reliability indicators of the entire RED are determined mostly by temperatures of ESE. This situation necessitates the calculation methods of both, proper temperatures and the reliability indicators associated with them.

DEGREE OF PERFECTION OF ENERGY UTILIZATION IN RED

The energy efficiency factor of RED is the ratio of power (or energy) N_F required for the execution of its direct functional task to the total power N_Σ required for ensuring the operation of the proper RED: