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Thermal Analysis for USB Digital Microscope Module

Scope : Thermal Analysis of PCB

Application : Efficient thermal performance for inspection applications

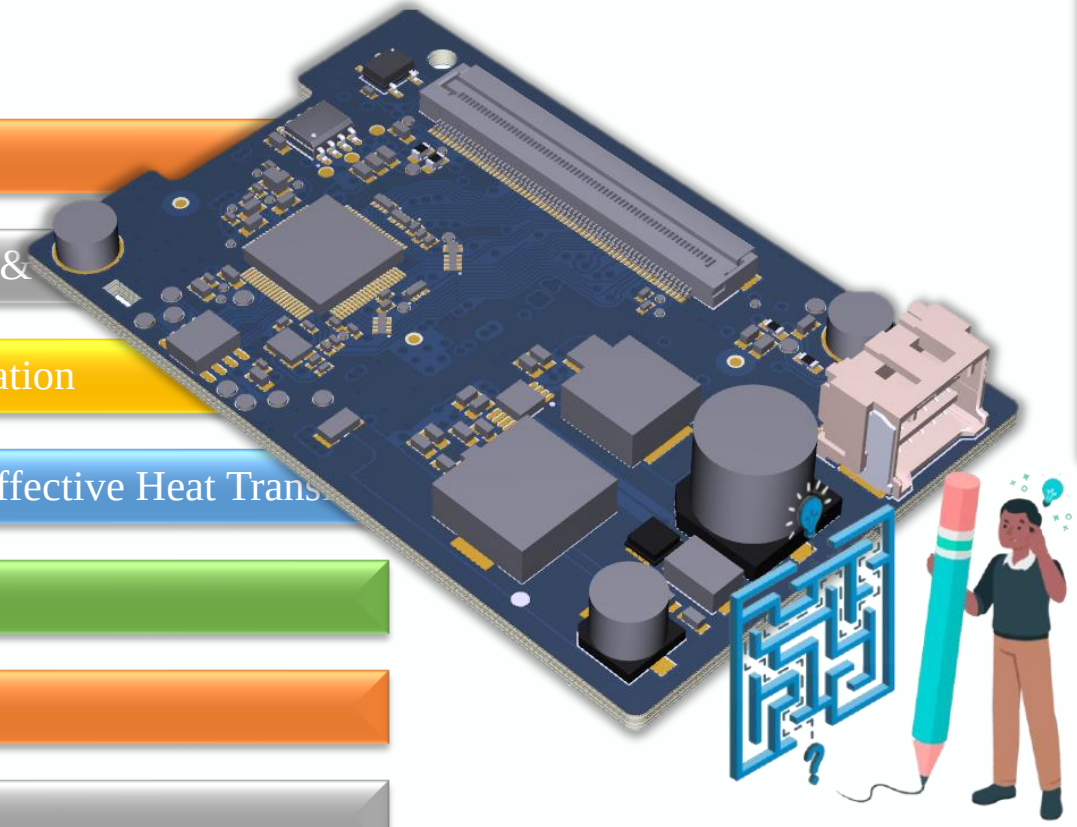
A USB Digital Microscope Module connects to a computer via USB, capturing high-resolution images and videos of small objects. It includes a magnifying lens, camera sensor, and LED light, with software to display and control the captured content. It's commonly used for inspecting PCBs, and small mechanical parts. This crucial aspect of the analysis focuses on ensuring both component-level and board-level reliability, influencing key design decisions. It also plays a vital role in promoting efficient heat dissipation and maintaining reliable performance.

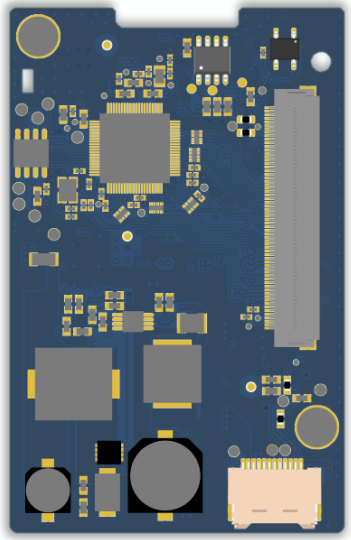
Thermal Analysis - Challenges

Conducting the layout analysis to achieve optimal thermal performance, as per the client's specifications, has been a significant challenge. Balancing thermal efficiency with design requirements has demanded careful attention and creative solutions to meet high expectations.

Challenges

- Heat Dissipation in Power Components
- Material Selection – Thermal Properties &
- Thermal Management for Heat Dissipation
- Copper Pours and Thermal Vias for Effective Heat Trans
- Thermal Resistance and Conductivity
- Cost-Effective Thermal Solutions
- Optimal Heat Flow





Thermal Analysis - SoW

- Evaluates heat distribution and dissipation in the board
- Modifying the layout to enhance heat dissipation.

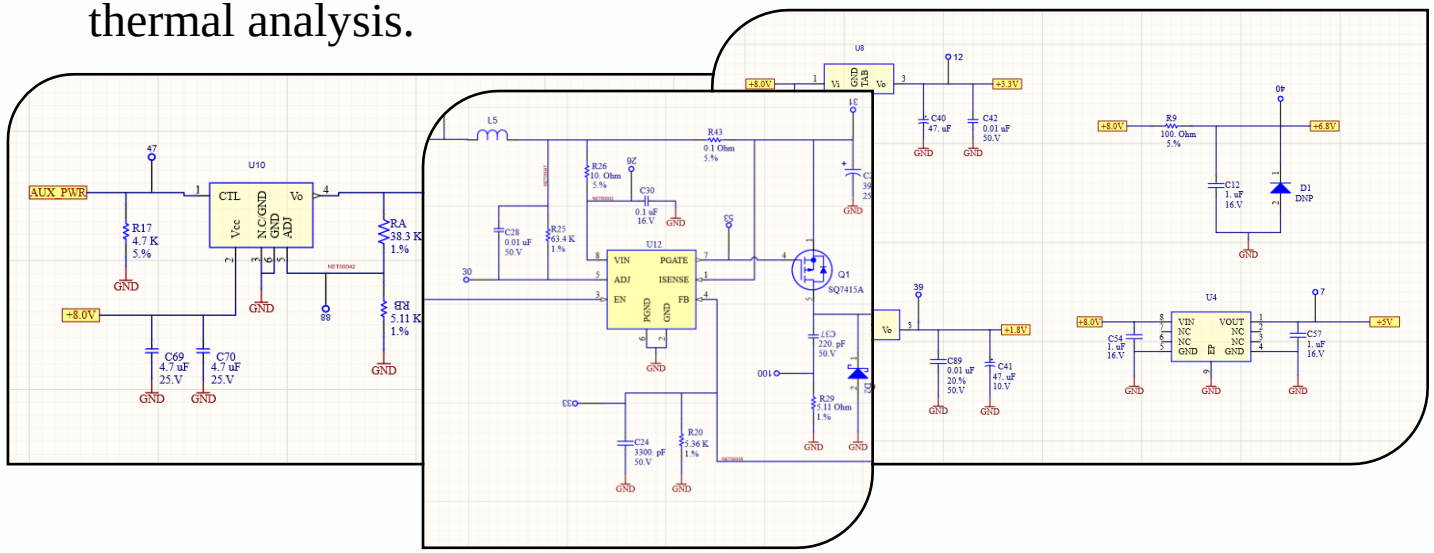
- Exploration of the design aspects and functionality of the board.
- Evaluation of the layout assesses heat flow and cooling efficiency.
- Achieve the final optimized PCB design

Study of the Design (Cont.)

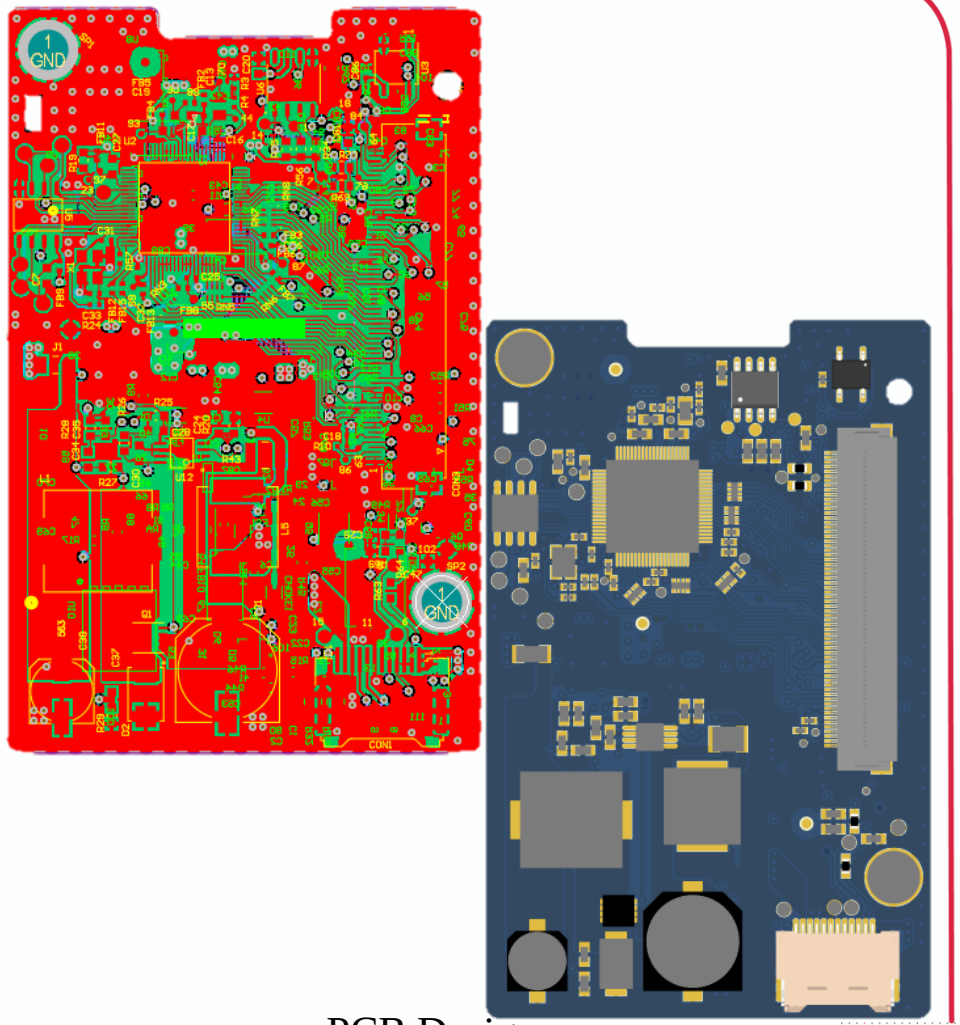
Schematics and PCB Design:

- The PCB design is reviewed to identify power components that generate heat and analyze their design parameters and operating conditions.

- This detailed assessment ensures that all factors influencing thermal performance are considered in preparation for a comprehensive thermal analysis.



Schematics



PCB Design

Study of the Design

Power Dissipation by Power ICs.

- To begin the analysis, it is crucial to determine the power dissipated by the heat-emitting components in the layout, as these are the primary sources of heat.

- The power dissipation for each component has been carefully calculated based on the detailed specifications provided in their respective datasheets, ensuring an accurate assessment of heat generation.

6.1 Absolute Maximum Ratings

See (1).

	MIN	MAX	UNIT
VIN voltage	–0.3	36	V
PGATE voltage	–0.3	36	V
FB voltage	–0.3	5	V
ISENSE voltage	–1	36	V
	–1 (<100 ns)		
ADJ voltage	–0.3	36	V
EN voltage (2)	–0.3	6	V
Power dissipation, T_A = 25°C (3)		417	mW
Junction temperature, T_J	–40	150	°C
Storage temperature, T_{stg}	–65	150	°C

6.5 Thermal Information

THERMAL METRIC (1)		LM3489 DGK (VSSOP) 8 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	163.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	56.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	83.3	°C/W
ψ_{JT}	Junction-to-top characterization parameter	5.4	°C/W
ψ_{JB}	Junction-to-board characterization parameter	82	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	—	°C/W

Temperature information

6.6 Electrical Characteristics

Typical values correspond to T_J = 25°C. Minimum and maximum limits apply over T_J = –40°C to 125°C for the LM3489 and LM3489-Q1. VIN = 12 V, V_{ISNS} = V_{IN} − 1 V, and V_{ADJ} = VIN − 1.1 V (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{SHDN}	Shutdown input supply current	EN = 0 V		7	15	µA
V_{EN}	Enable threshold voltage	Enable rising	1.15	1.5	1.85	V
V_{EN_HYST}	Enable threshold hysteresis			130		mV
I_Q	Quiescent current at ground pin	FB = 1.5 V (not switching)		280	400	µA
V_{FB}	Feedback voltage (1)		1.214	1.239	1.264	V
V_{HYST}	Comparator hysteresis			10	20	mV
V_{CL_OFFSET}	Current limit comparator offset	V_{FB} = 1 V	–20	0	20	mV
I_{CL_ADJ}	Current limit ADJ current source	V_{FB} = 1.5 V	3	5.5	7	µA
T_{CL}	Current limit one-shot off-time	V_{ADJ} = 11.5 V, V_{ISNS} = 11 V, V_{FB} = 1 V	6	9	14	µs
R_{PGATE}	Driver resistance	Source, I_{SOURCE} = 100 mA		5.5		Ω
		Sink, I_{SINK} = 100 mA		8.5		
I_{PGATE}	Driver output current	Source, V_{IN} = 7 V, PGATE = 3.5 V		0.44		A
		Sink, V_{IN} = 7 V, PGATE = 3.5 V		0.1		
I_{FB}	FB pin bias current (2)	V_{FB} = 1 V		300	750	nA
T_{ONMIN_NOR}	Minimum ON time in normal operation	V_{ISNS} = V_{ADJ} + 0.1 V, C_{load} on OUT = 1000 pF (3)		100		ns
T_{ONMIN_CL}	Minimum ON time in current limit	V_{ISNS} = V_{ADJ} – 0.1 V, V_{FB} = 1 V, C_{load} on OUT = 1000 pF (3)		200		ns
$\%V_{FB}/\Delta V_{IN}$	Feedback voltage line regulation	4.5 V ≤ V_{IN} ≤ 35 V		0.01%		V

Datasheets

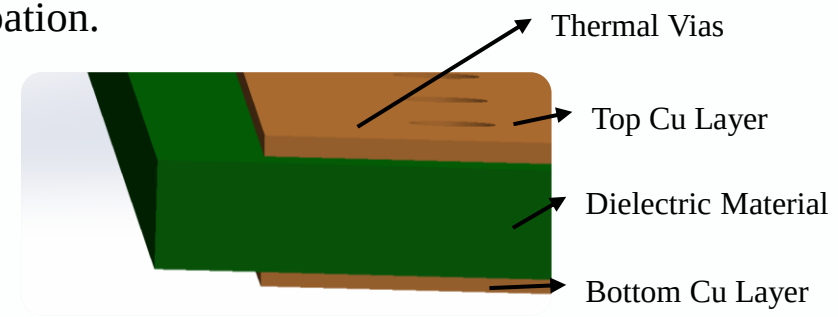
Thermal Analysis-Execution

- The thermal performance of the PCB is thoroughly evaluated through detailed simulation, which incorporates power dissipation calculations along with the application of carefully defined boundary conditions.
- This process allows for an in-depth analysis of the thermal behavior, ensuring that all critical factors are considered to optimize the PCB's performance under real-world operating conditions.

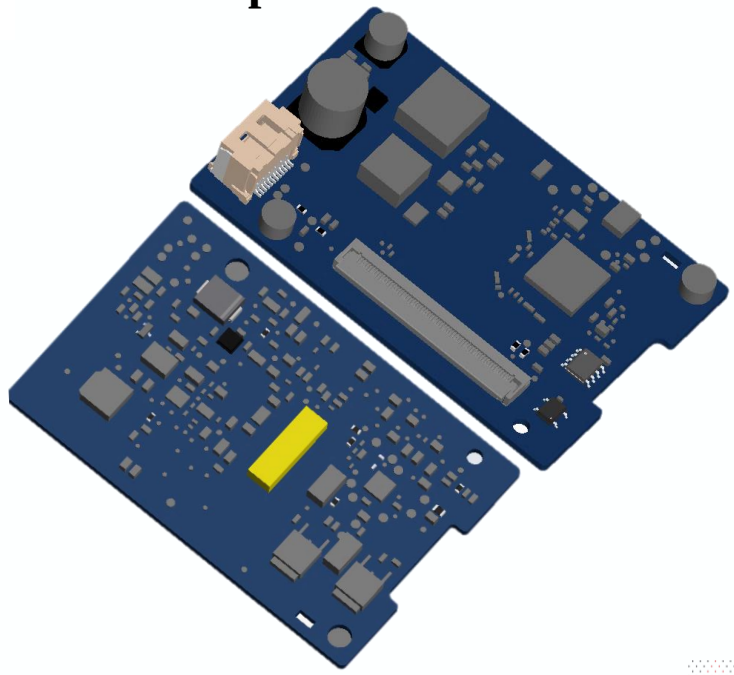
Analysis Flow: ECAD - MCAD → Boundary condition → Thermal performance

Boundary Condition:

- Power IC (U1) will generate 1.28W power.
- External temperature (Surrounding) = 150°C.
- Placed in a sealed environment with only natural convection for heat dissipation.
- Steady State Analysis



Layer Stack-up (reference)



PCB – 3D Model

Performance Evaluation

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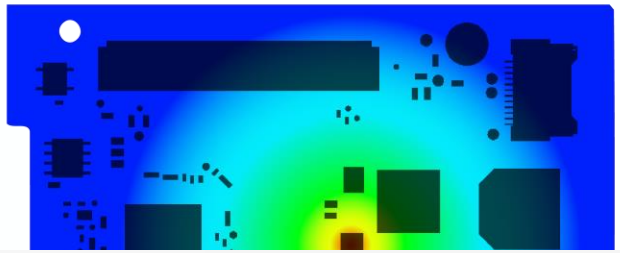
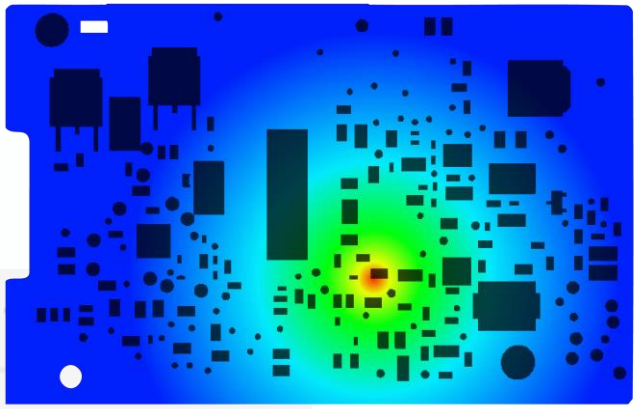
Thermal performance of the Layout is shown below:

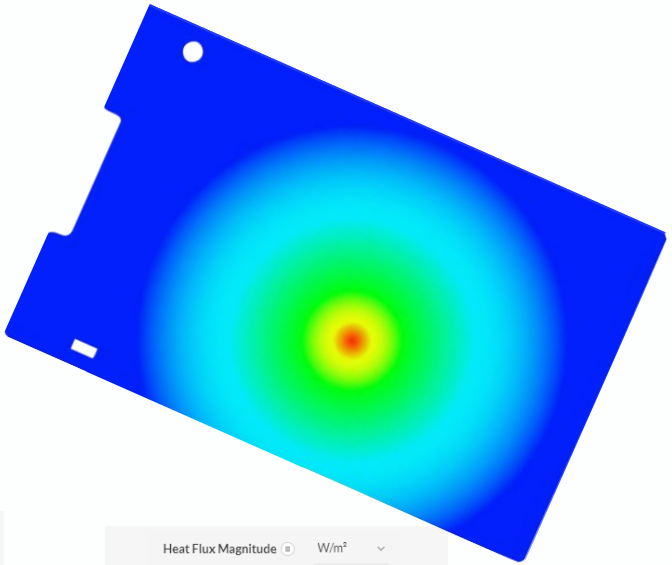
- The analysis demonstrates that the temperature of the PCB could potentially rise to 152.3°C, as illustrated in the graph.
- This temperature falls within the PCB's acceptable limits, ensuring safe operation without surpassing the maximum threshold for optimal performance and reliability.
- To ensure further more efficient and optimal performance, the temperature can slightly be reduced.

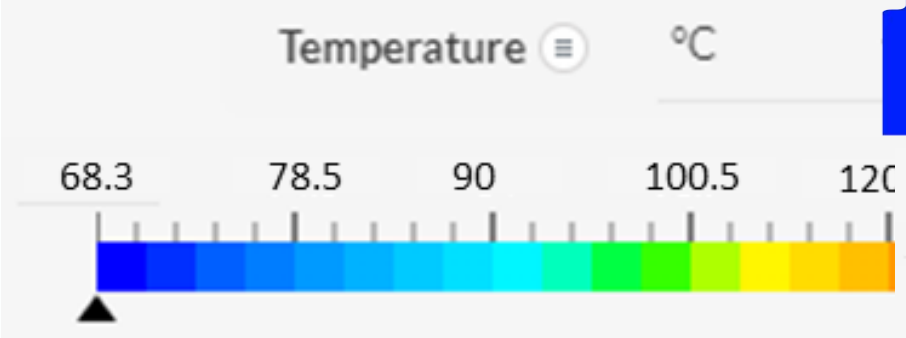
Top

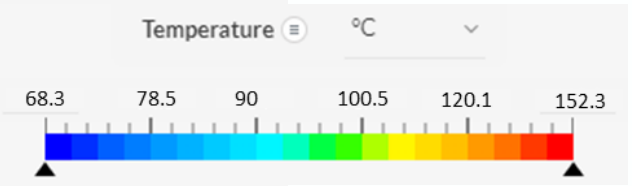


Bottom

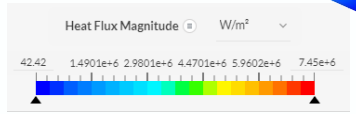








Temperature



Heat Flux

Design Optimization

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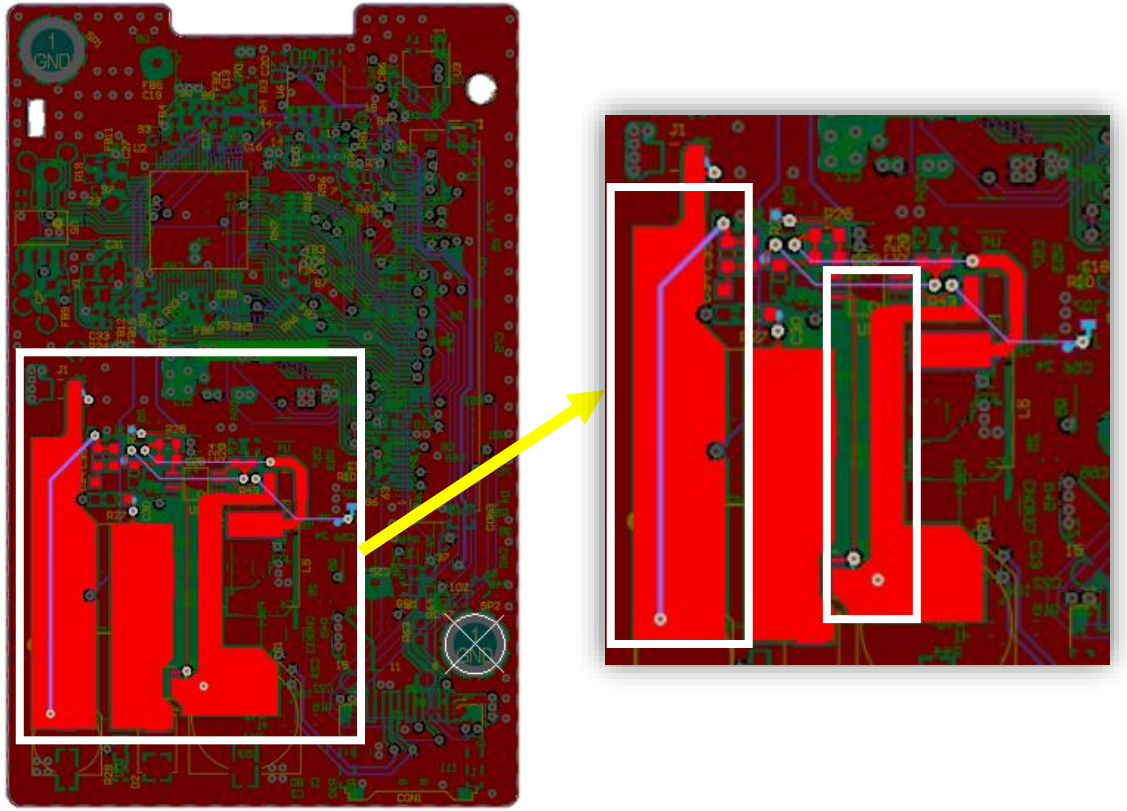
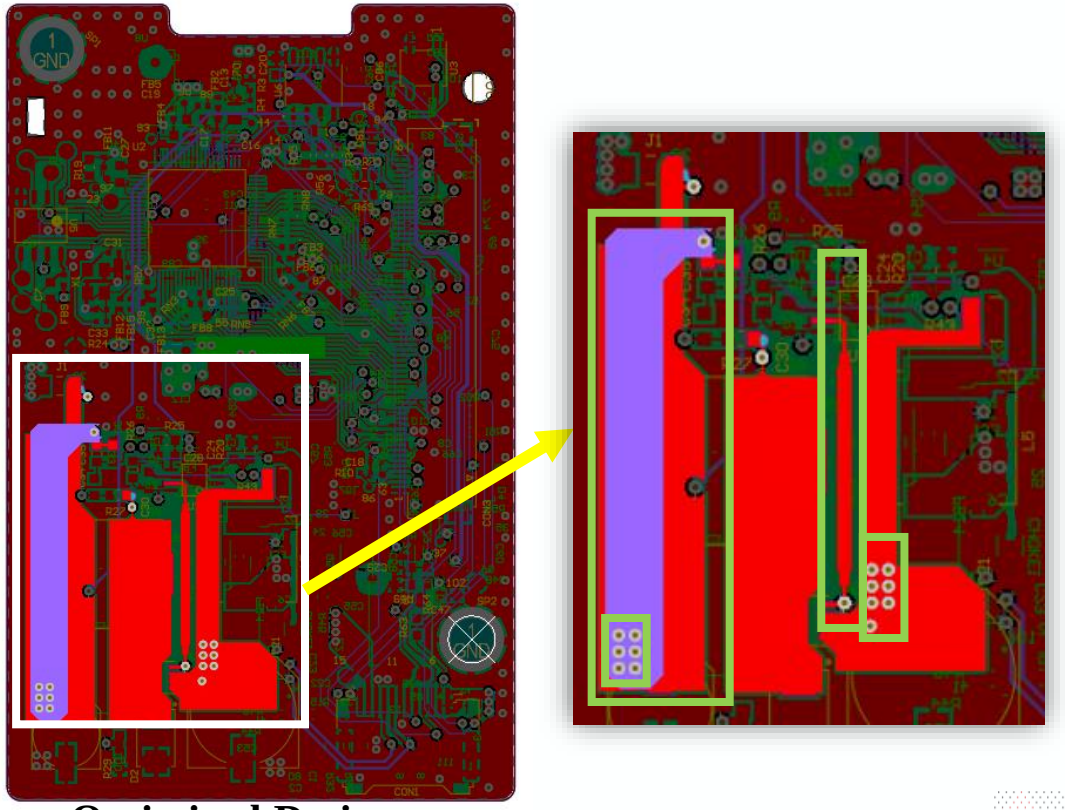
- **Enhanced Thermal Efficiency**: Increased copper pour areas have been implemented to improve heat dissipation.
- **Added Thermal Vias**: Additional thermal vias are included to further facilitate heat transfer.



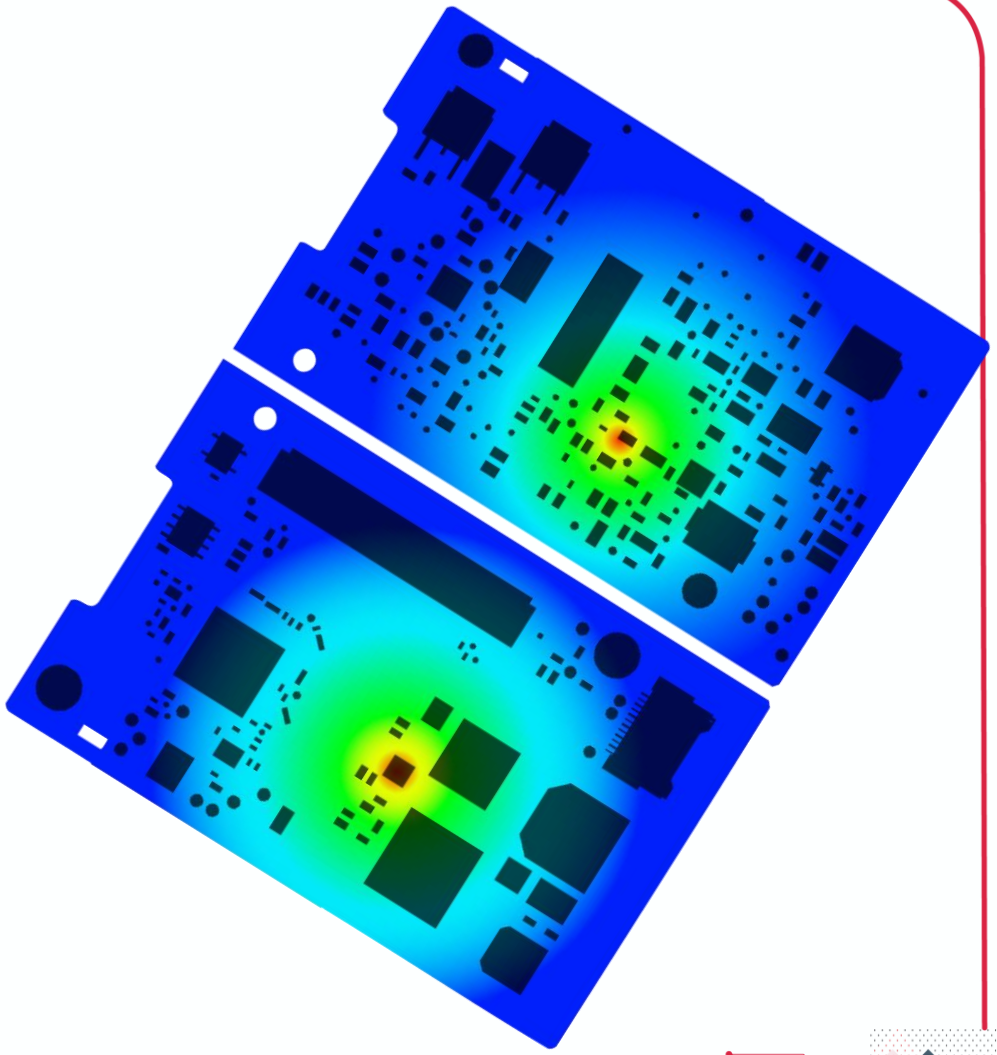
Previous Design



Optimized Design

Outcomes

- **Thermal Safety Assurance:** The analysis verifies that the PCB's operating temperature remains well within safe limits, with the temperature rise contained below the maximum threshold of 160°C.
- **Effective Heat Management:** These results demonstrate that the PCB layout efficiently dissipates heat, maintaining optimal thermal performance.
- **Reliability and Safety:** By keeping the temperature under control, the design ensures reliable operation and safeguards the components from thermal stress.



Customer Testimonial

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We're excited to share a client testimonial that highlights our dedication to quality and commitment to exceeding expectations in every project.

"We are thoroughly impressed with the analysis services provided. The final outcome exceeded our expectations, meeting our specifications with remarkable precision and showcasing exceptional expertise and attention to detail. The project was completed on schedule, demonstrating their efficiency and dependability. Additionally, they enhanced the design without compromising quality, highlighting their commitment to customer satisfaction. We highly recommend their services to any organization in need of top-quality design solutions. Their outstanding contribution played a crucial role in our project's success, and we look forward to collaborating with this talented team in the future."

Conclusion

In summary, our team successfully addressed challenges and delivered effective analysis solutions by utilizing our expertise and engaging in thorough brainstorming sessions.

Through careful and precise execution, we delivered results that exceeded client expectations, fine-tuning every detail for optimal performance.

Our collaborative approach went beyond technical aspects to enhance the design in alignment with the client's unique requirements.

We are dedicated to delivering exceptional analysis services, upholding our commitment to excellence and reliability in every project.