Comparative Study of Layout Effects on Thermal Management in PCB Hot-Plate

Vlad Cristescu, Alexandra Fodor, and Liviu Viman

Applied Electronics Department,
Faculty of Electronics, Telecommunications, and Information Technology,
Technical University of Cluj-Napoca,
Cluj-Napoca, Romania,
vladcristescu1@gmail.com

Summary: *This paper explores thermal management strategies for PCBs with embedded heating elements, focusing on mitigating heat spread to sensitive components. The research investigates how different PCB layout modifications can contain heat and prevent it from spreading to adjacent components, which could damage or reduce their lifespan. The study compares the thermal performance of an unprotected board with various heat containment techniques. These include removing copper fills on internal layers beneath the heating element, optimizing the gap between the heating element and electronic components, and incorporating thermal vias to block heat transfer. Simulations show that these measures significantly improve thermal isolation, resulting in a more localized and efficient temperature distribution. The results offer actionable insights for PCB designers, emphasizing the importance of layout optimization in enhancing thermal performance. This contribution offers practical guidance for minimizing thermal propagation and protecting sensitive components in automated soldering and other high-temperature PCB applications.*

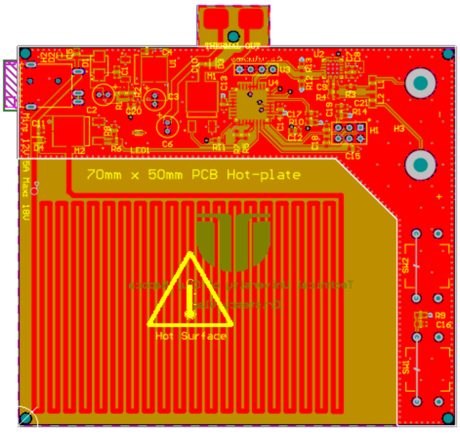
Keywords: PCB, embedded heating element, thermal management, layout

Motivation

Printed Circuit Board (PCB) layout plays a critical role in determining the thermal behavior of a board [1], influencing its ability to efficiently dissipate heat and maintain temperature control. This study aims to identify which layout modifications most significantly impact thermal management in the context of a previously designed PCB temperature controller for automated soldering, shown in Fig. 1 and Fig. 2. This system integrates a meander copper track as an embedded heating element and closely resembles a commercial hot plate embedded in a single board [2]. The primary objective is to confine heat to the intended region, preventing its spread to adjacent components, potentially leading to reduced lifespan or damage. By systematically evaluating layout changes, this work seeks to provide practical solutions for enhancing PCBs' thermal performance and reliability in high-temperature applications.

Results

The thermal simulations demonstrate the significant impact of layout modifications on heat distribution within the PCB. A comparison is made between the temperature profiles of two configurations: a PCB without thermal management techniques (shown in Fig. 1, simulated in Fig. 3) and one incorporating optimized layout strategies (shown in Fig. 2, simulated in Fig. 4).



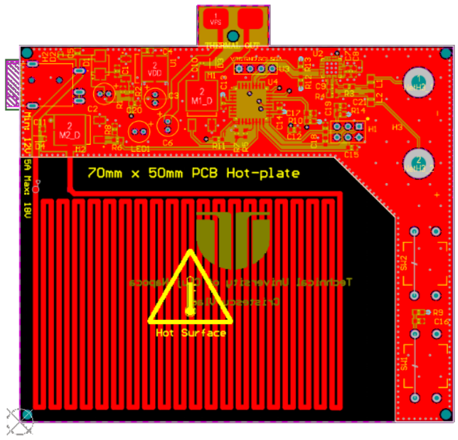
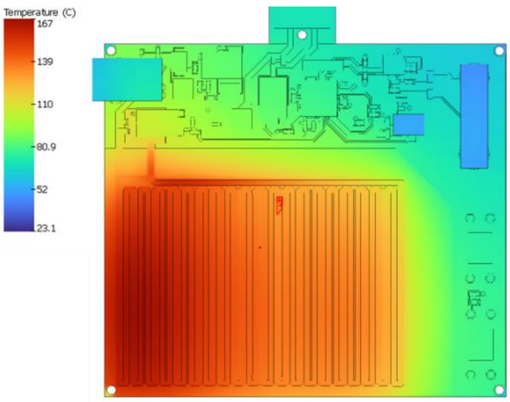


Fig. 1: PCB without thermal management techniques

Fig. 2: PCB with isolated copper and thermal vias



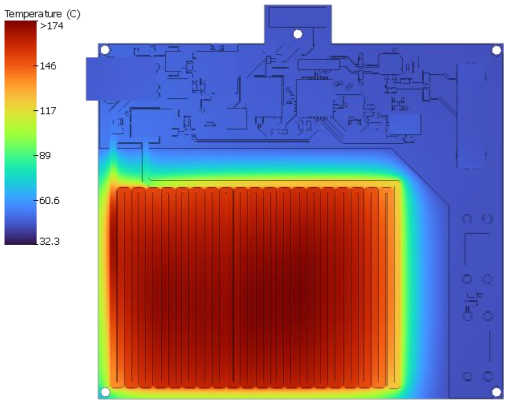


Fig. 3: Thermal simulation for first PCB

Fig. 4: Thermal simulation for second PCB

The copper pours on internal layers act as heat sinks, causing heat to spread beyond the intended area. By removing these pours, the heat remains confined to the region of the embedded heating element, resulting in a more localized and efficient temperature distribution. Increasing the separation between the heating element and adjacent components significantly reduces heat transfer to sensitive areas. Incorporating a row of thermal vias in the gap further enhances thermal isolation by directing heat away from the PCB surface and into the substrate.

Acknowledgement

This work was supported by the “Software instrument for generating a thermal contour for component placement on a PCB” grant funded by the National Grant Competition - GNaC ARUT 2023, contract no. 15/01.07.2024.

References

[1] L. Wang and Y. Yang, "Design and optimization of thermal vias in PCB thermal management," *IEEE Transactions on Components, Packaging and Manufacturing Technology*, vol. 7, no. 5, pp. 764-771, 2017.

[2] Z. Wang and X. Zhang, "Thermal performance analysis of PCB with embedded heating element," *Journal of Electronics and Packaging*, vol. 141, no. 2, pp. 021003, 2019.