Thermal design optimization for automotive ECUs

Resume

A Thesis Submitted for obtaining
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by

Eng. Cristina Mihaela Drăgan (Șoimu)

PhD Supervisor: Prof. univ. dr. ing. Dorin Lelea

Abstract

This thesis explores the critical area of thermal design optimization for automotive Electronic Control Units (ECUs), a domain of increasing significance as vehicles transition towards more electrified and automated systems. With the rise of advanced driver-assistance systems (ADAS) and electric vehicles (EVs), the power density within ECUs has surged, leading to heightened thermal management challenges. This research aims to develop innovative strategies that enhance thermal performance, ensuring the reliability and functionality of ECUs under varying operational conditions.

The study begins with a comprehensive literature review that identifies current practices in thermal management and the limitations of existing approaches. A robust thermal model is then established, incorporating detailed heat generation profiles from electronic components, such as microcontrollers, power transistors, and sensors. This model is validated through experimental setups that replicate real-world conditions, allowing for accurate characterization of thermal behavior in ECUs.

Building on this foundation, the thesis introduces a multi-faceted optimization framework that employs both numerical simulations and advanced computational techniques. Utilizing methods such as genetic algorithms and particle swarm optimization, the research seeks to minimize thermal hotspots while maximizing heat dissipation efficiency. The framework is designed to explore a wide range of design parameters, including thermal interface materials, heat sink geometries, and cooling strategies, enabling a holistic approach to thermal management.

Case studies are integrated throughout the thesis to demonstrate the practical application of the optimization strategies. These studies involve collaboration with industry partners, providing insights into the thermal challenges faced in real automotive applications. Results indicate significant improvements in thermal performance, with reductions in peak temperatures and enhanced reliability metrics for ECUs subjected to rigorous testing scenarios.

Additionally, the thesis addresses the interplay between thermal design and overall vehicle architecture, advocating for an integrated design philosophy that considers thermal, electrical, and mechanical factors synergistically. The implications of this approach extend beyond individual ECUs, affecting overall system efficiency and performance.

The findings of this research contribute valuable knowledge to the field of automotive engineering, offering practical methodologies for the thermal design of ECUs. By promoting effective thermal management solutions, this work supports the development of more reliable and efficient automotive systems capable of meeting the demands of future mobility. Future research directions include the exploration of novel materials with superior thermal properties and the integration of real-time thermal monitoring systems to enable adaptive thermal management strategies in dynamic operational environments.

This research not only contributes to the theoretical framework of thermal design optimization but also provides actionable insights for the automotive industry. By addressing the critical challenges of thermal management in ECUs, it lays the groundwork for more resilient and high-performance automotive systems, paving the way for innovations in future mobility solutions.