Załącznik 1

Abstract

This doctoral dissertation describes the results related to the development of a thermal management system for electronic systems in small satellites. In recent years, the space industry has observed a trend associated with increasing the electrical power of devices per unit mass. The role of thermal management systems is to ensure appropriate operating conditions for electronic devices in accordance with their technical specifications, dedicated mission requirements, and to limit their premature wear. To select the appropriate technology that could be part of such a system for data processing units (DPUs) based on FPGA circuits, an extensive literature study was conducted. As a result of this analysis, phase change materials (PCMs) were identified as a candidate for limiting the temperature amplitudes of the computational unit during its cyclical operation in orbital motion. For this purpose, the high value of the phase change heat (latent heat) of the organic material n-eicosane was utilized, which absorbs a large amount of energy during the phase change and releases it as heat during cooling, thus stabilizing the temperature of electronic systems. However, to lead to the industrial implementation of the proposed solution, actions were taken to build a computer numerical model of the computational unit, including sensitivity analysis and uncertainty quantification. This approach contributed to demonstrating which variables, along with their uncertainties involved in the simulations, have the greatest impact on the results and in what manner. This knowledge was then used to build a simple experimental setup for validating the description of thermal parameters of the selected PCM. The conducted validation showed high consistency between simulation parameters and experimental results, which enabled the construction of the target device. The final stage was the construction of a thermal management system for the computational unit developed by KP Labs Sp. z o.o., compliant with the SpaceVPX standard. This standard imposed the main mechanical and thermal requirements for the device, and the proposed PCM-based system had to fit within them, which, according to the review of industry solutions, bears the hallmarks of market novelty. The final experiments conducted using high-class research equipment such as a thermal-vacuum chamber, as well as numerical simulations based on them, demonstrated the usefulness of the proposed solution by reducing the operating temperature amplitudes of the device. Such results lead to benefits associated with reducing the failure rate of devices and enable operation with higher computational efficiency than the baseline, contributing to building a competitive advantage for KP Labs Sp. z o.o. products.

Keywords: Thermal management system, PCM, phase change material, FPGA, DPU, satellite