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Comparisons of Board-side and Back-side Thermal Management Techniques for eGAN FETs in a Half-Bridge Configuration

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Credits

Comparisons of Board-side and Back-side Thermal Management Techniques for eGAN FETs in a Half-Bridge Configuration

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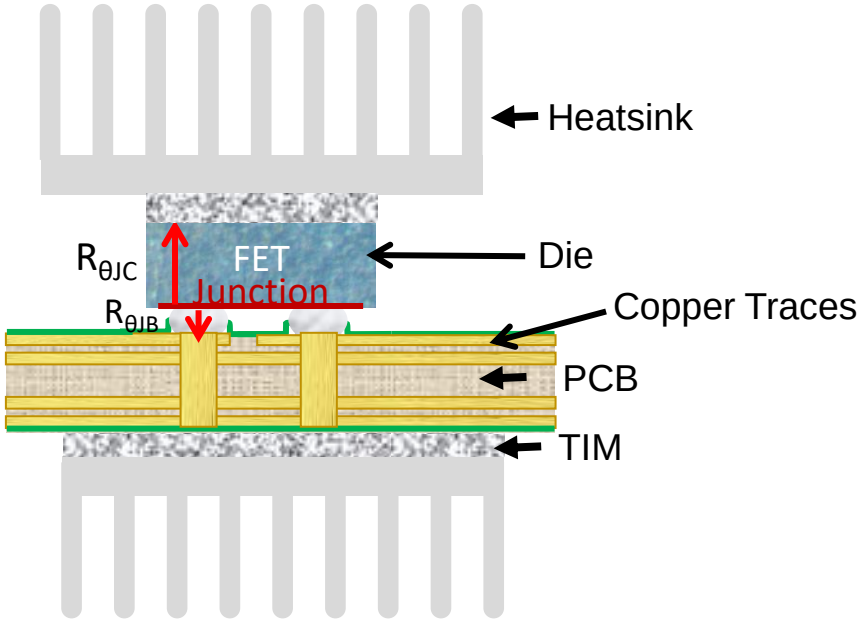
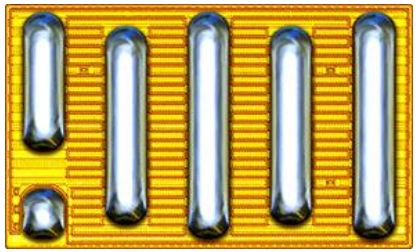
Problem Definition

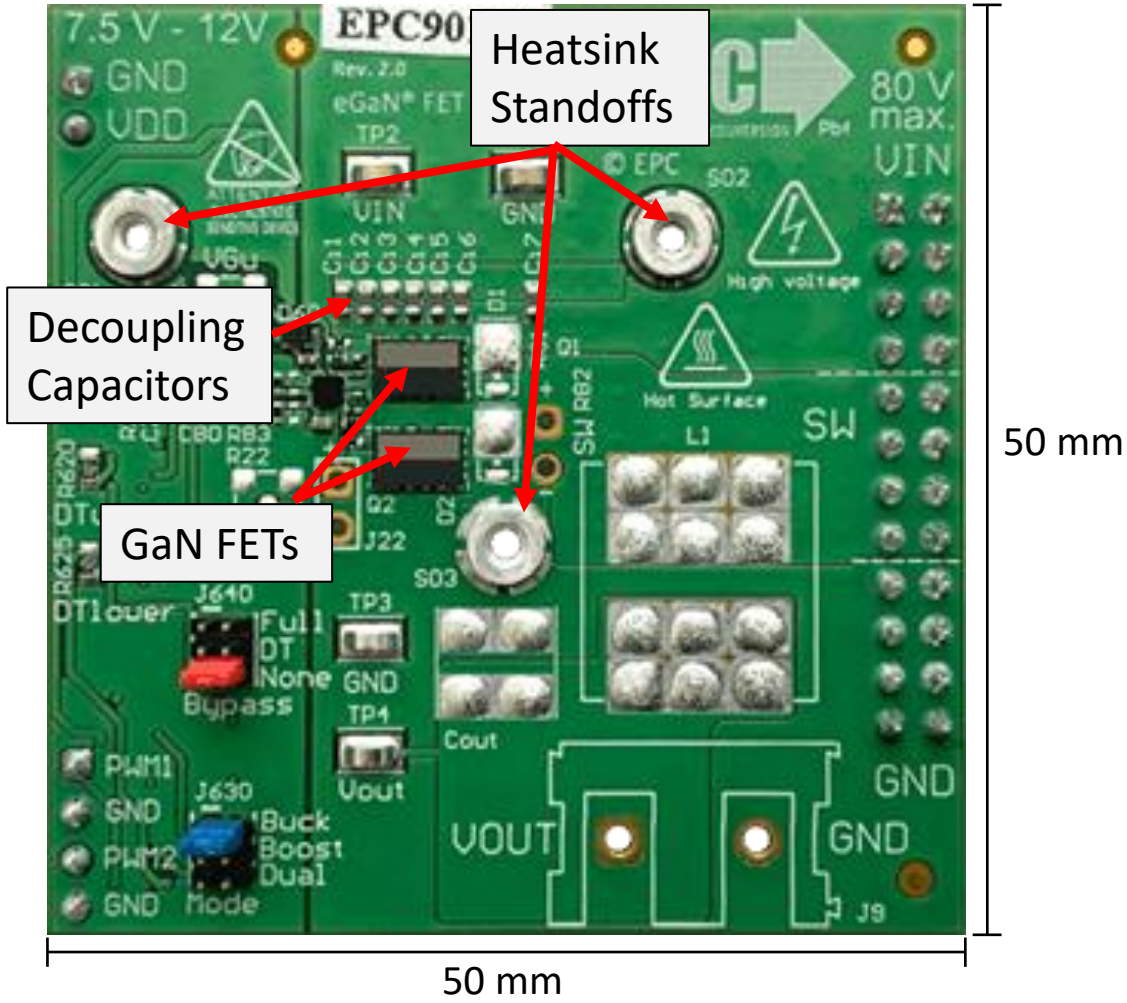
- eGaN FETs offer high power-density with ultra-fast switching and low on-resistance; improving thermals increases converter current capability
- Three cooling conditions compared:
  - PCB only cooling
  - Bottom side cooling: heatsink attached to the bottom of the PCB
  - Backside cooling: heatsink attached directly to the back of the FETs using a thermal interface material (TIM)



Baseline and Analysis Overview

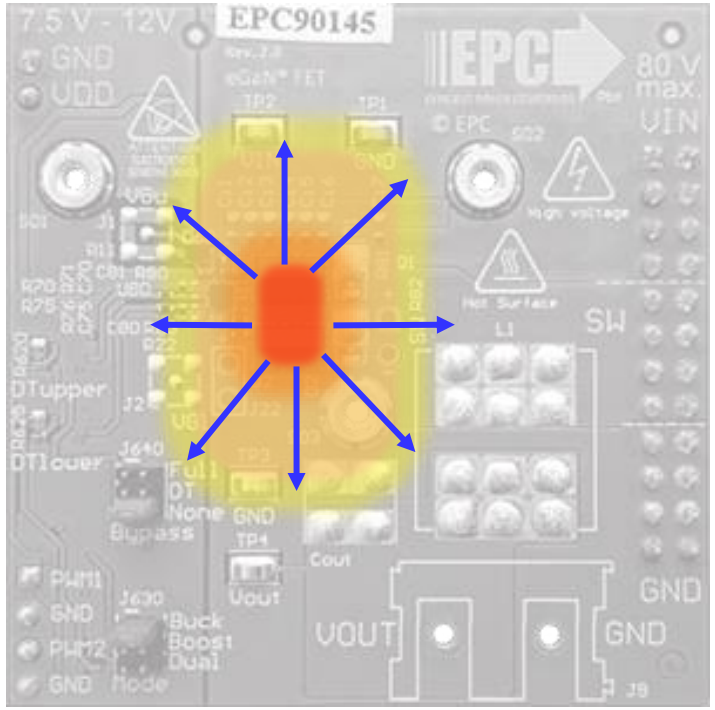
- 4-layer 50 mm x 50 mm PCB
- FET is EPC2619
  - 2.5 x 1.5 mm
  - $R_{\theta JB}$ = 2.6 K/W
  - $R_{\theta JC}$ = 1 K/W
- Simulated in CelsiusEC FEA software
- Experimentally verified





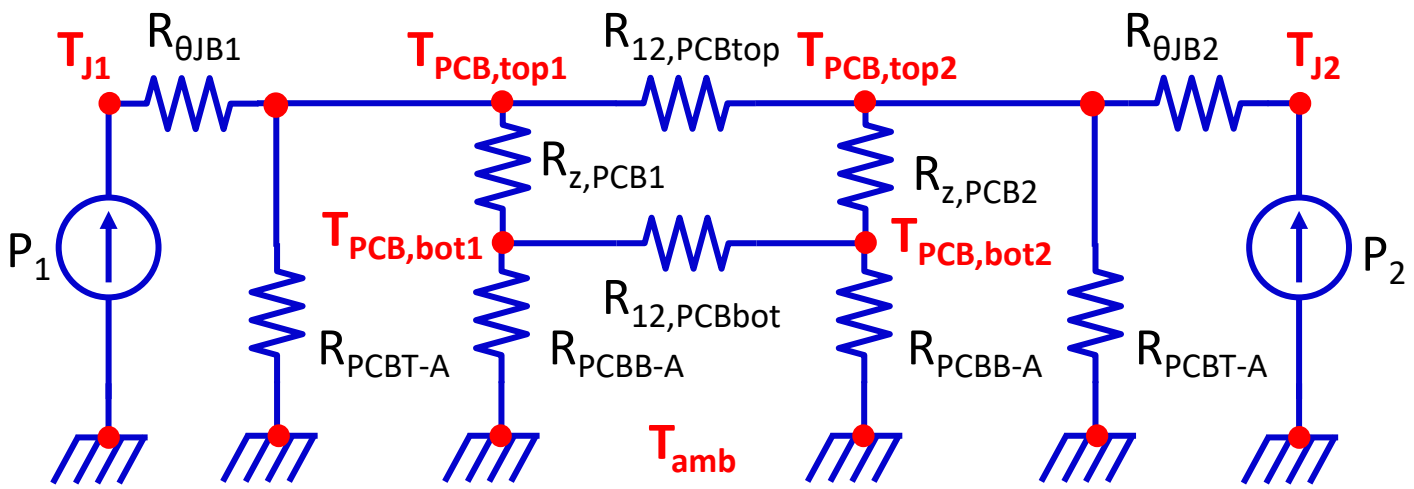
PCB Cooling Motivation

- Determine how $R_{\theta JA}$ can be lowered using only PCB characteristics
- Relies on heat spreading
- Suitable for low heat-flux applications



PCB only - Thermal Resistance Network

- Half-bridge configuration
- A thermal resistance network was modeled to approximate $R_{\theta JA}$
- Includes coupled heat flux exchange



PCB-cooling thermal resistance network

PCB Cooling Factors Evaluated

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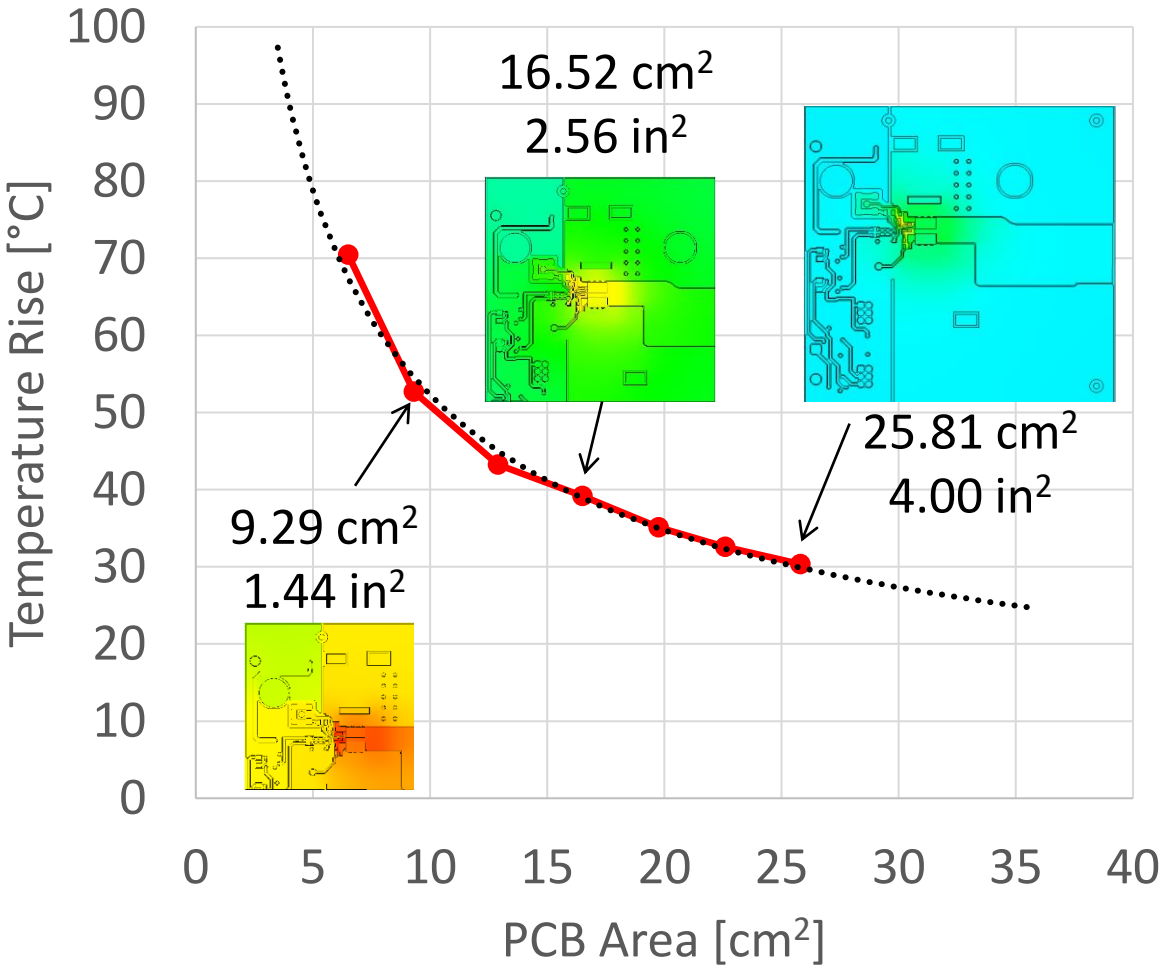
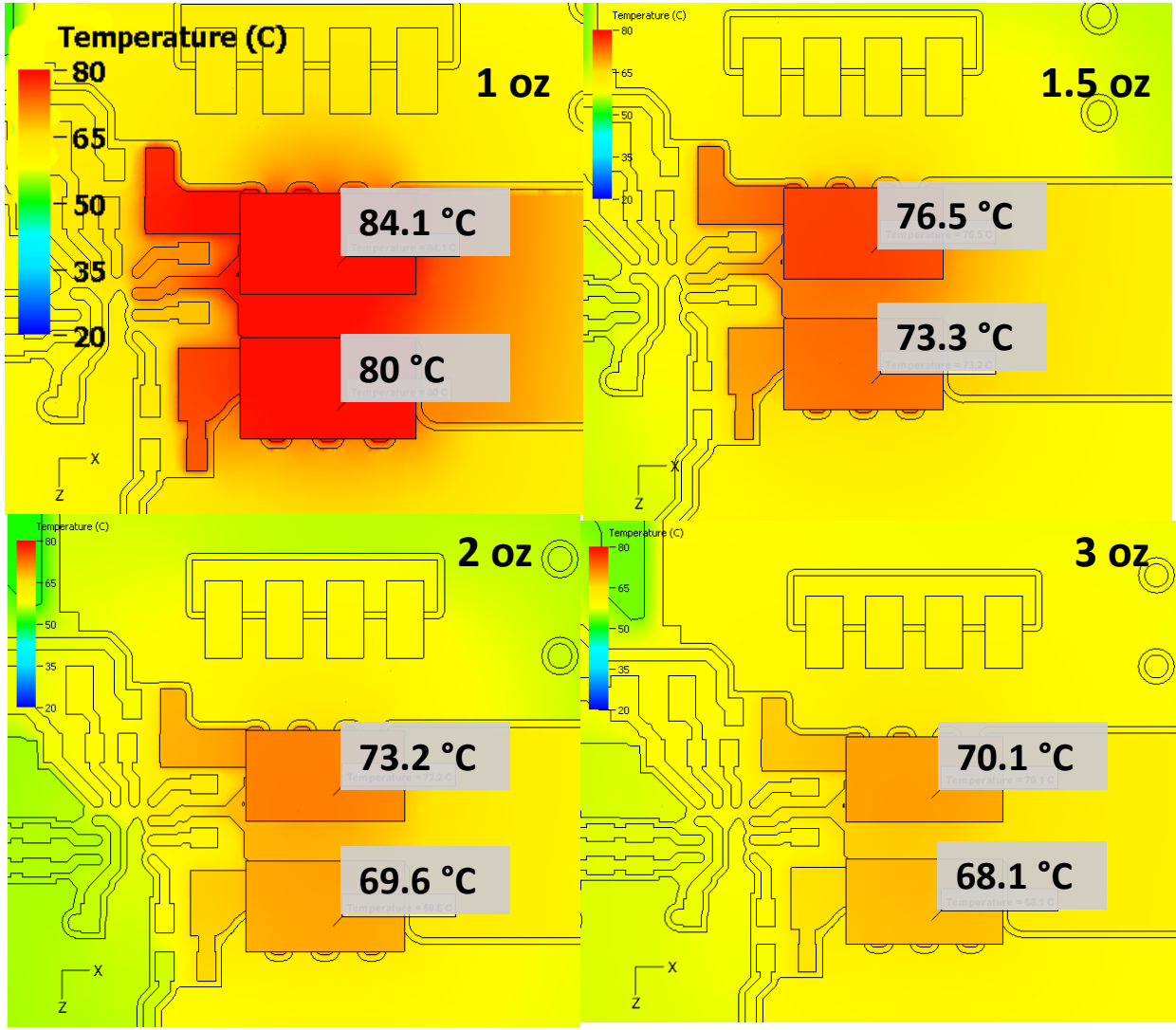
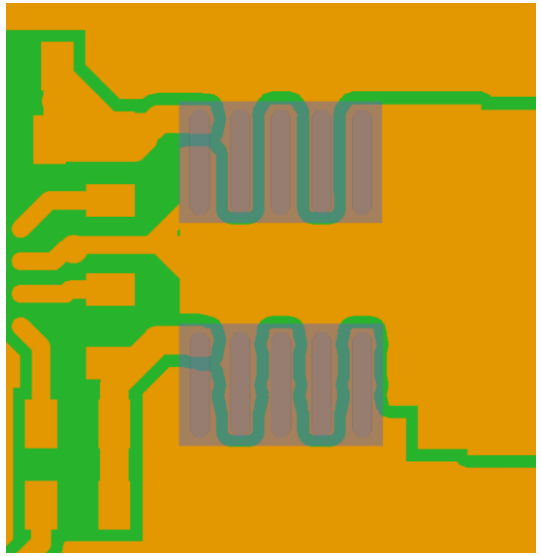
Board Area

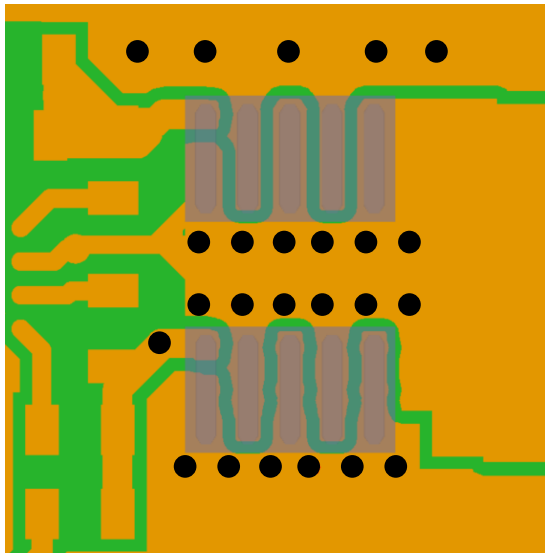


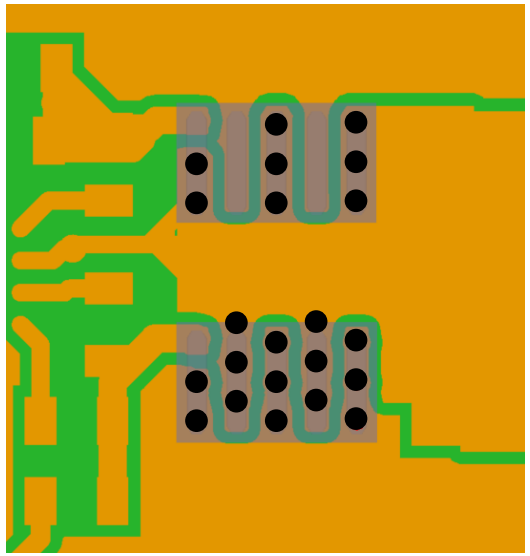
Copper Thickness

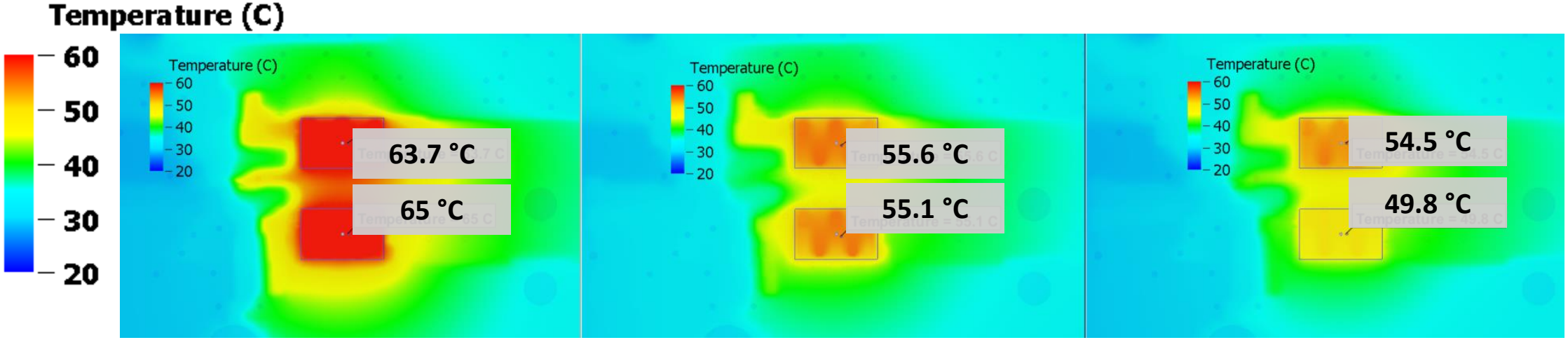


PCB Cooling Factors Evaluated: Vias









$R_{\theta,JMA}$ =45 K/W

$R_{\theta,JMA}$=35 K/W (22% ↘)

$R_{\theta,JMA}$=30 K/W (33% ↘)

PCB Cooling Factors Evaluated

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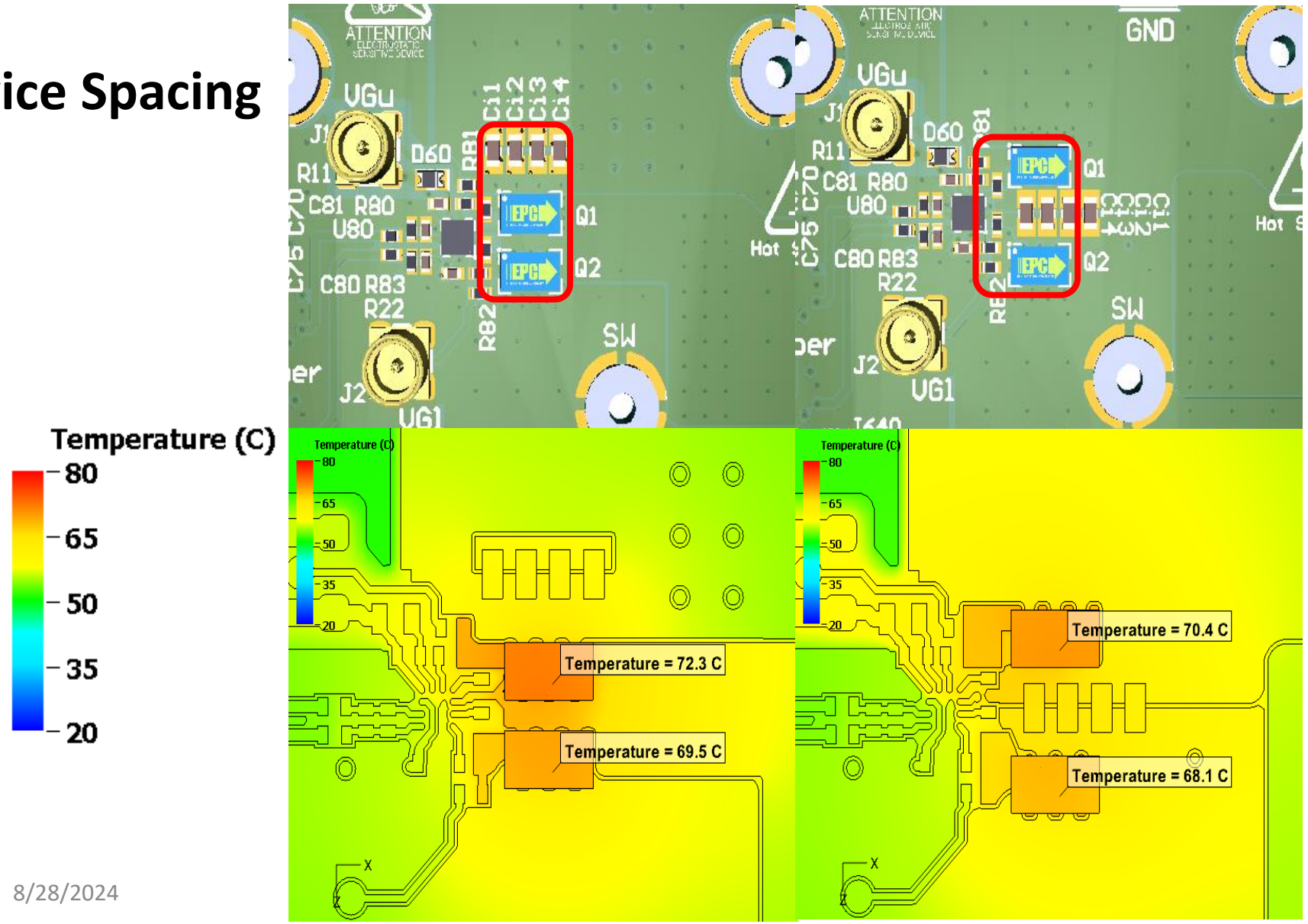
Device Spacing

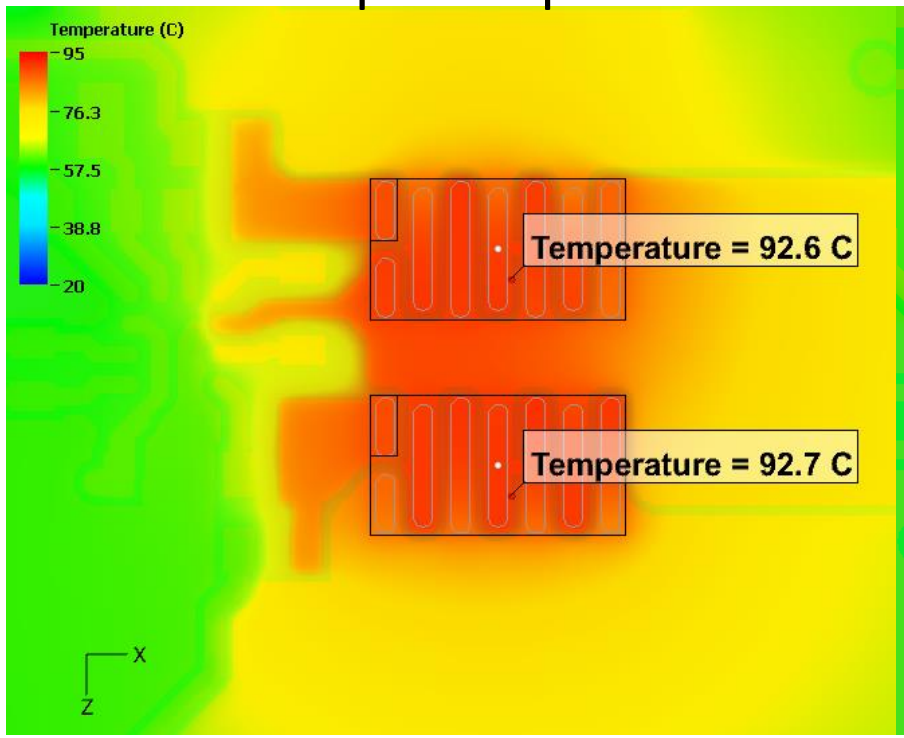


4-5% decrease in $R_{\theta JA}$

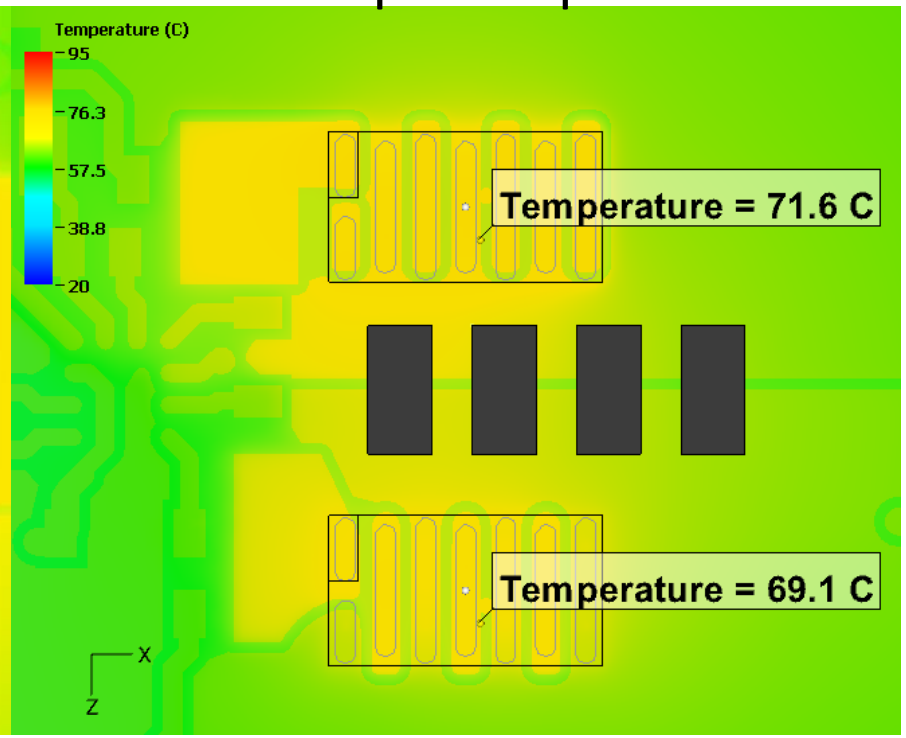
Combined Effectiveness

ΔT = 21°C, 35% decrease in $R_{\theta JA}$, Natural Convection

No techniques implemented

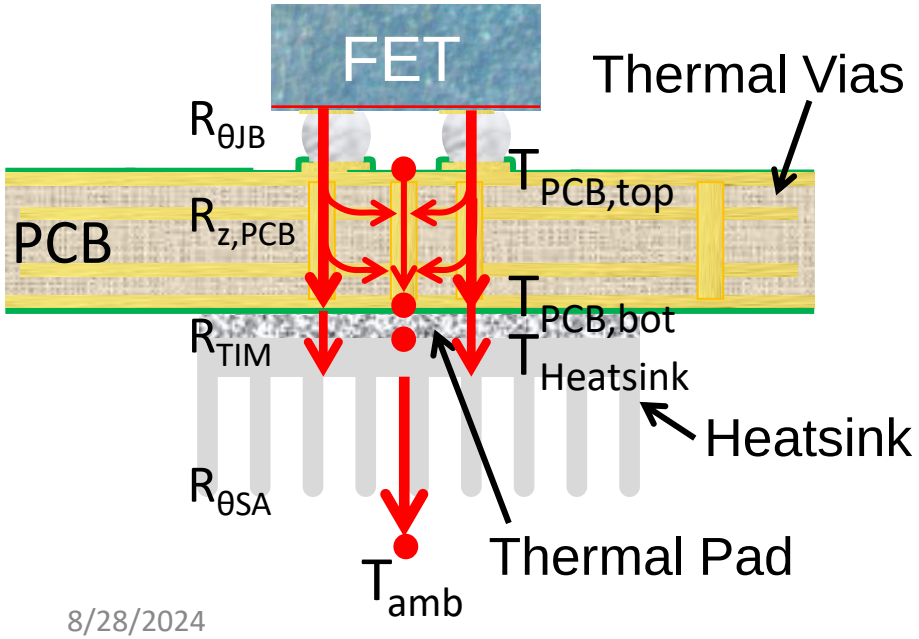


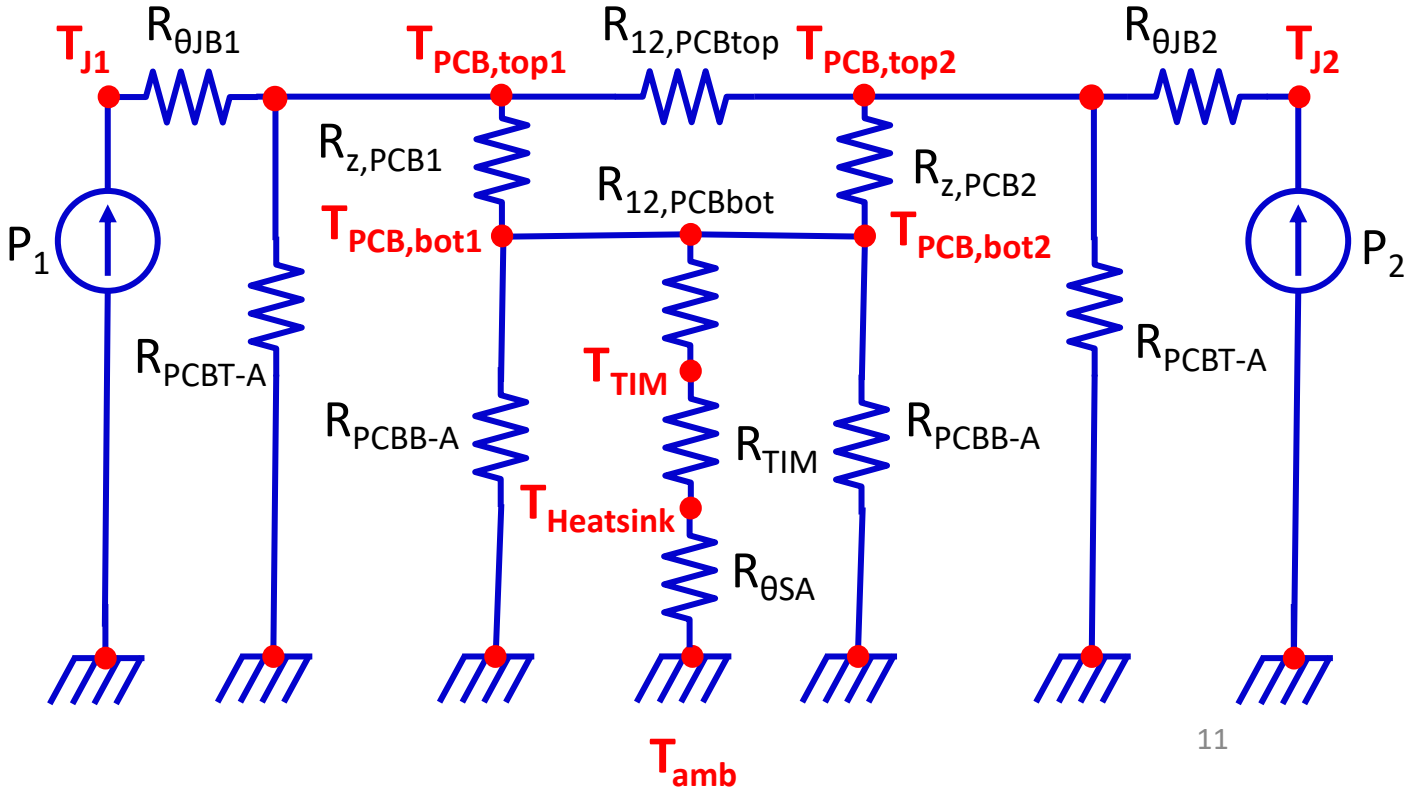
All techniques implemented



Bottom-side Heatsink Cooling Motivation

- Increase current capability over PCB only – increased heat flux
- Simple to attach – requires no bottom side components present
- No mechanical stress on the devices





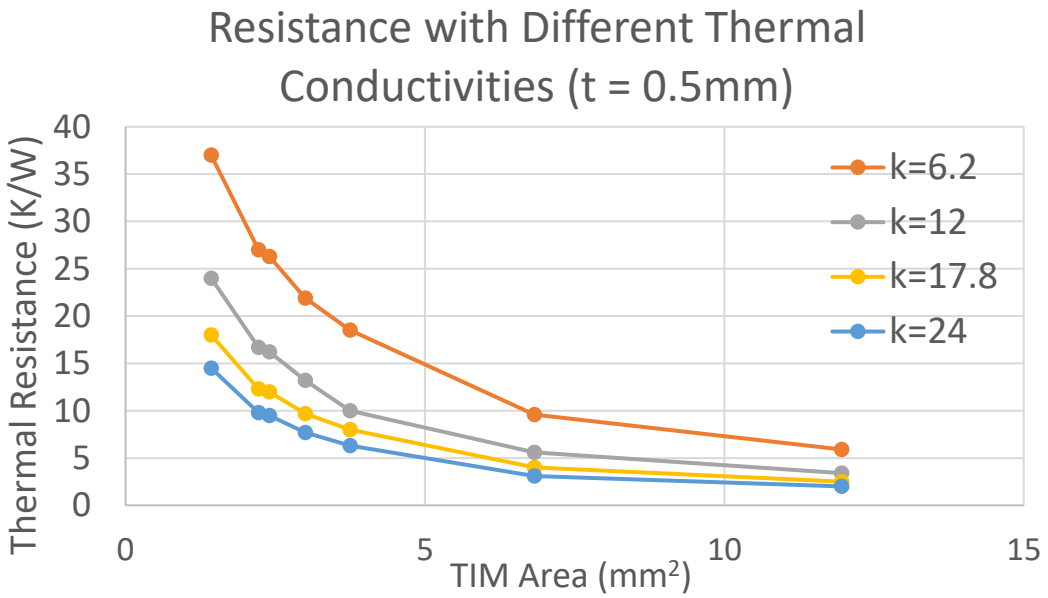
TIM Analysis Overview

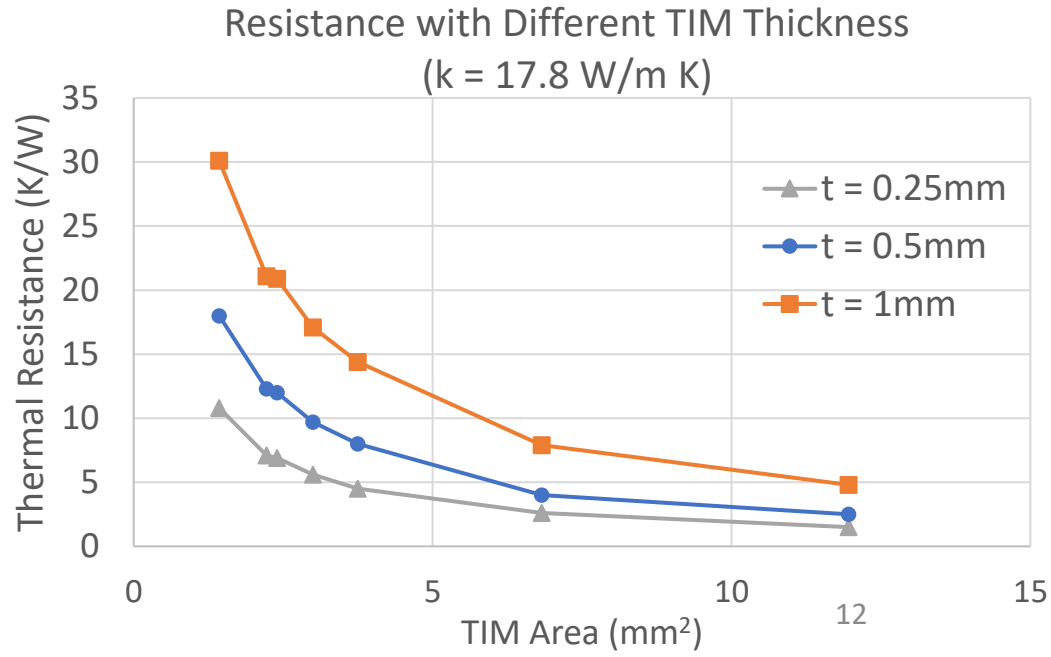
TIM requirements

- Electrical isolation
- Low thermal contact impedance

Analysis overview

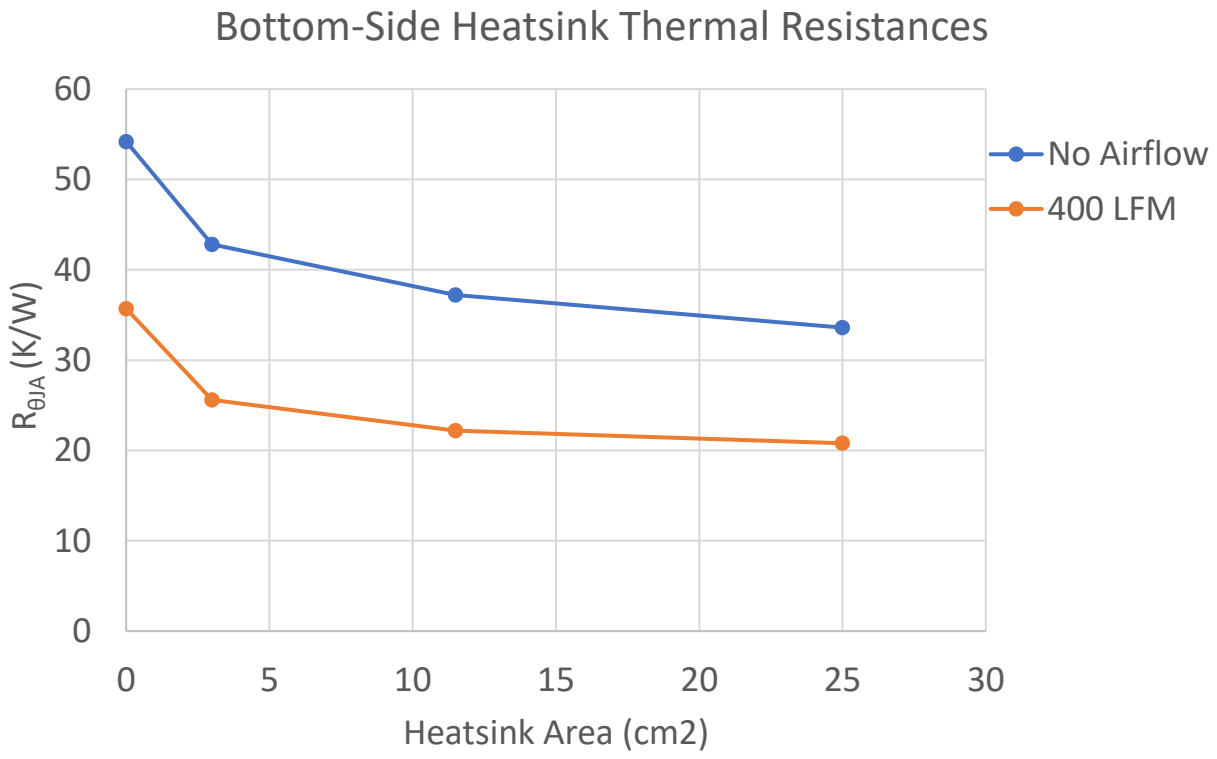
- Thermal resistance from junction to heatsink
  - Various TIM areas
  - Various TIM thicknesses
- For large bottom side PCB area, TIM thickness importance is low

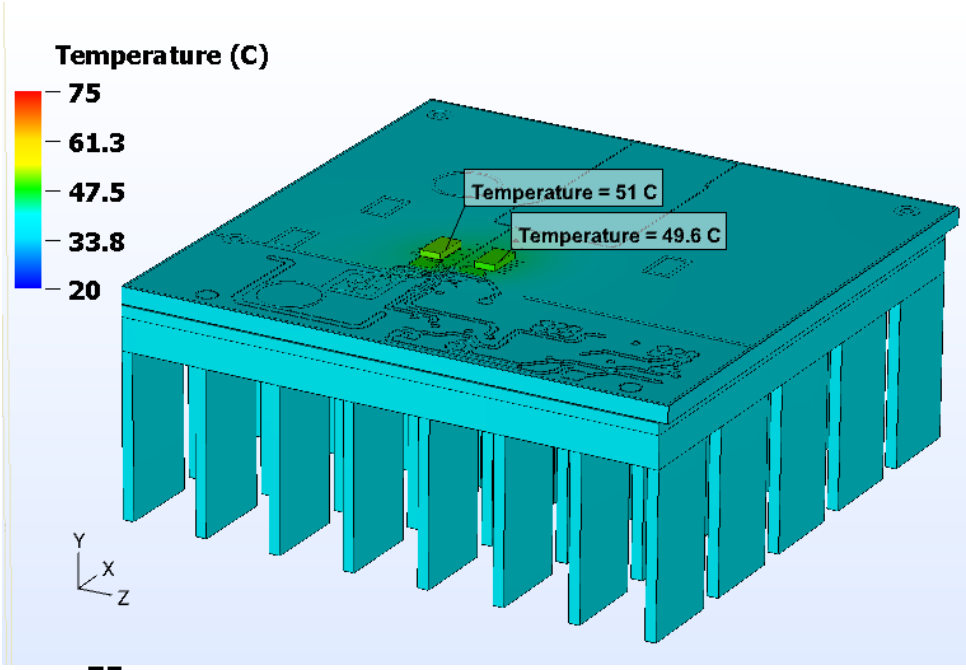


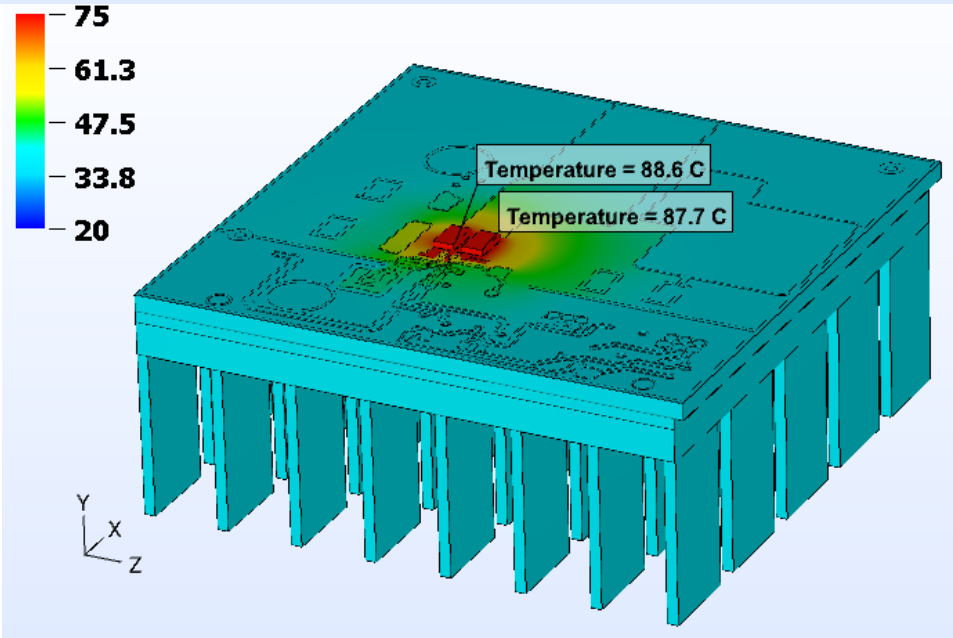


Bottom side Simulation Results

- 30-40% improvement in $R_{\theta JA}$
- Requires all PCB-only cooling techniques

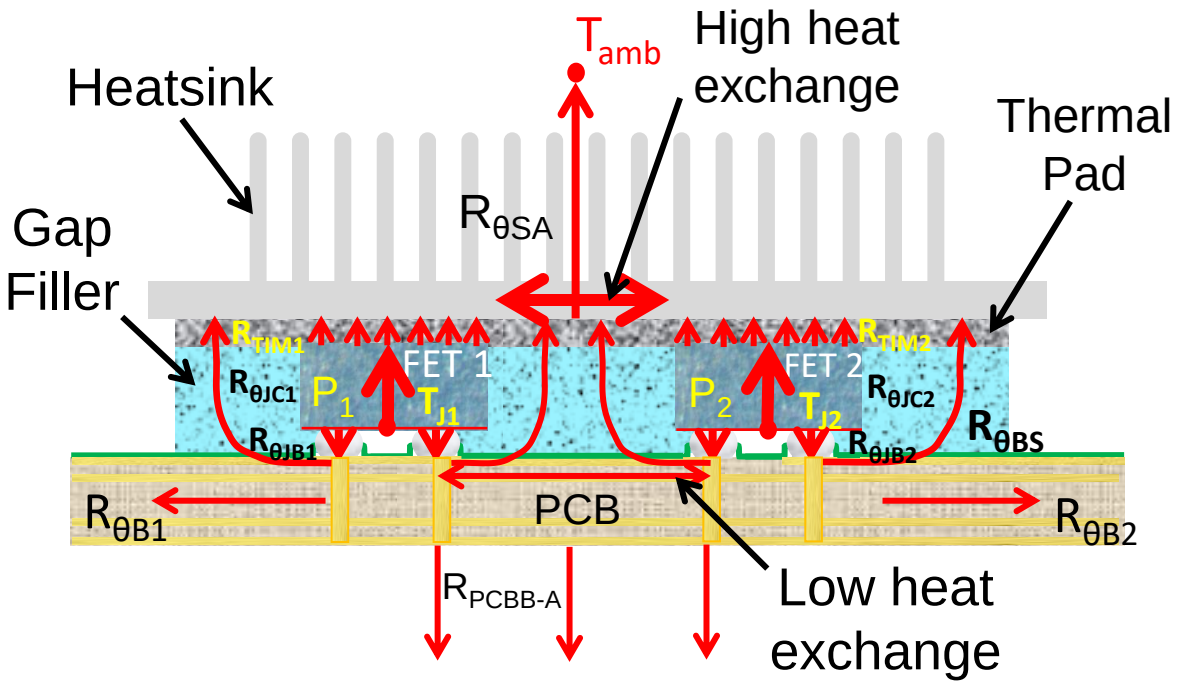


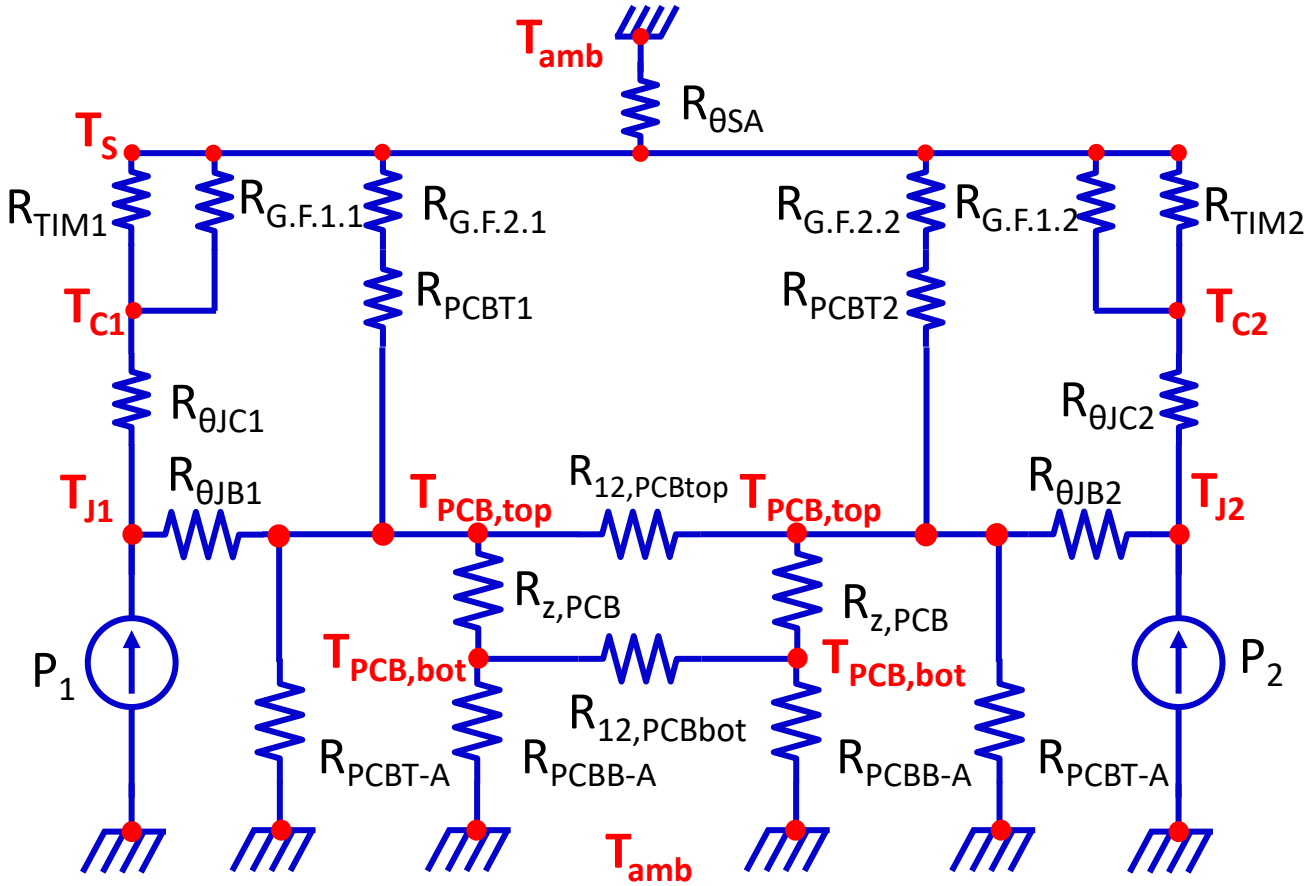




Back-Side Cooling Motivation

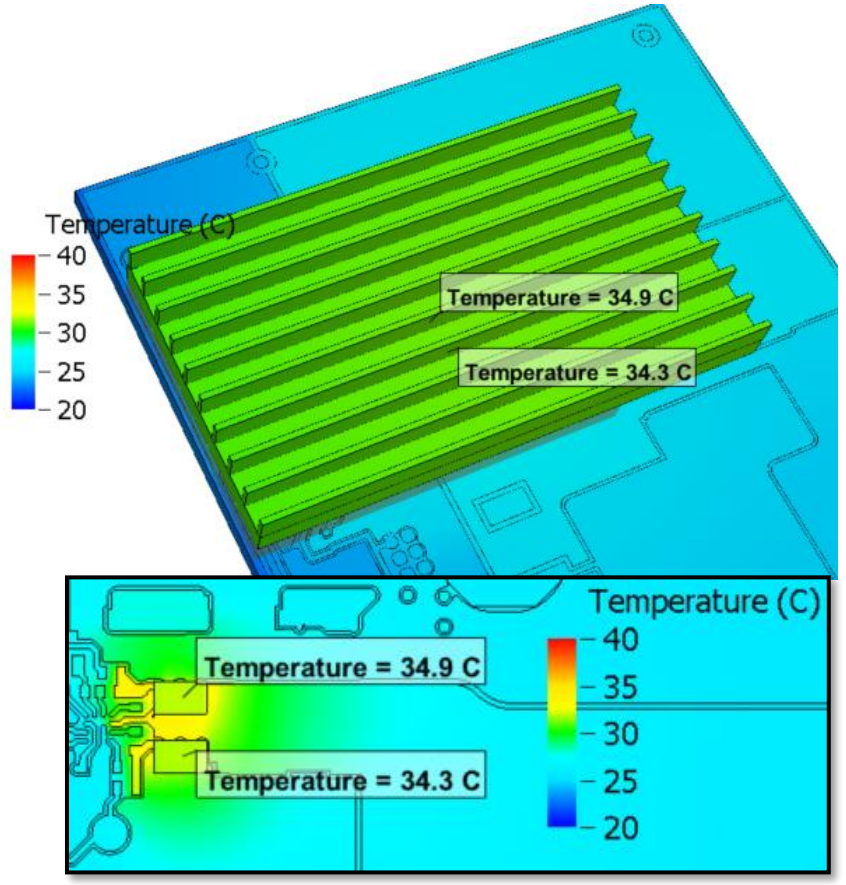
- Most effective cooling path
  - Leverages the lower $R_{\theta JC}$ value of eGaN FETs
- Higher conductivity TIMs needed
  - Device area is small





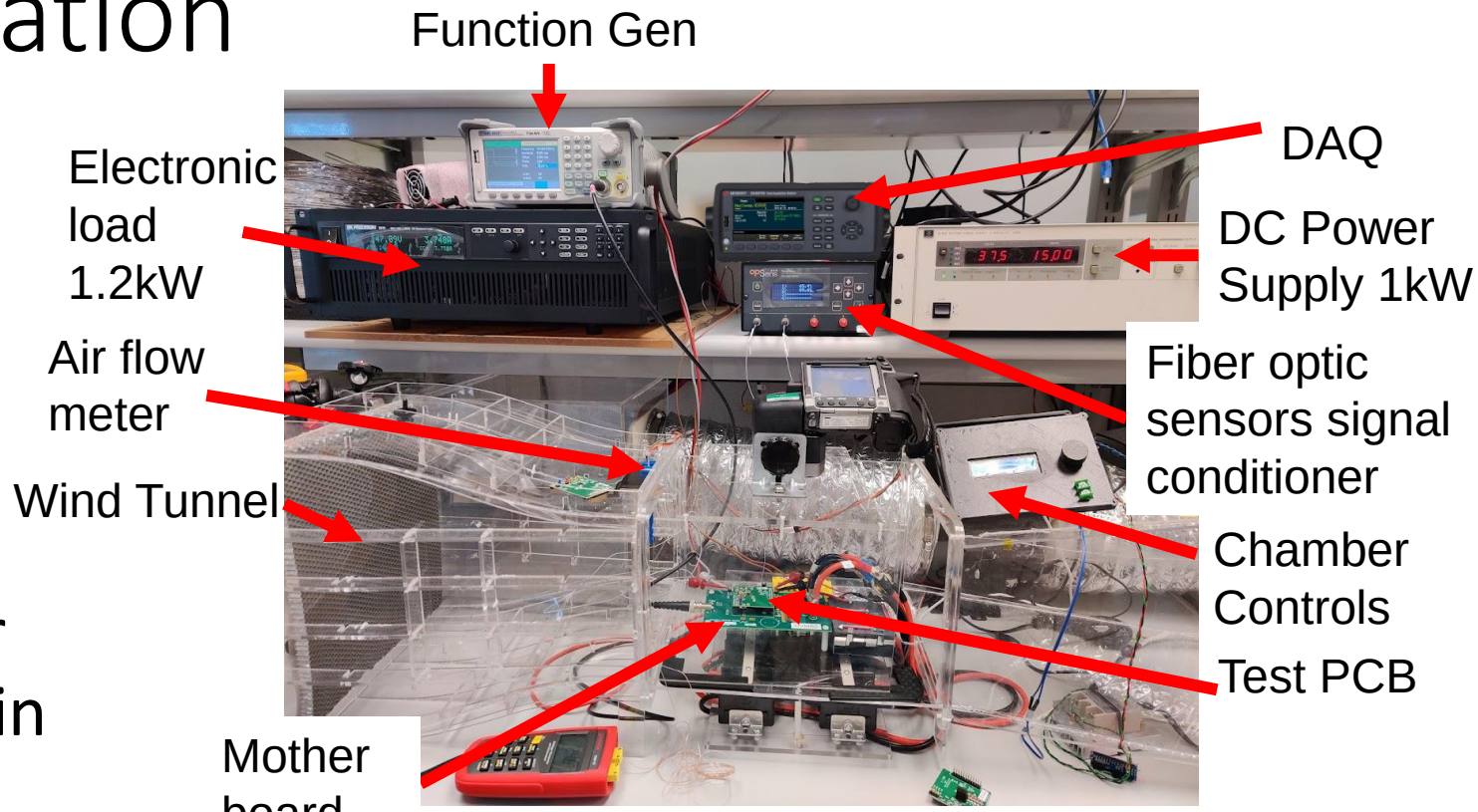
Back-side cooling Simulation Results

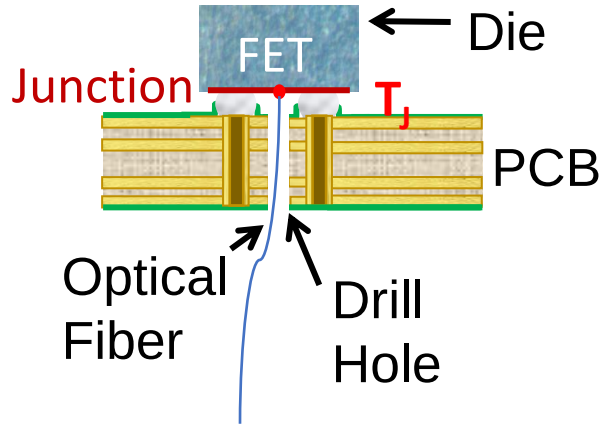
- TIM of κ = 17.8 W/m·K and 10 cm^2 aluminum heatsink
  - $R_{\theta JA}$ = 14.9 K/W
  - 32% improvement over 12 cm^2 bottom-side heatsink case
- Can be further improved with a thinner TIM or more optimized heatsink
  - $R_{\theta JA}$ can be < 10 K/W with TIM < 1 mm thick



Experimental Validation

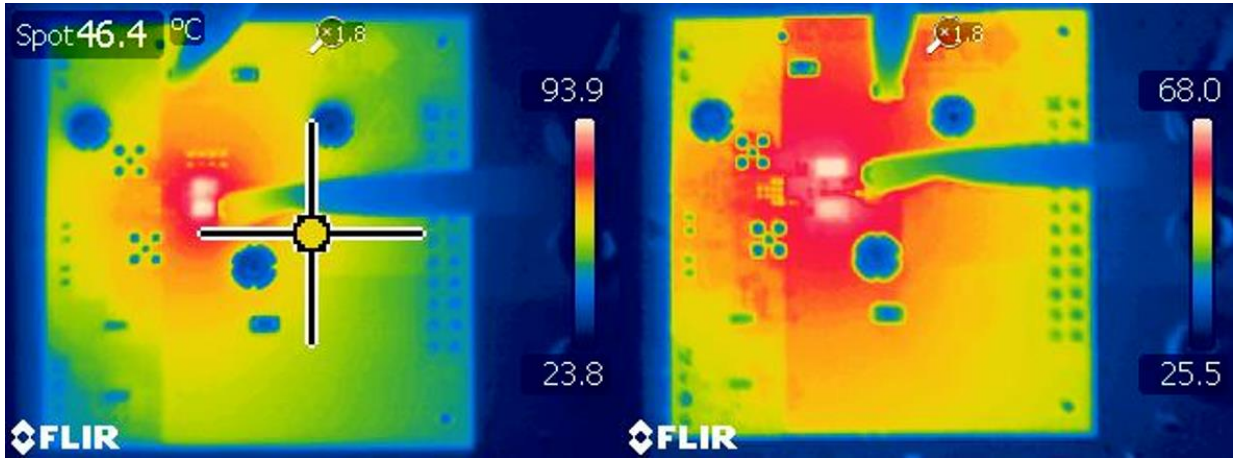
- PCB-only and Back-side heatsink configurations
- Two EPC2619 on a test board mounted to motherboard; connected as shown in image
- OpSense® OTG-F sensor used for temperature measurement within 0.1°C
- Placed in a wind tunnel to control airflow





Experimental Validation Results

PCB-only Cooling



0.5 oz Cu, minimal vias, adjacent FETs

2 oz Cu, vias under the FETs, separated FETs

- PCB-only cooling cases show a close match with the simulated results

Backside Cooling

Airflow	Sim. $R_{\theta JA}$ [K/W]	Exp. $R_{\theta JA}$ [K/W]
200 LFM	18.8	21.06
400 LFM	14.9	17.2
600 LFM	14.6	15.92

- Around ~10% error
- Simulation underestimates $R_{\theta JA}$

Conclusions

For GaN FETs:

- PCB cooling techniques such as vias in pad and thicker copper can double current carrying capability
- Bottom-side cooling about 30% more effective than PCB-only cooling
  - Uses a large area TIM
  - Requires implementation of all PCB-cooling techniques
- Back-side cooling solution is the most effective for reducing $R_{\theta JA}$
  - $R_{\theta JC}$ is the most direct heat path
  - 30% improvement over bottom-side cooling
  - Must manage mechanical stress

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Thank you for your time. Any questions?