

Challenges to Extending Semiconductor Cooling Limits

July 29th, 2004

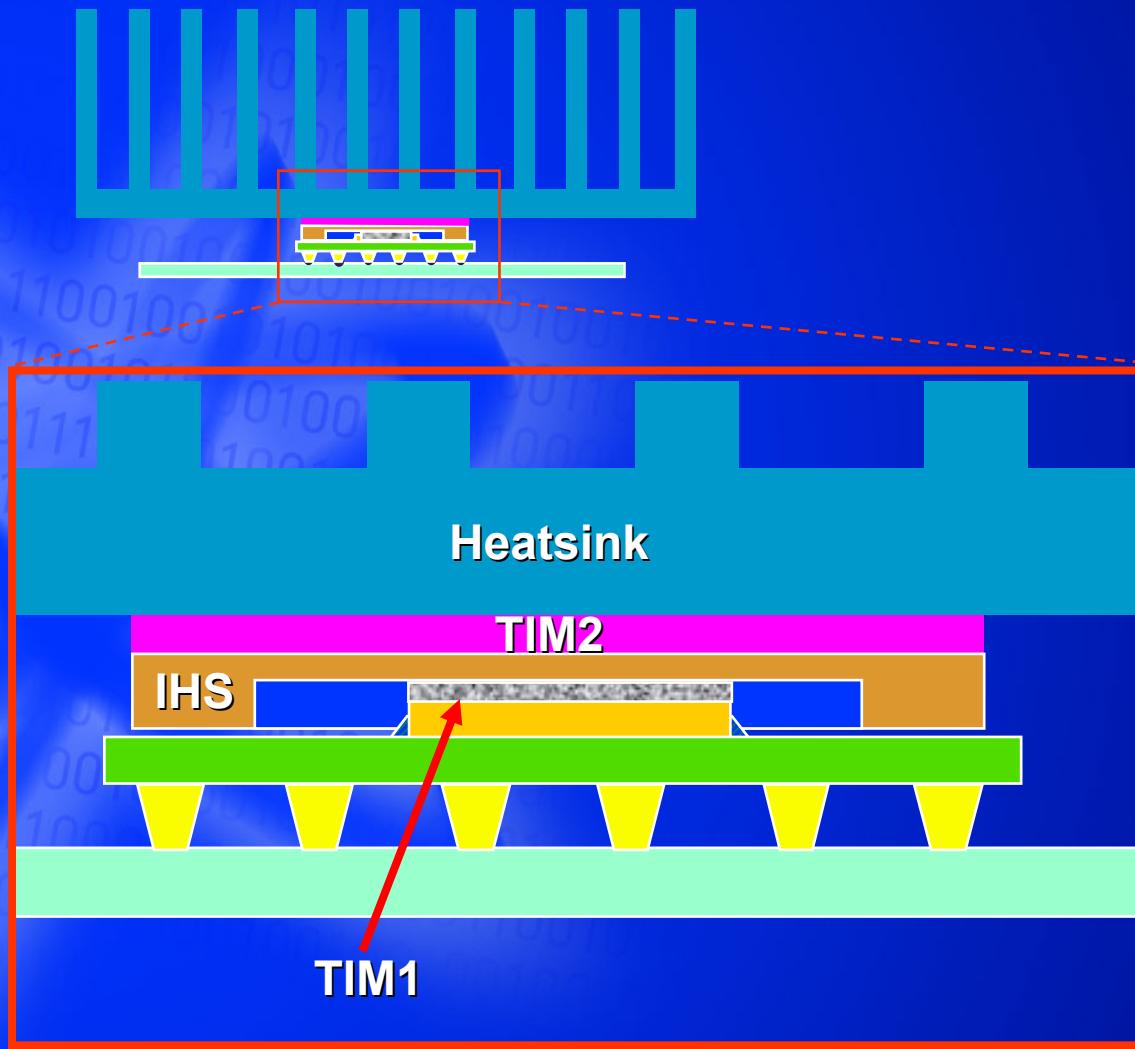
Martin Rausch

Assembly Technology Development
Technology Manufacturing Group

Agenda

- **Limits**
 - Hotspots
 - Thermal Capacity
 - System Constraints
- **Technology Direction**
 - Fluid-based cooling
 - Refrigeration

Thermal Limits

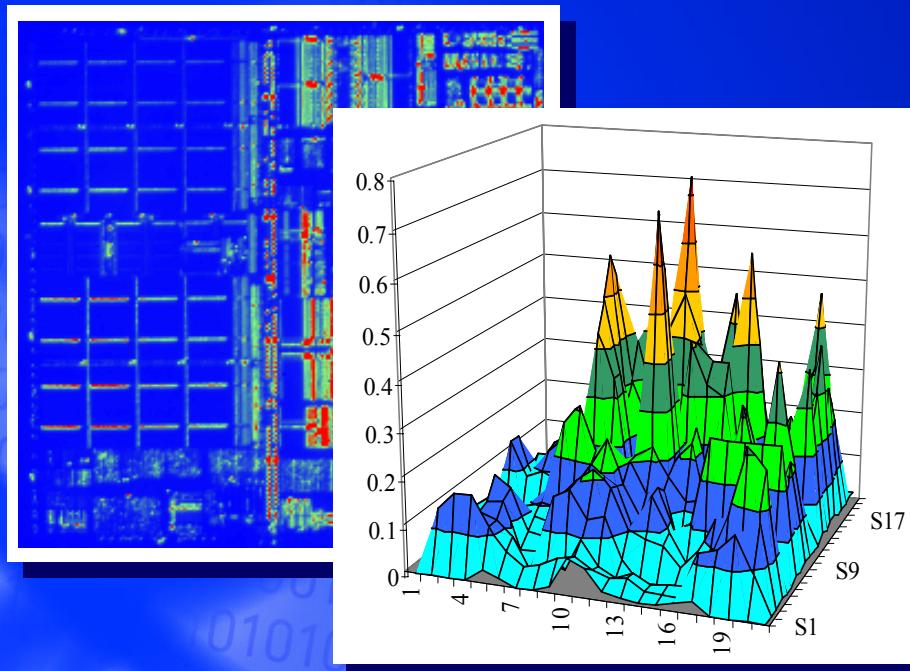


Two Challenges

- Hotspots
(heatspreading)
- Thermal capacity
(resistance)

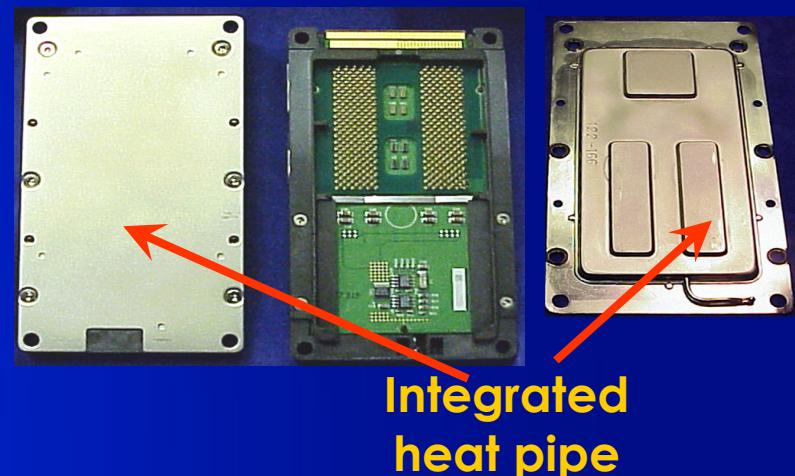
Limits

Hotspots



Example #1

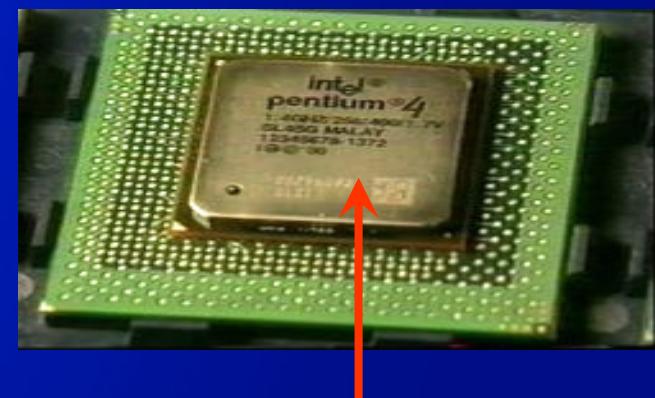
Intel® Itanium® Processor



Integrated
heat pipe

Example #2

Intel® Pentium® 4 Processor

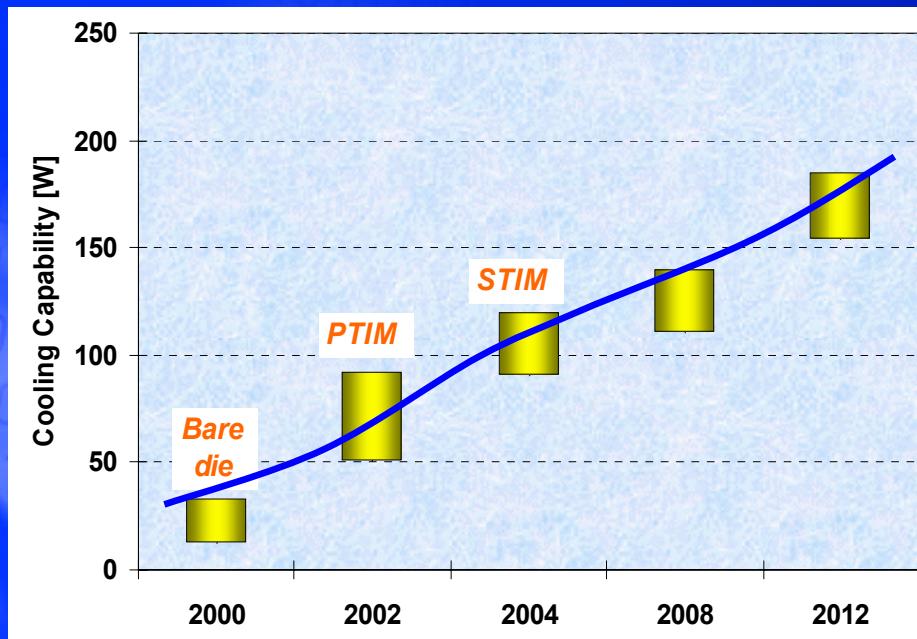


Integrated Heat
Spreader

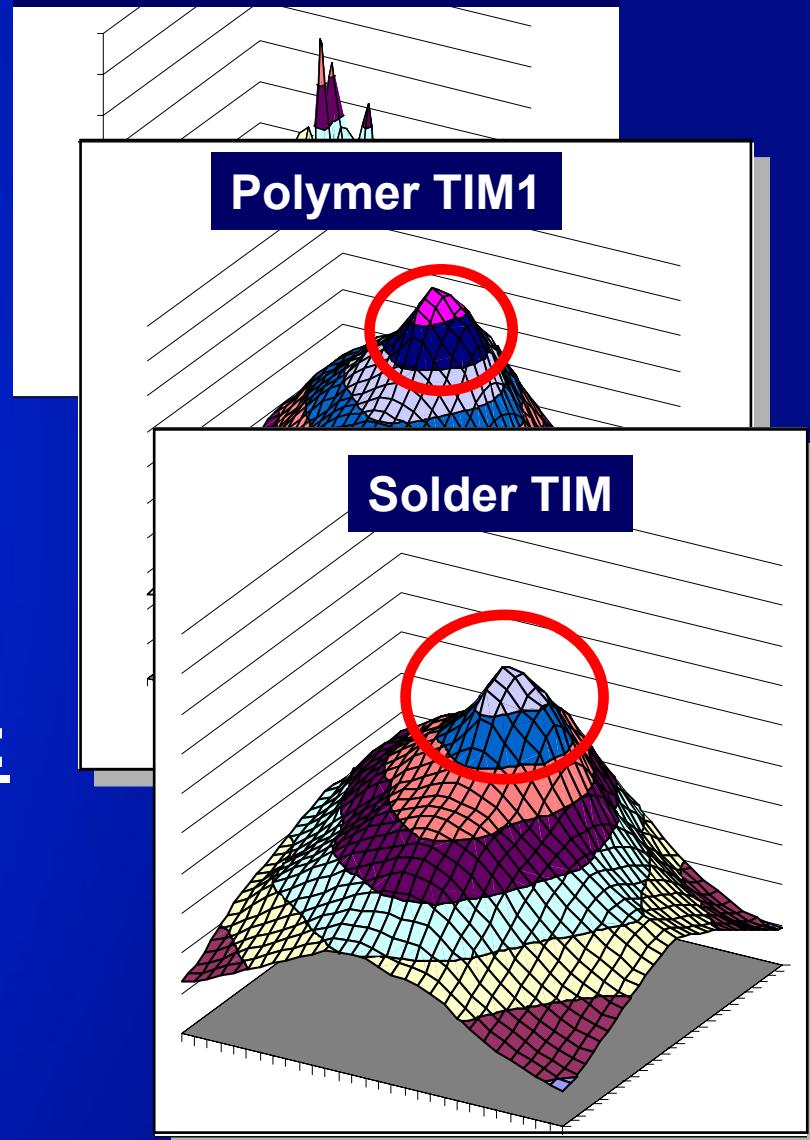
Hotspot Challenge:

- Improve die-pkg heatspreading
 - Smooth hot spots so commodity system solutions are viable

Capacity



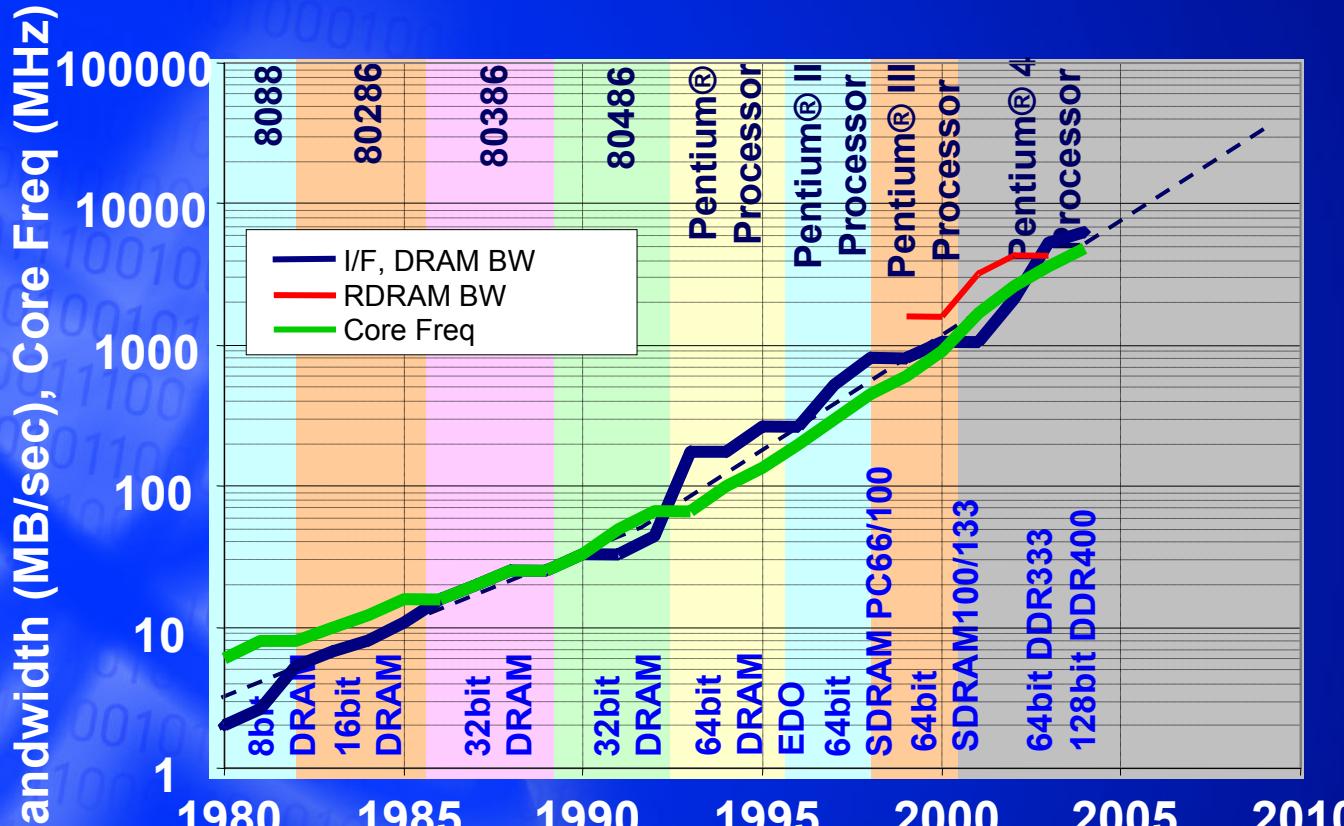
On-Die Power Distribution
Intel® Pentium® 4 Processor



Thermal Capacity Challenge:

- Decrease thermal resistance
 - Die substrate metallization (Si)
 - Low bulk resistance materials
 - Low resistance heatsinks

System: Signaling



Challenges

Short buses or
Non-Cu medium?

~20GTs

+advanced pkg/IO

~10GTs

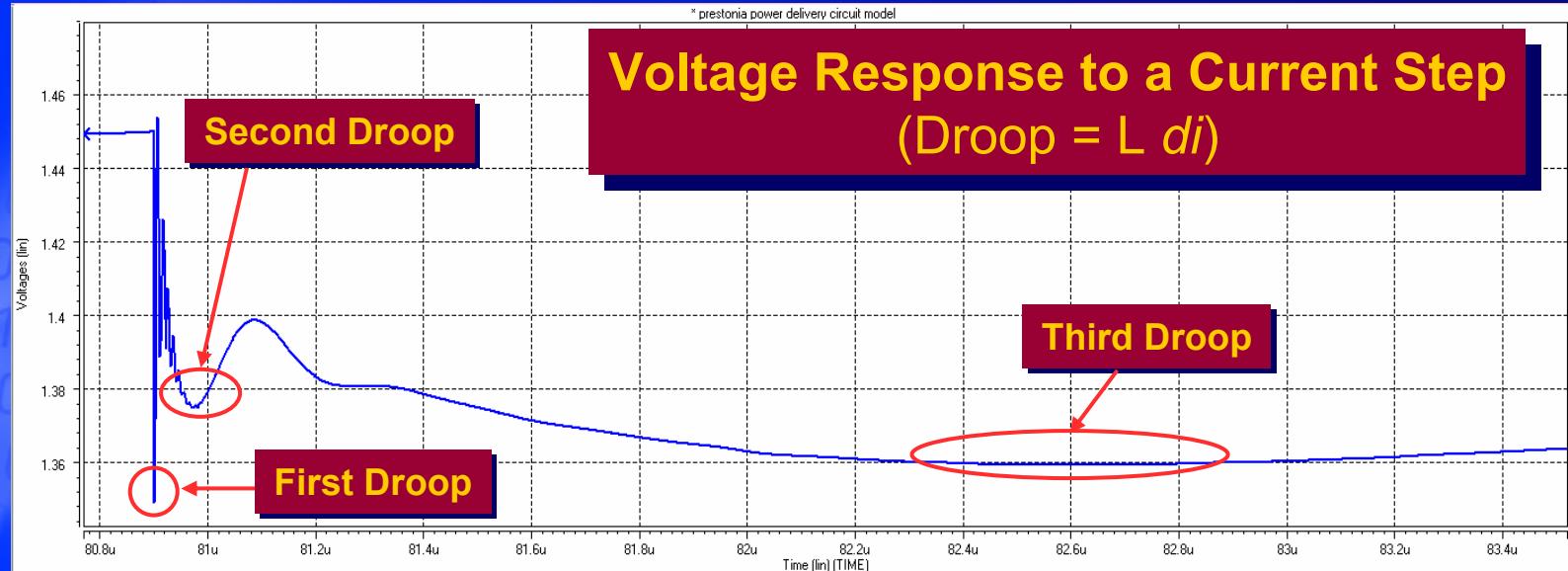
+differential

2GTs

point-to-point

Faster buses drives shorter bus lengths
– Pulls thermal loads closer together

System: Power Delivery



3rd droop challenge:

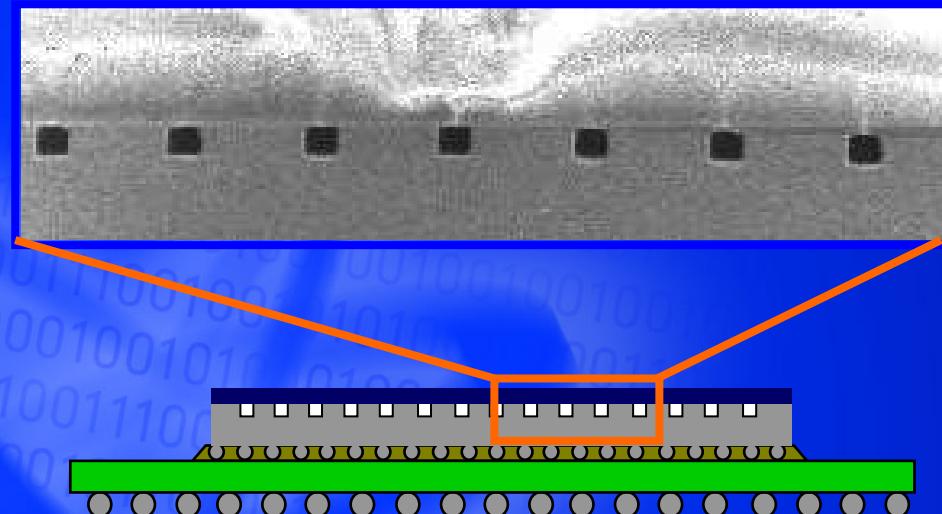
- Faster Voltage Regulator response time
 - Requires dealing with thermal impact of high performance VR's
- Cut VR / board / socket / package resistance
 - At minimum, involves increasing heat dissipation across path

Requires voltage regulator to be close to load
– Adds to power load in proximity of high power devices

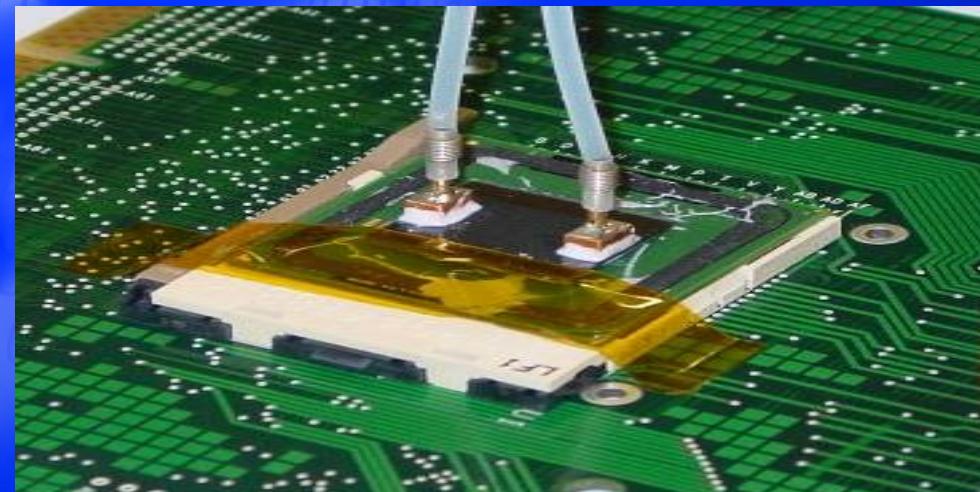
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Fluid Based Cooling

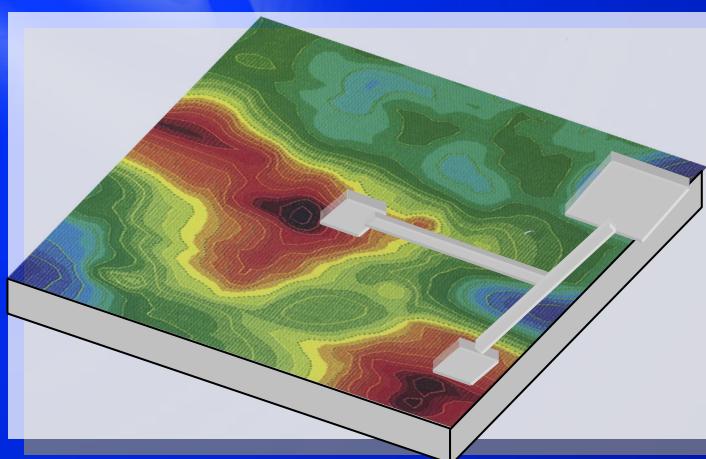
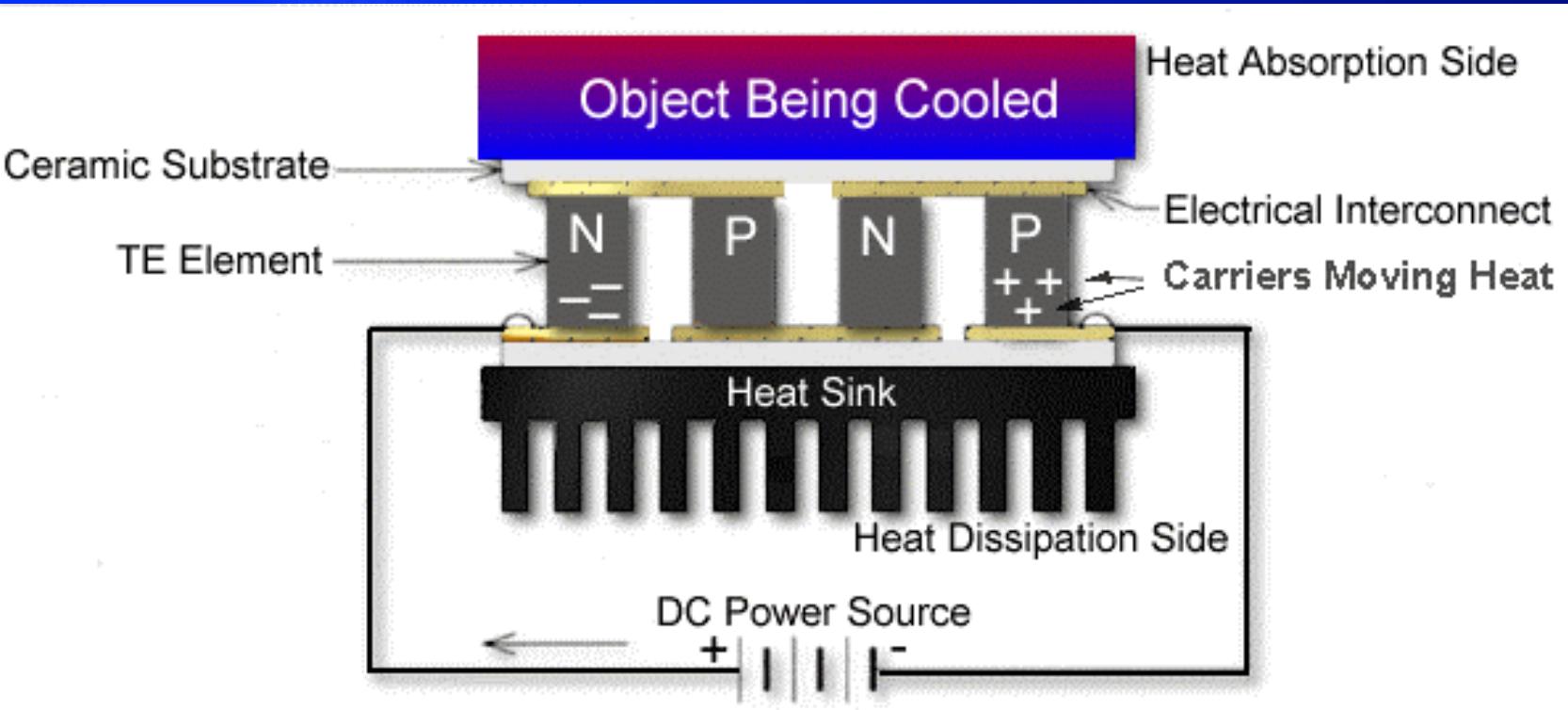


Concept
Single phase or 2-phase
fluid based cooling
with flow thru micro-channels
(on-die or on-package)



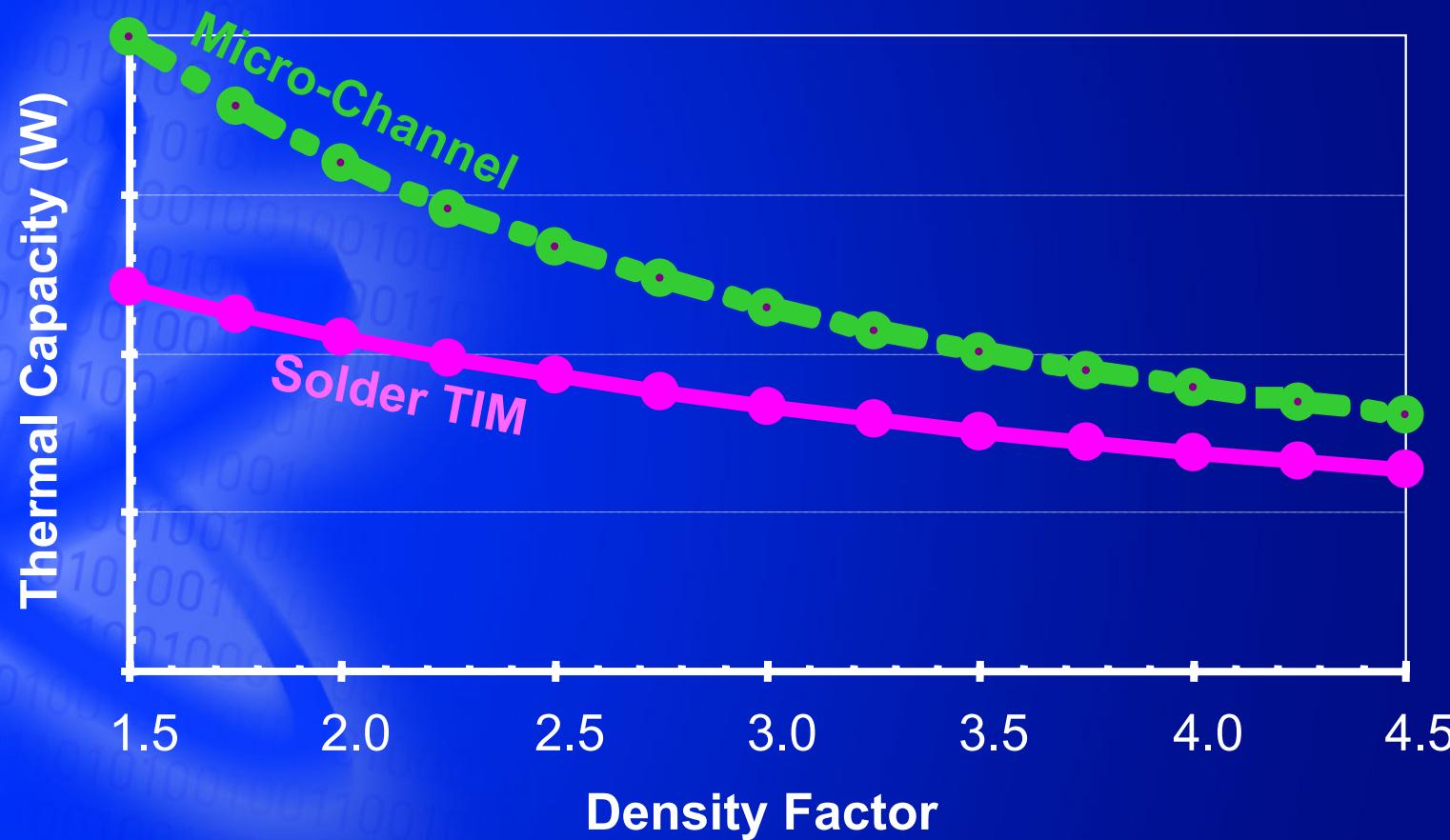
Micro-Fluidics is under investigation at a number of leading schools as the next generation cooling technology

Solid State Refrigeration



Concept
Spot cooling with
TEC refrigerators
integrated on die/pkg

Cooling Capacity



Capacity increases possible but require significant change

Summary

- Extending thermal limits requires improving die-package heatspreading and decreasing thermal resistance.
- Signaling and power delivery trends are pulling heat loads closer together.
- Delivering a solution requires tightly integrating silicon-level solutions and system design.