FLOMERICS

FLOPCB

Temperature-Aware Design of Printed Circuit Boards

Co-design of PCBs for electrical, mechanical and thermal engineers

Based on EDA Design for Manufacturing Flows

CDNLive 2007

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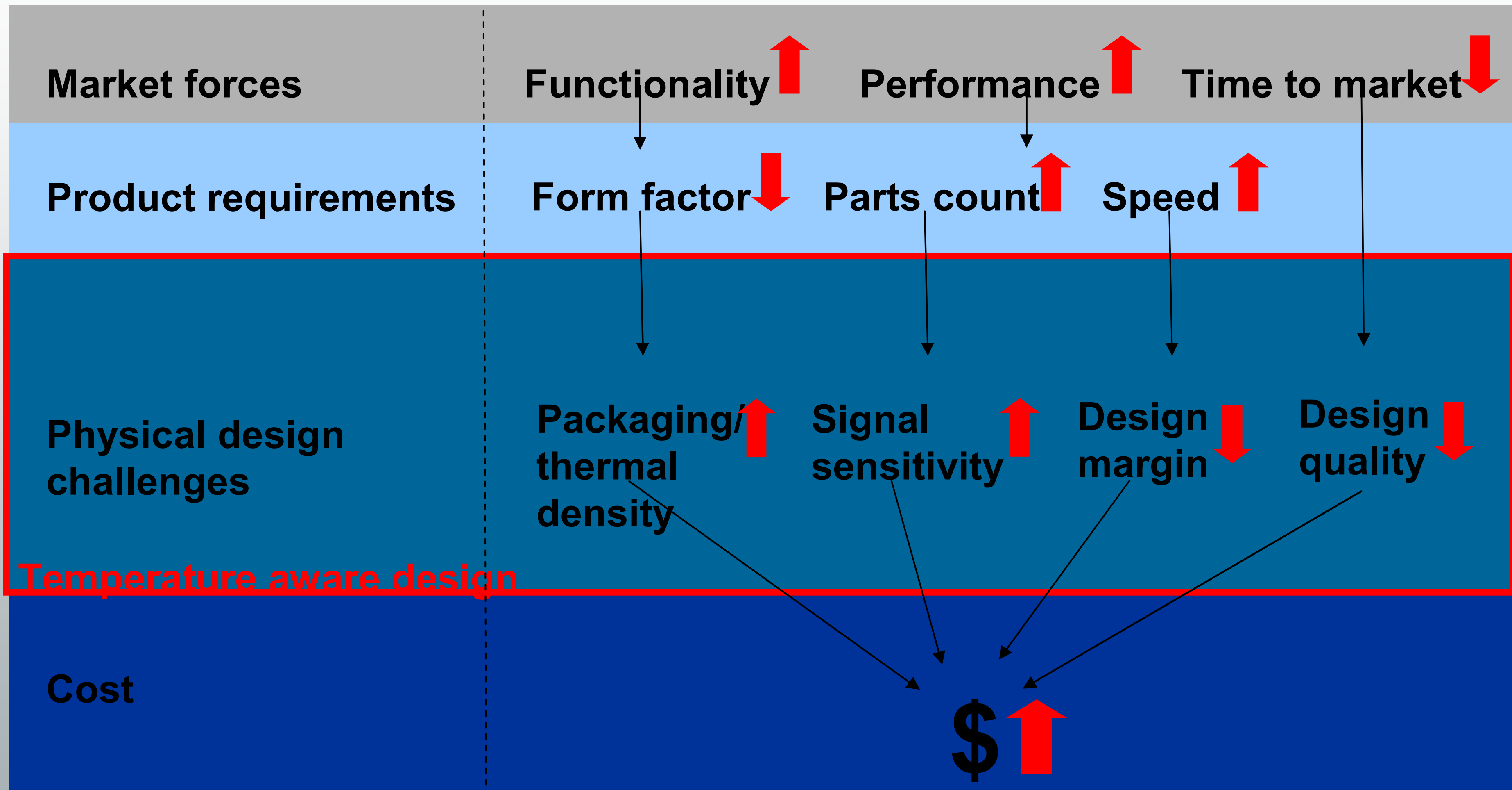
Support Manager
Flomerics Ltd.

AGENDA

- Drivers for temperature - aware design
- Impact on PCB design
- Making the Allegro design flow temperature - aware
- Case Study
- Summary & Conclusions

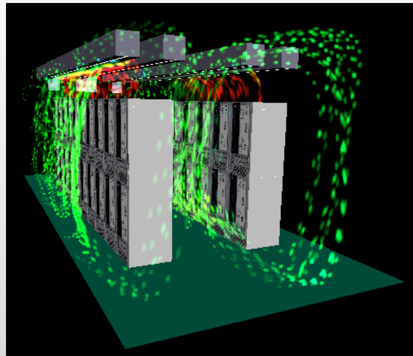
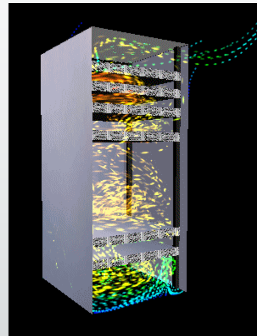
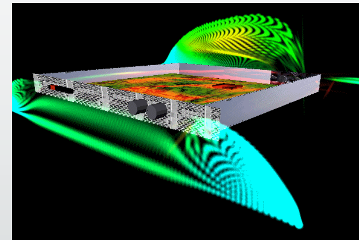
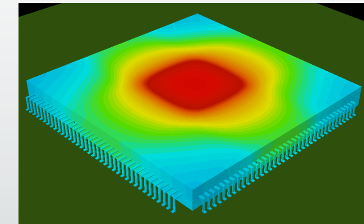
Drivers for Temperature Aware Design



Product Requirements

- Designs are complex
  - High transmission speeds
  - High PCB layer count
  - High pin count ASICs
  - Embedded passives
  - Daughter cards
  - Extensive heat sinking
- Design margins are small, risk is high
  - Performance, reliability are compromised
  - 80-90% of nets are constrained, restricting component placement
  - Heat sinks are large and complex, requiring placement flexibility
- Design closure is difficult and costly
  - Signal integrity, thermal & component placement requirements clash
  - Co-design is critical
  - Performance is being impacted

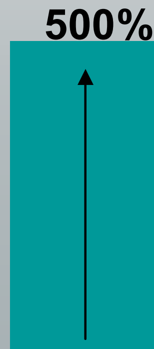
Physical Design Challenges: Five Year Thermal Density Trends*

Datacenter	Rack	System/PCB	IC/package
			

*Flomerics customer survey data

900%

500%



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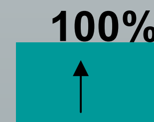
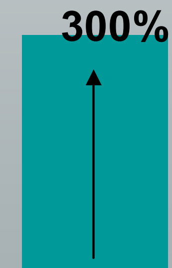
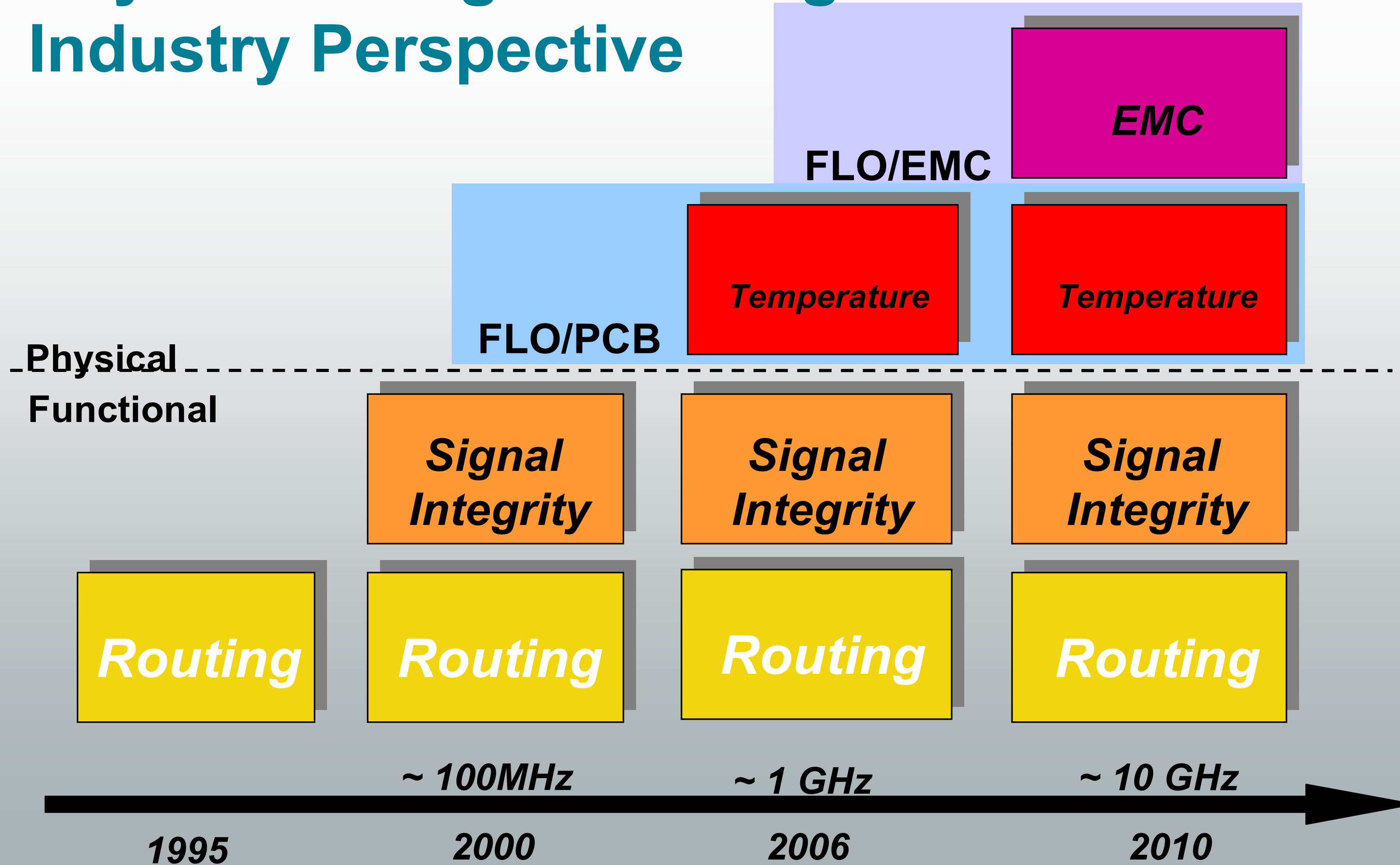


300%

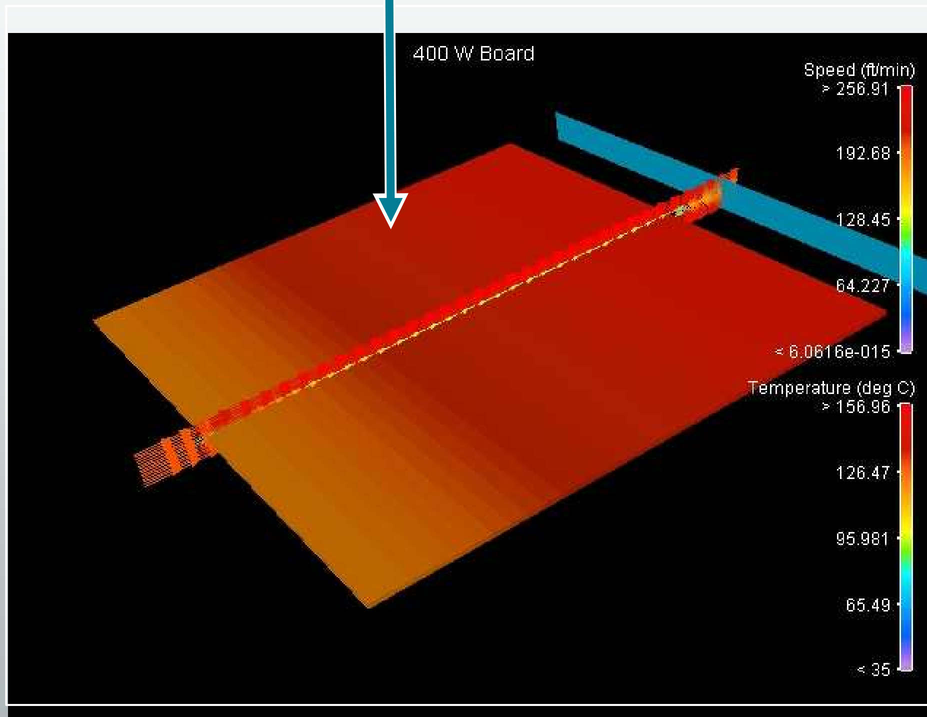


Physical Design Challenges: Industry Perspective



Physical Design Challenges

Components @ 120 ºC

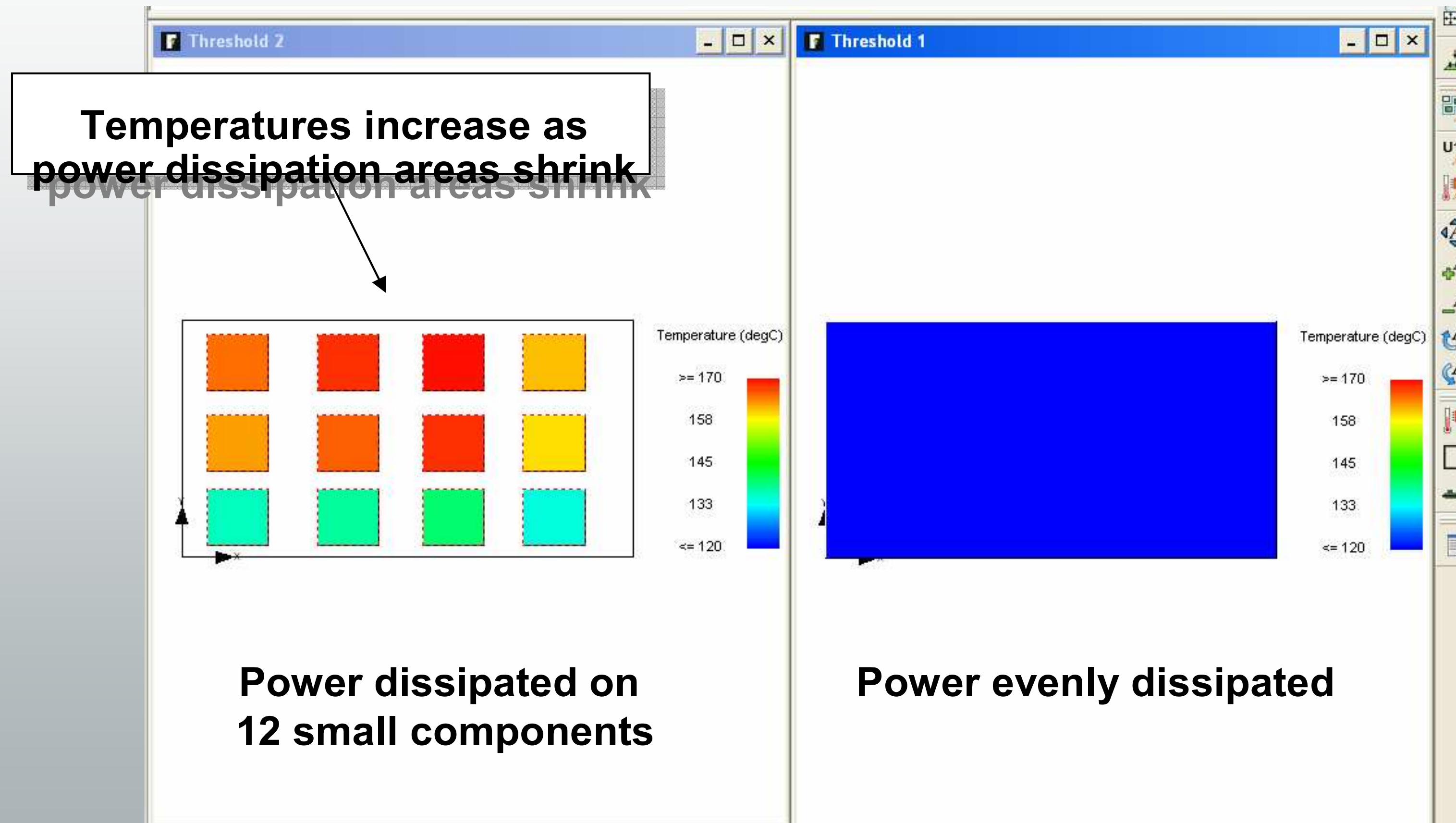


PCB at 1.5 W/in^2, 1 m/s

- PCB power densities are reaching 1.5 W/in^2 for high speed applications
- At this level, the PCB has reached its heat sinking limit
- Thermally unworkable designs are common
- 20% of Flomerics customers have reached this threshold and the percentage is rising
- The industry in general can see the approaching threshold

How Effective is a PCB as a Heat Sink?

15” x 8” PCB, 180 W, 1 m/s airflow

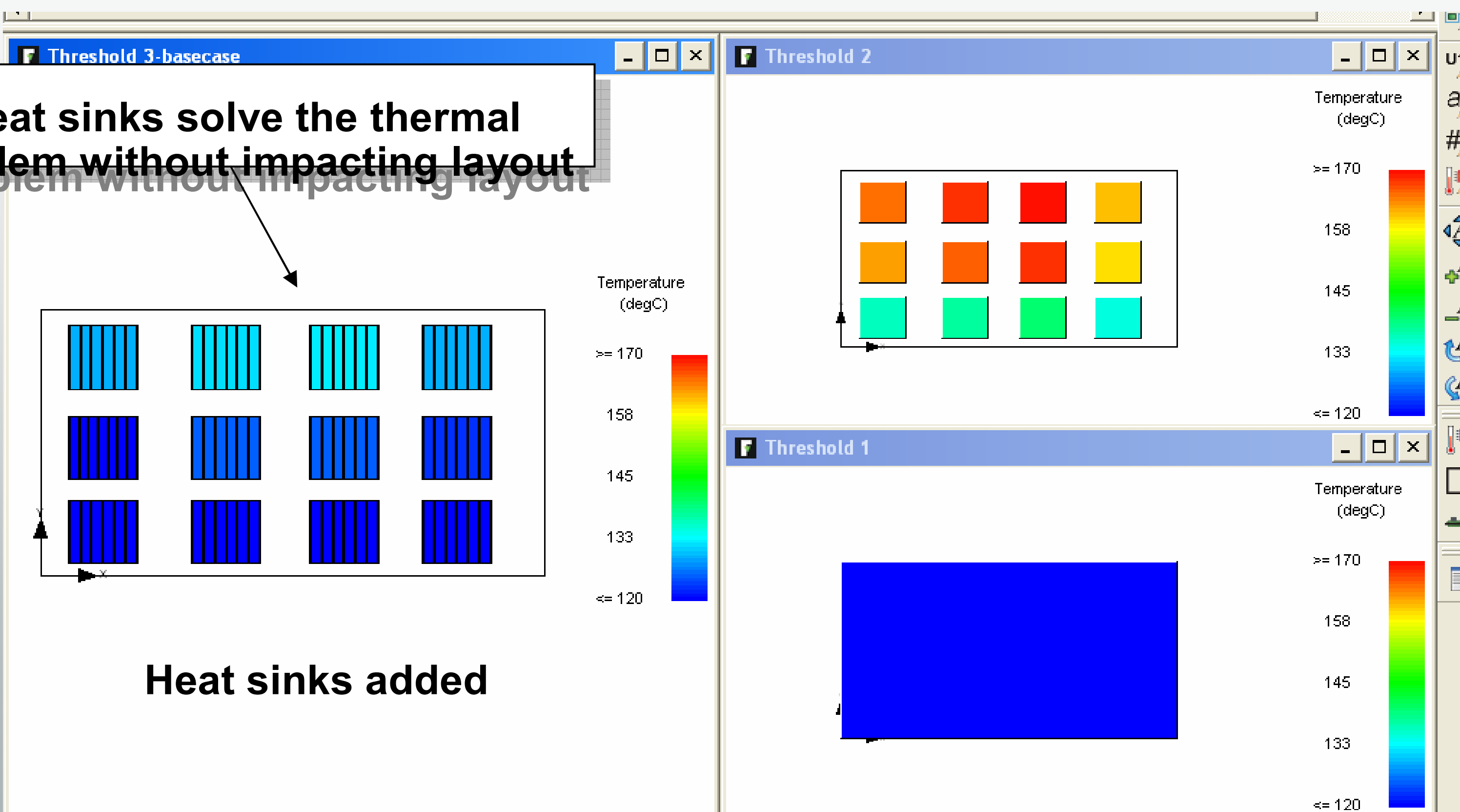


Power dissipated on 12 small components

Power evenly dissipated

How Effective is a PCB as a Heat Sink?

15” x 8” PCB, 180 W, 1 m/s airflow

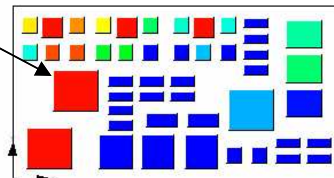
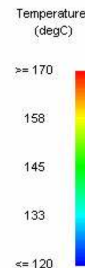


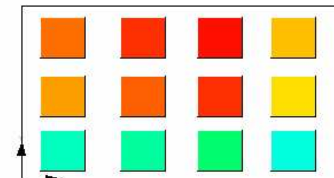
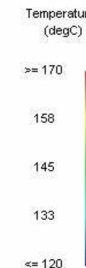
How Effective is a PCB as a Heat Sink?

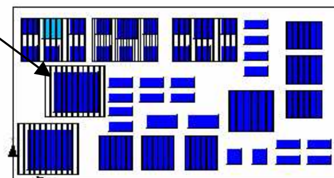
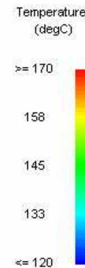
15" x 8" PCB, 180 W, 1 m/s airflow

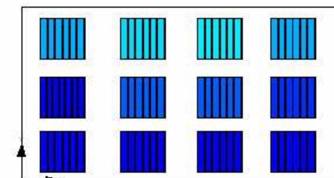
High temperatures due to high power density components

Heat sinking is to more complex

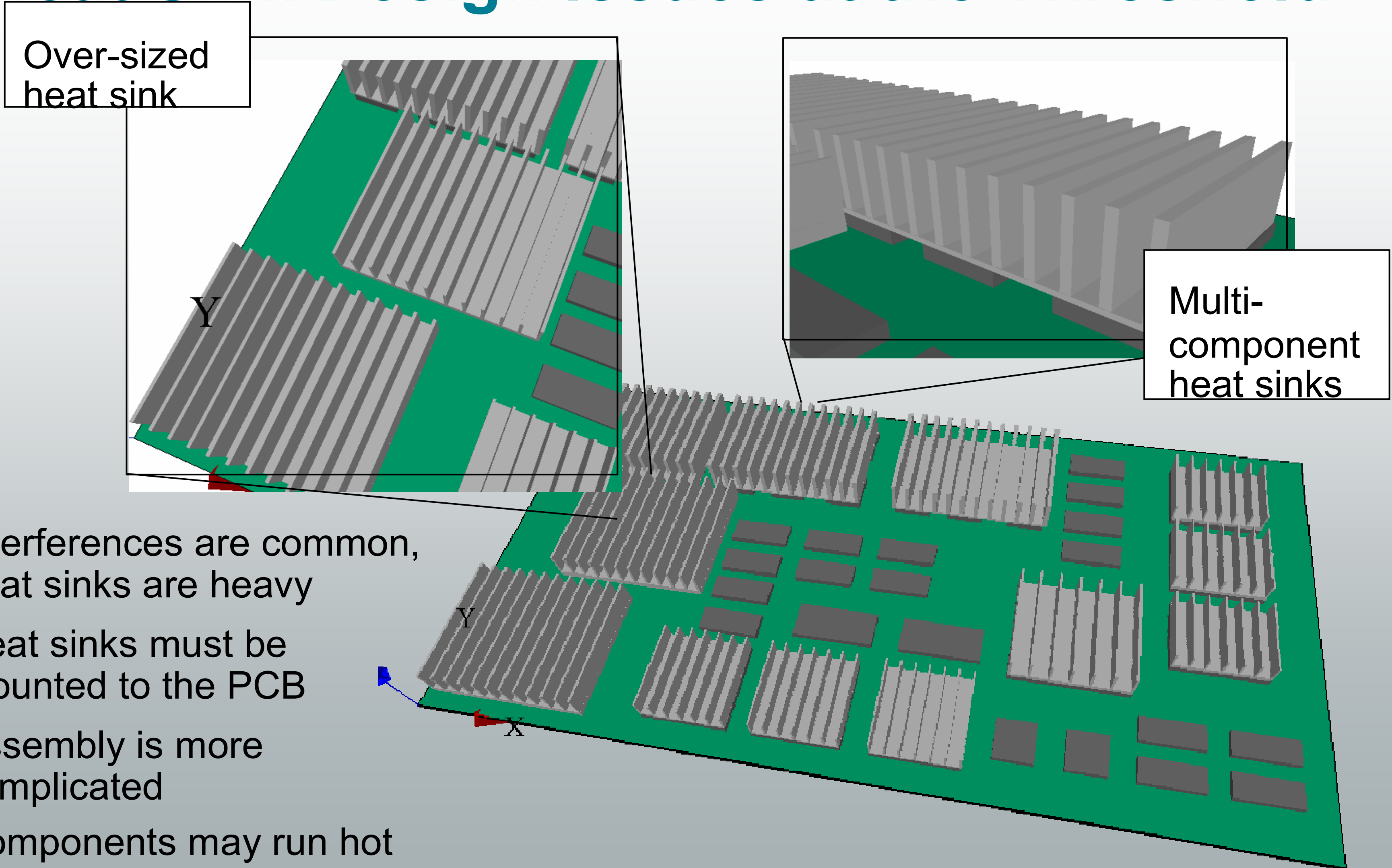





Real world PCB

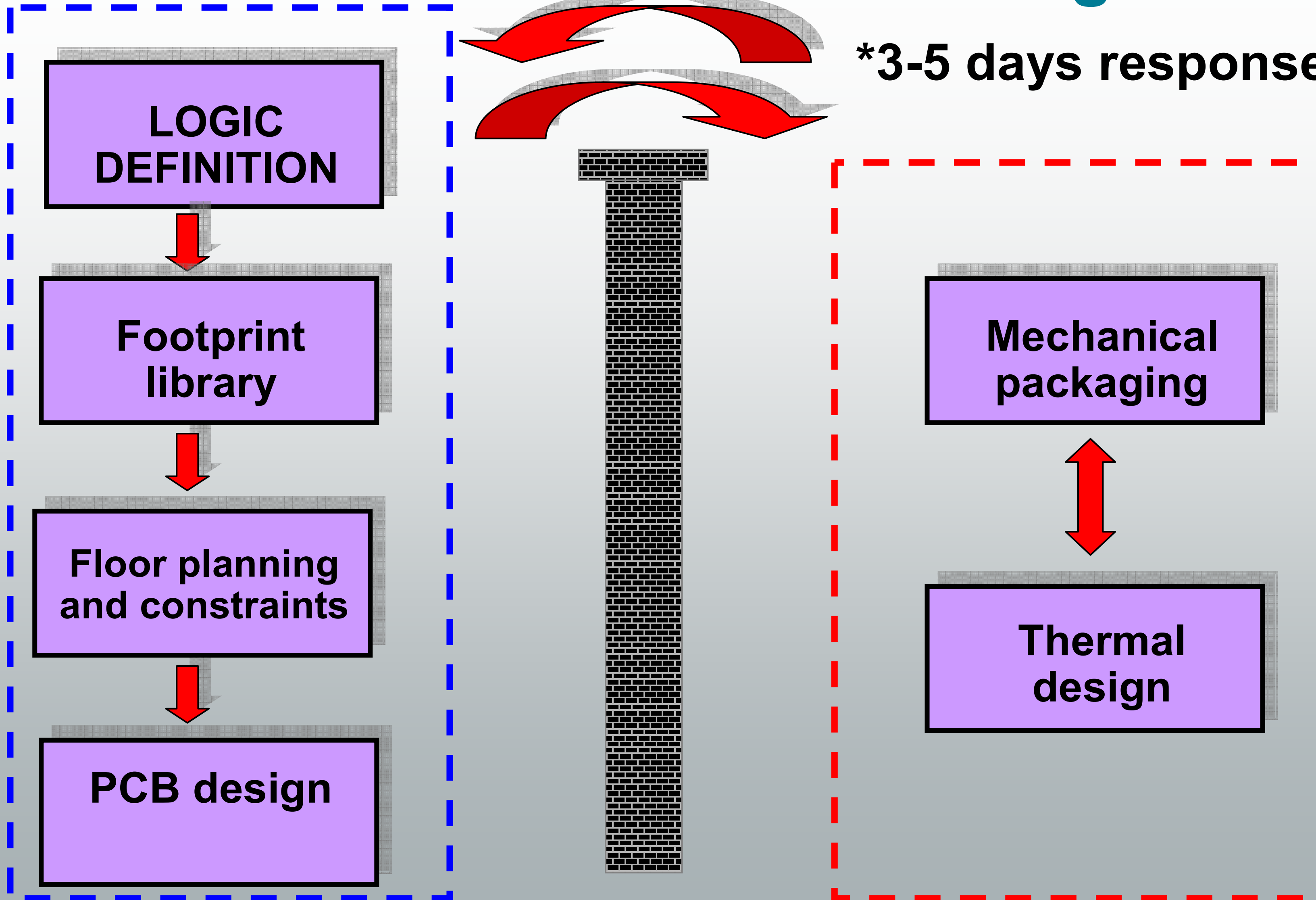
Idealized PCB

Heat Sink Design Issues at the Threshold



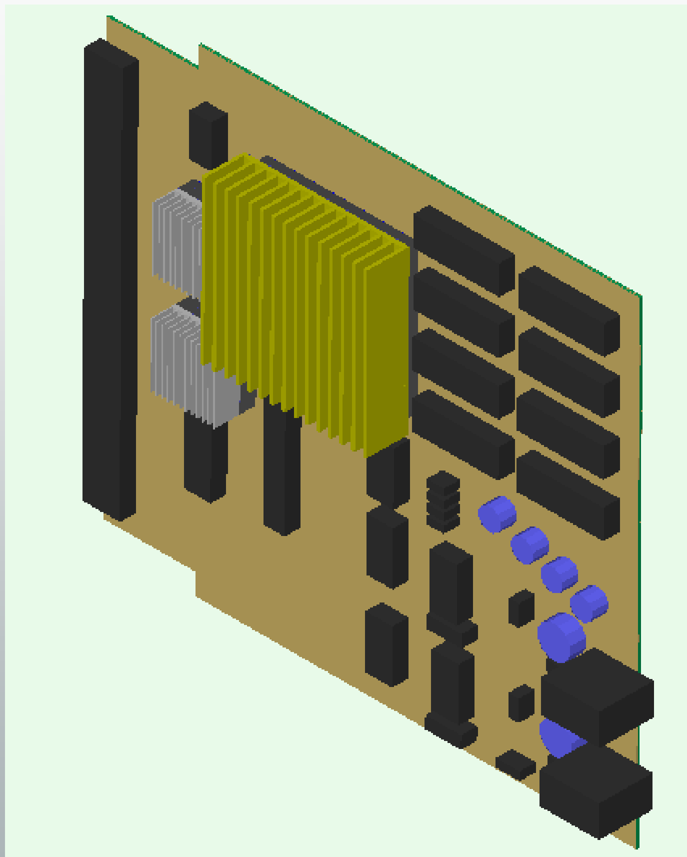
- Interferences are common, heat sinks are heavy
- Heat sinks must be mounted to the PCB
- Assembly is more complicated
- Components may run hot

Traditional PCB Design



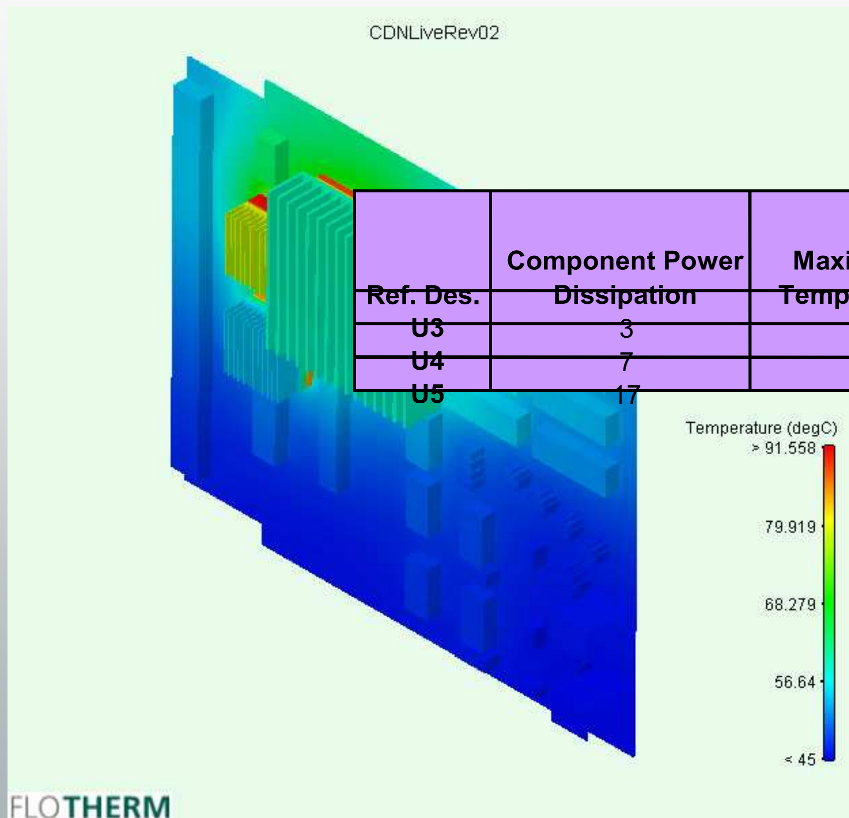
*3-5 days response time

Traditional PCB Design



- ► Thermal Solution Design Requirements
  - ► Junction temperature
  - ► Shock and vibration
  - ► Cost
  - ► Mechanical fit
  - ► Parts availability
  - ► System level performance

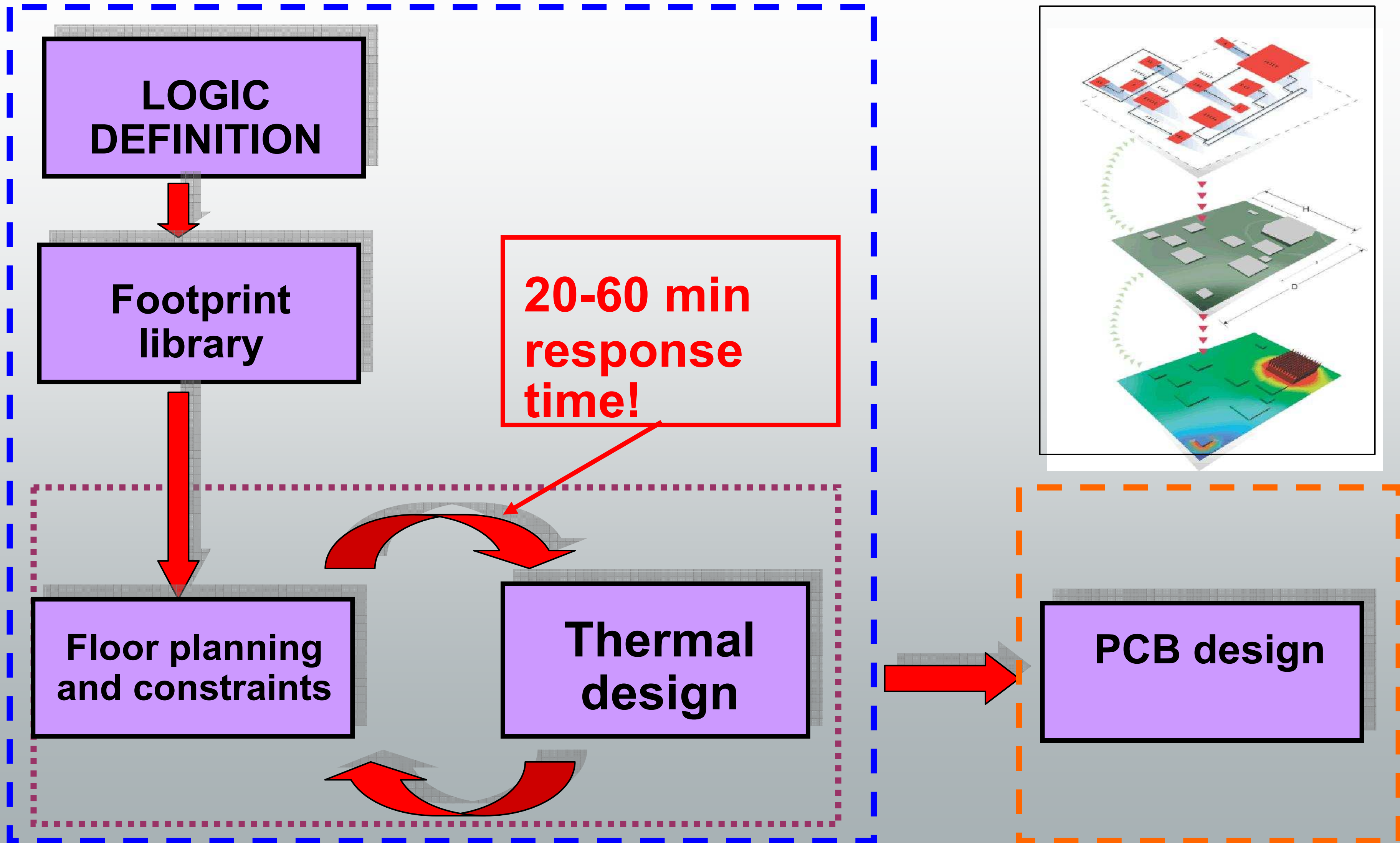
Traditional PCB Design



Ref. Des.	Component Power Dissipation	Maximum Case Temperature (°C)	Predicted Case Temperature (°C)	Margin (°C)
U3	3	75	65.3	9.7
U4	7	75	107	32
U5	17	80	80.4	0.4

- ►Attempt is made to meet cooling requirements by heat sinking based on design
- ►…ks cannot be p… …al estate problems
- ►Components are still operating above their required case temperature limit
- ►Use of Cu heatsink instead of cheaper, lighter heatsink (aluminum)

Temperature-Aware PCB Design

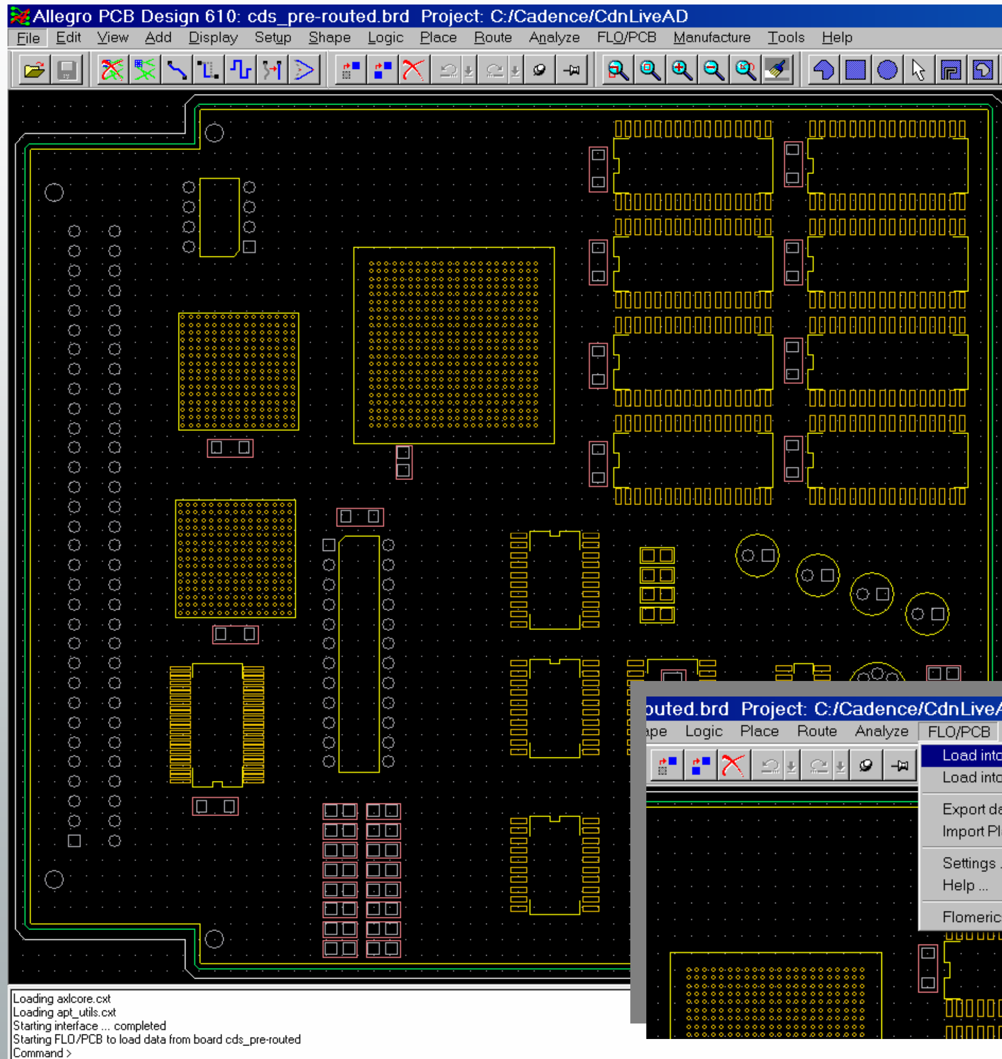


Temperature-Aware PCB Design

- Bi-directional model transfer
- High-degree of automation
  - Model transfer and filtering
  - Model-set up
  - Solver automation
  - Results viewing and interpretation
- Intuitive user control
  - Drag ‘n Drop model modification
  - SmartParts
  - Intelligent modeling rules
  - Interactive 3D viewing
- The time to complete the loop from SI constraints to thermal design, back to SI constraints must be completed in minutes
- Traditional loop response time 3-5 days
- Temperature aware response time 20-60 minutes

Case Study
of a Temperature-Aware Design Flow

SI Constraints -> Thermal Design



- Constraints are set in Allegro PCB SI
- Launch thermal tool from within Allegro PCB SI
- Board Information, Component Footprints/Height etc are filtered and passed into FLO/PCB

SI Constraints -> Thermal Design

No Name - FLOPCB 3.1 FOR ALLEGRO (Build 6.23.5)

Component Filter Options

Combine Parameters By	Or	
Side Length Less Than	1	mm
Height Less Than	1	mm
Power Less Than	0	W
Power Density Less Than	0	W/m^2
Name Contains	Undefined	

Filter | Delete | Cancel | Help

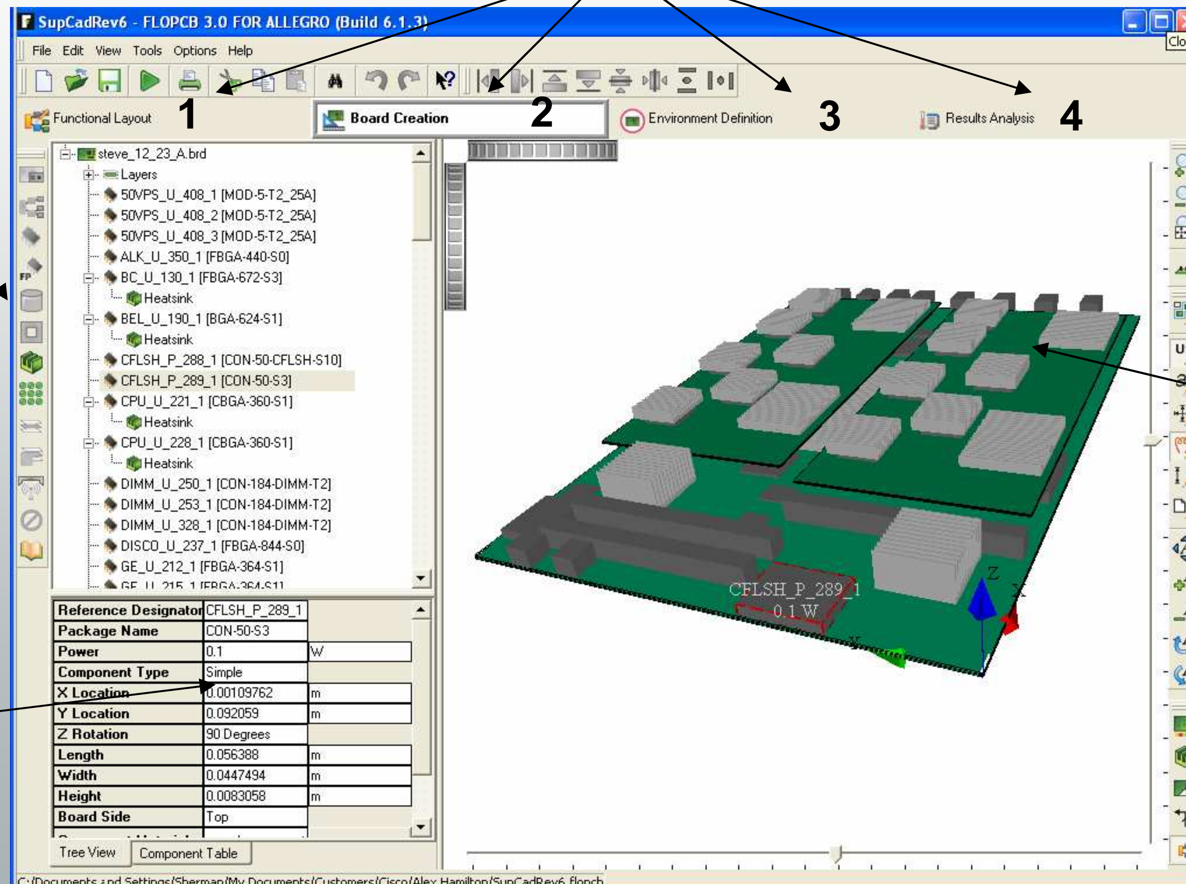
Name	MotherBoard
Z Rotation	None
Flip Board	
Length	400
Width	200
Thickness	1.6
Dielectric Material	FR4
Notes	

► **Component filter allows for only the critical components to be passed**

FLO/PCB User Interface: Designed for Quick Thermal Verification

Four steps to model creation and analysis

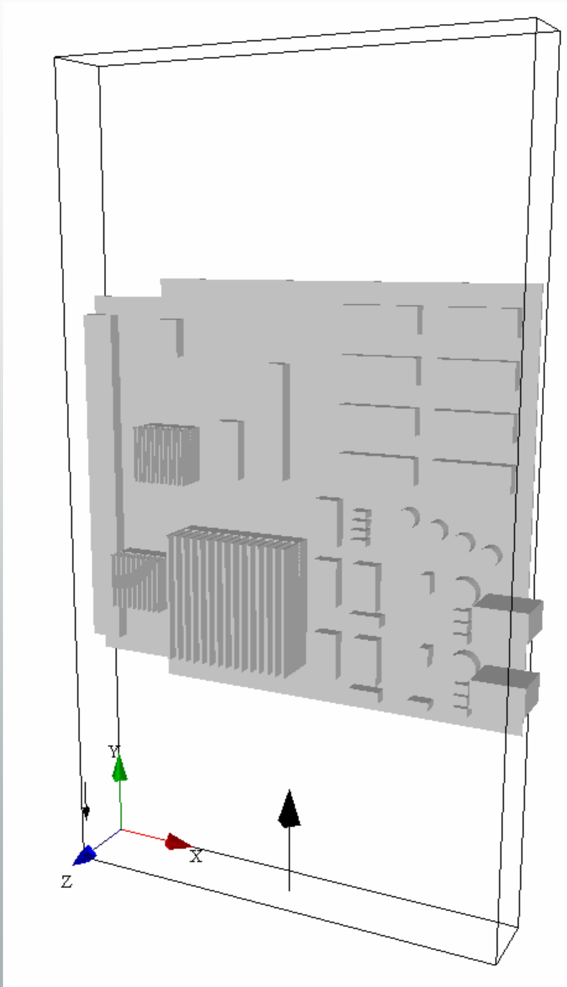
SmartParts



3D model

Property sheet input

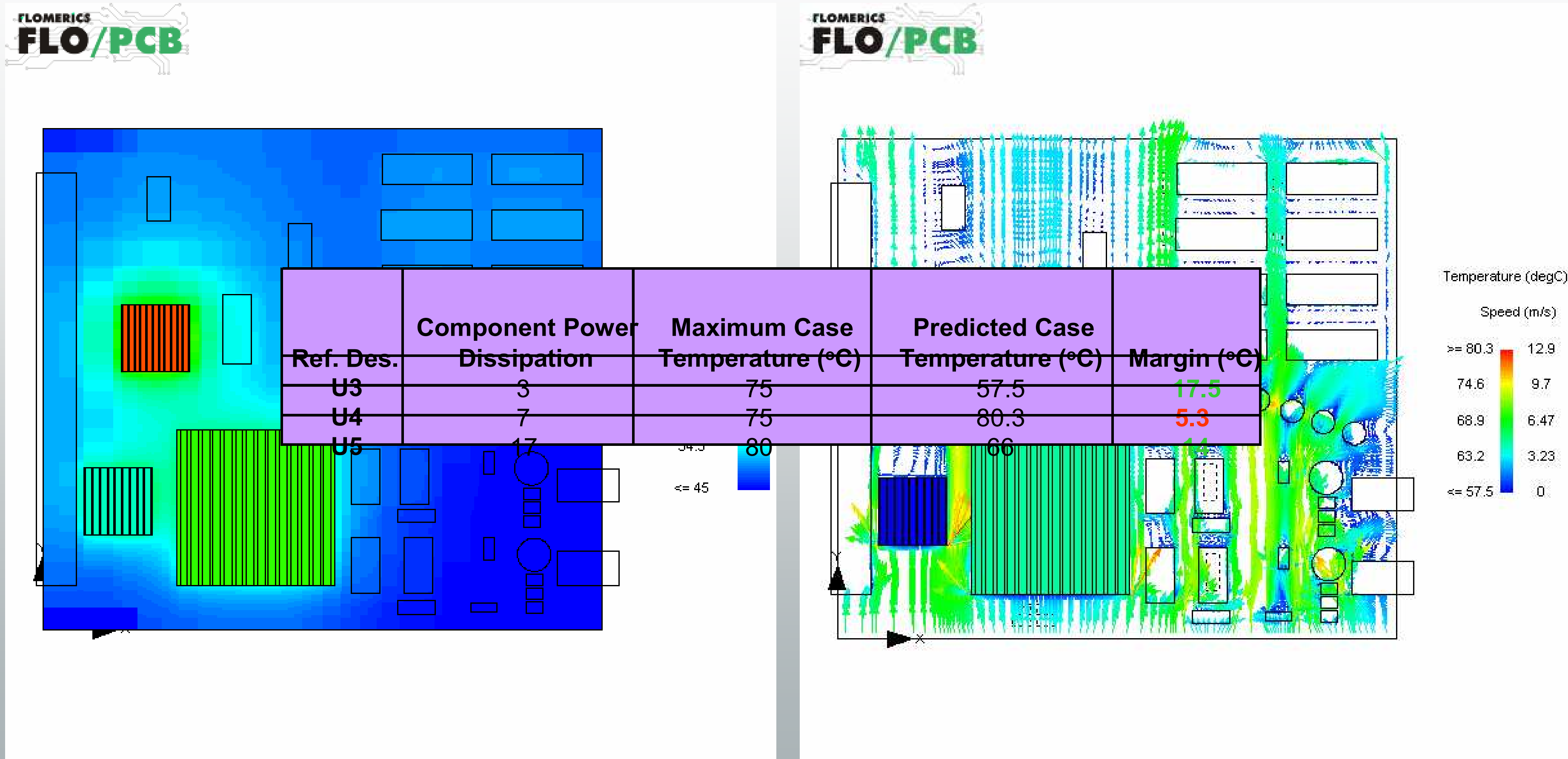
Layout 1 Variant Definition



1. **Heatsinks added to thermally critical components**
   - **Check mechanical fit**
2. **Proposed thermally optimized layout manually defined in thermal tool**
3. **Ensure that appropriate up-to-date power dissipation values are entered**
4. **Select the environment in which the design is to operate, e.g. card slot**
5. **Perform a thermal prediction and inspect results**

Response time: 20 minutes!

Layout 1 Variant Results

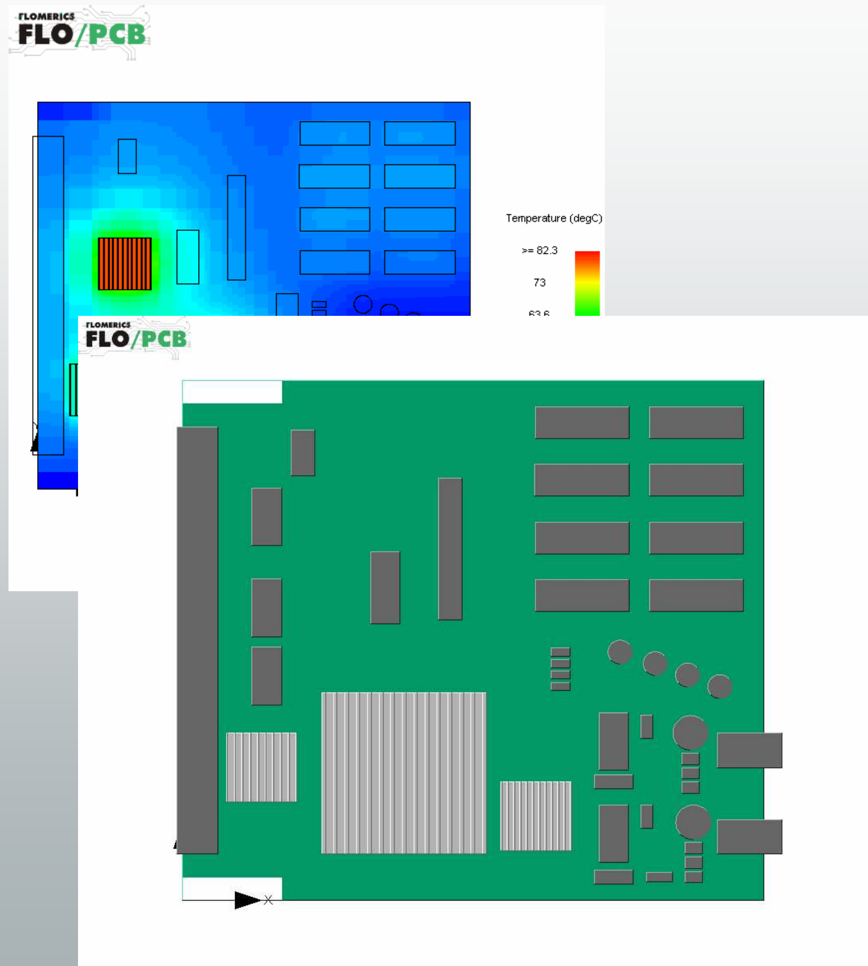


Ref. Des.	Component Power Dissipation	Maximum Case Temperature (°C)	Predicted Case Temperature (°C)	Margin (°C)
U3	3	75	57.5	17.5
U4	7	75	80.3	5.3
U5	17	80	66	14

► Temperature Contour (thru the board)

► Velocity Contour (3 mm above board)

Layout 2 Variant



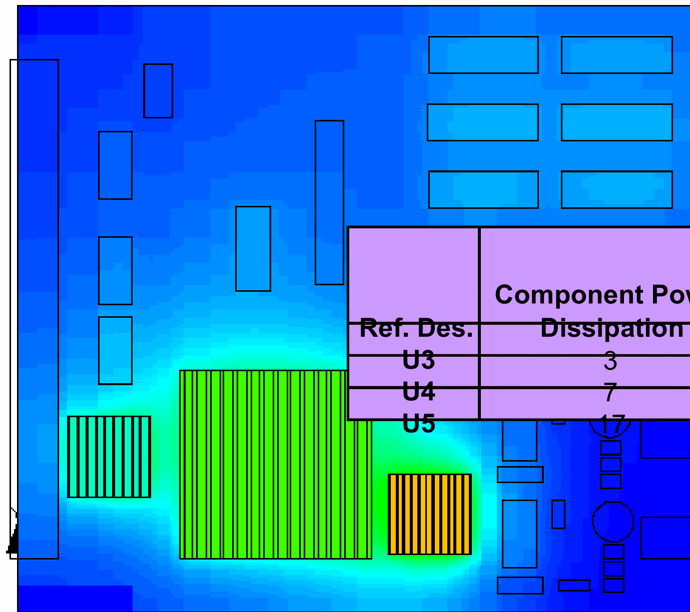
1. **Critical component moved in an attempt to decrease its case temperature**
    1. **Check mechanical fit**
2. **All other settings retained**
3. **Perform a second thermal prediction!**

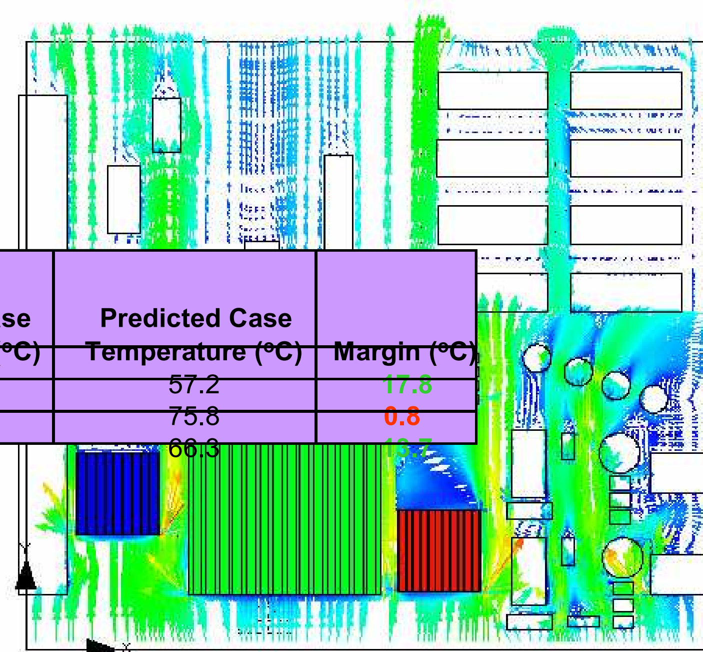
Response time 10 minutes

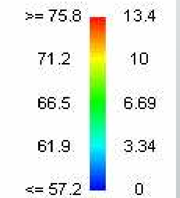
Layout Variants

- PCB properties
  - Layers
  - Copper patches
  - Material properties (Stablecor)
  - Thermal vias
- PCB layout
- Heat sinks
- Environmental conditions
  - Airflow
  - Air temperature

Layout 2: Results







Ref. Des.	Component Power Dissipation	Maximum Case Temperature (°C)	Predicted Case Temperature (°C)	Margin (°C)
U3	3	75	57.2	17.8
U4	7	75	75.8	0.8
U5	17	80	66.3	13.7

► **Temperature Contour (thru the board)**

► **Velocity Contours (3 mm above board)**

Back Annotate the Proposed Design

Allegro PCB Design 610: cds_pre-routed_final.brd Project: C:/Cadence/CdnLiveAD

No Name - FLOPCB 3.0 FOR ALLEGRO (Build 5.50.2)

File Edit View Tools Options Help

- New Ctrl+N
- Load... Ctrl+O
- Save Ctrl+S
- Save As...
- Import...
- Export...
  - Export FLOPLC... Ctrl+R
  - Export PACK... Ctrl+A
  - Export PDML... Ctrl+D
  - Export CSV...
  - Export IDF...
  - Export Power List...
- Check Model... Ctrl+L
- Save Image...
- Print... Ctrl+P
- C:/temp/FLOhq10113_rev2_updated.flopcb
- C:/temp/FLOhq10113_rev2.flopcb

Allegro Constraint Manager (connected to Allegro PCB Design 610 15.5) - [Nets: Routing]

▶ ... layout from thermal tool

▶ Multiple violations found by constraint manager

▶ SI rules must be revisited

▶ The new layout can then again be passed into thermal tool, automatically updating the existing model definition

Loading signal.cxt
Performing a partial database check before saving.
Writing database to disk.
'cds_pre-routed_final.brd' saved to disk.
Command >

Fast Response Time

- 20 minutes for:
  - Data transfer
  - Thermal model set up
  - Solution
  - Results processing
  - Report generation
  - Back annotation
- Four design variants

Summary & Conclusions

- Temperature aware design makes SI, thermal and mechanical considerations an integral part of pre-route floor planning
  - Enough thermal detail is considered to “close” the floor plan design
- Thermal validation can be performed by EE or ME, depending on response time requirements
  - Thermal closure is typically the responsibility of the thermal engineer

Summary & Conclusions

- Temperature aware design is possible through design tool automation
  - Bi-directional compatibility
  - All thermal data stored in Allegro database
  - Intuitive user interface
  - High-degree of modeling and results processing automation
- Temperature aware design is interactive and dynamic as compared to traditional 'over the wall' thermal design
  - Common data transfer mistakes and oversights are eliminated
  - All players are working at the same rate and are synchronized
  - Design space for SI, mechanical and thermal closure is maximized
  - Overall design time and effort is minimized

Summary and Conclusions

- Reduce risk of late-cycle redesign by fully considering thermal requirements before routing
- Reduce communication bottlenecks and errors between electrical and mechanical engineers
- Increase data reuse by leveraging the EDA database for thermal design
- Reduce overall design cost and increase quality by opening design space