AAVID THERMALLOY

Power Thermal Solutions Division

Cooling to keep your Key Chips Alive

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Agenda

- From the Chip to the Fluid
  - The story of conductivity and heat density
  - Technologies and Heat Transfer coefficients
  - Automotive Constrains
  - Solutions
- Balancing Chips Temperatures
  - Mass Flow Rate or Latent Heat
  - Solutions
- Emergency situations
  - Can we store heat?
  - Solutions

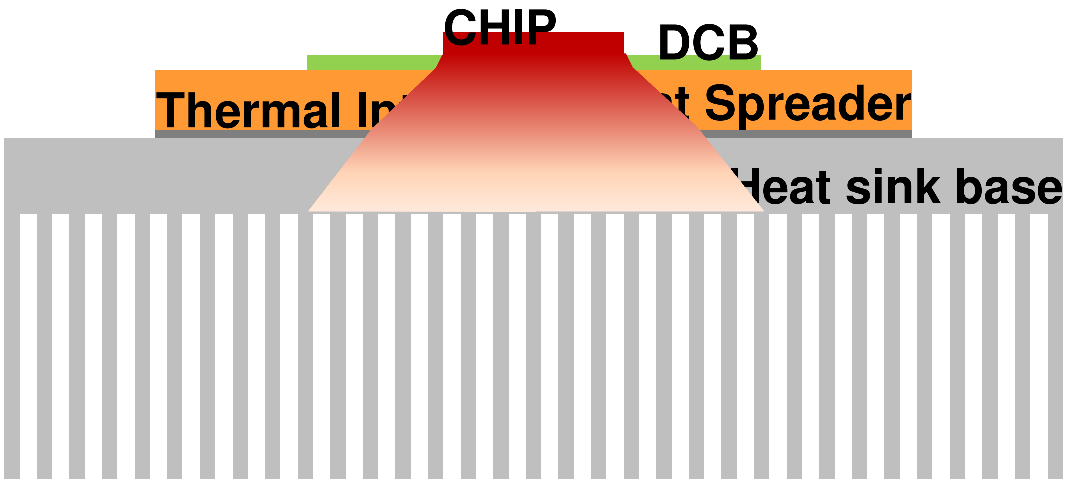
From the Chip to the Fluid

- Straightforward point of view
  - In a car the only available cold source is the surrounding air
  - $P\ [W] = H\ [W/m^2\ °C]\ S\ [m^2]\ \Delta_{Tsolid/Tfluid}\ [°C]$
  - The surface of the heat exchanger with surrounding air is mainly defined by the power to extract
  - The volume of the heat exchanger is generating the pressure drop : smaller size => higher pressure drop!

From the Chip to the Fluid

❑ Conductivity & Heat density

- Simple rules !



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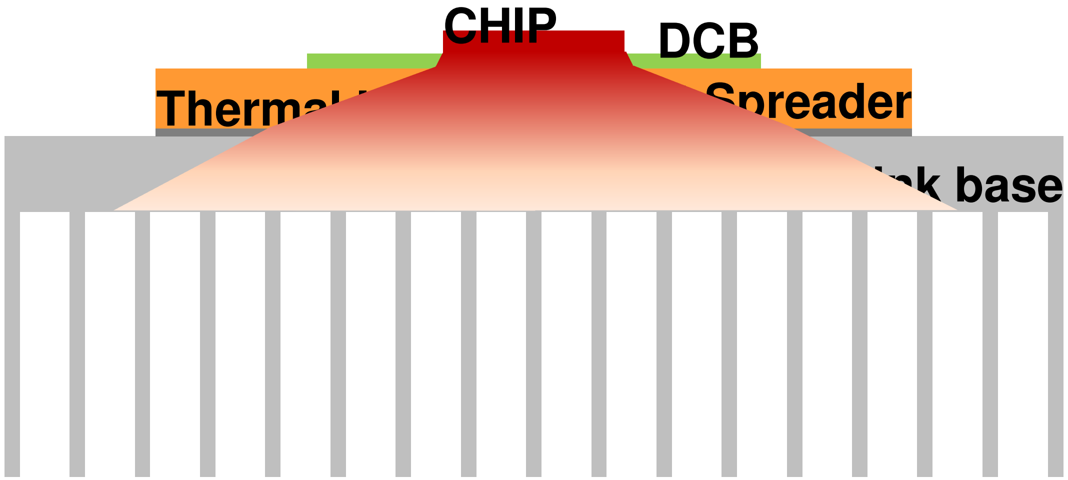
From the Chip to the Fluid

Conductivity & Heat density

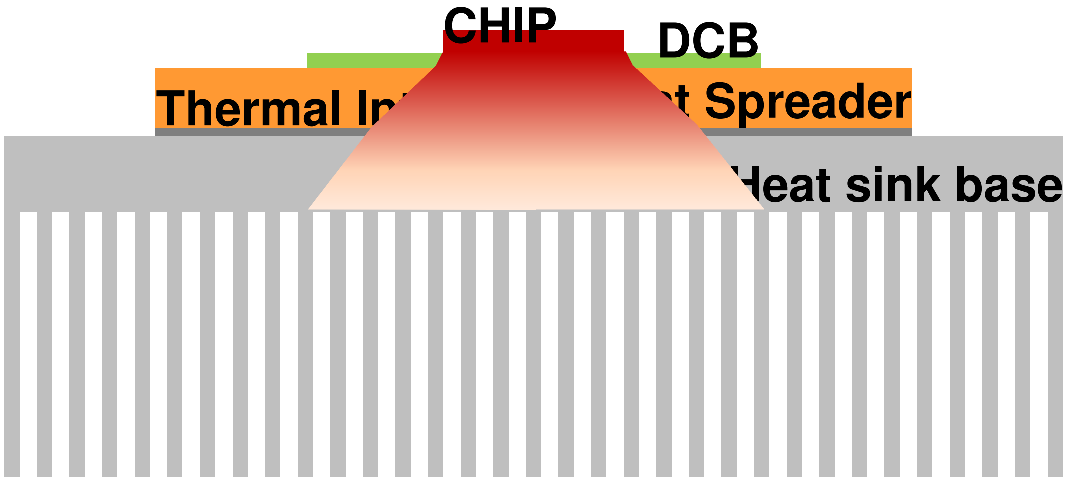
- Simple rules !



- The heat is lazy, always searching the easiest way which is a combination of distance and resistance

From the Chip to the Fluid

- Conductivity & Heat density
  - Simple rules !

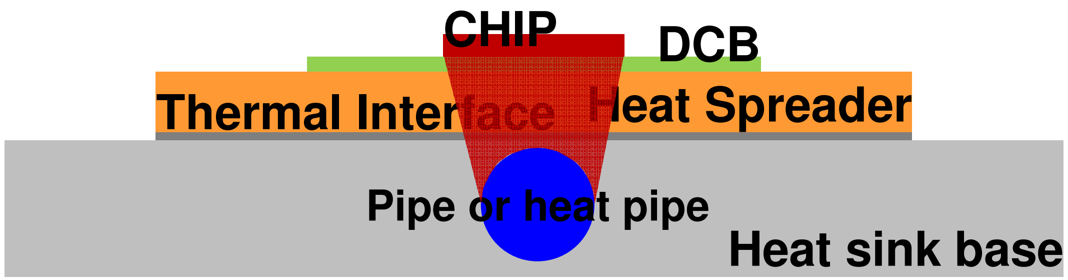


  - Conductivity increases heat spreading
  - Thickness increases heat spreading
  - Heat density decreases

From the Chip to the Fluid

❑ Conductivity & Heat density

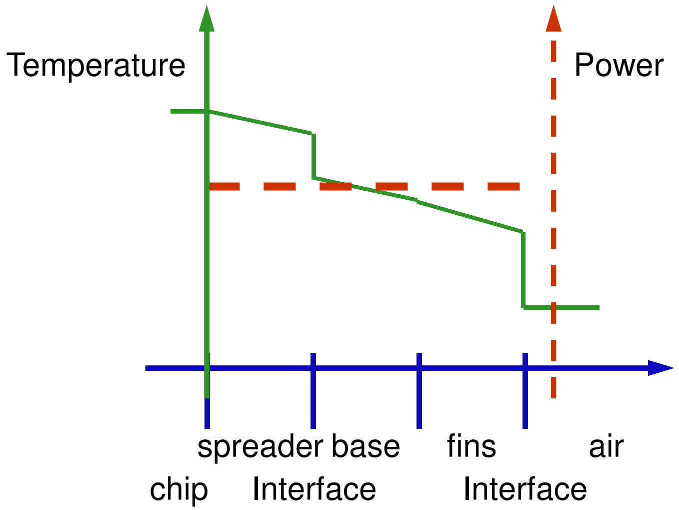
- When the cold source is small:



- The heat density may remain stable or may increase!
  - ❑ Thermal Interfaces are more critical
  - ❑ Heat Transfer Coefficient must increase

From the Chip to the Fluid

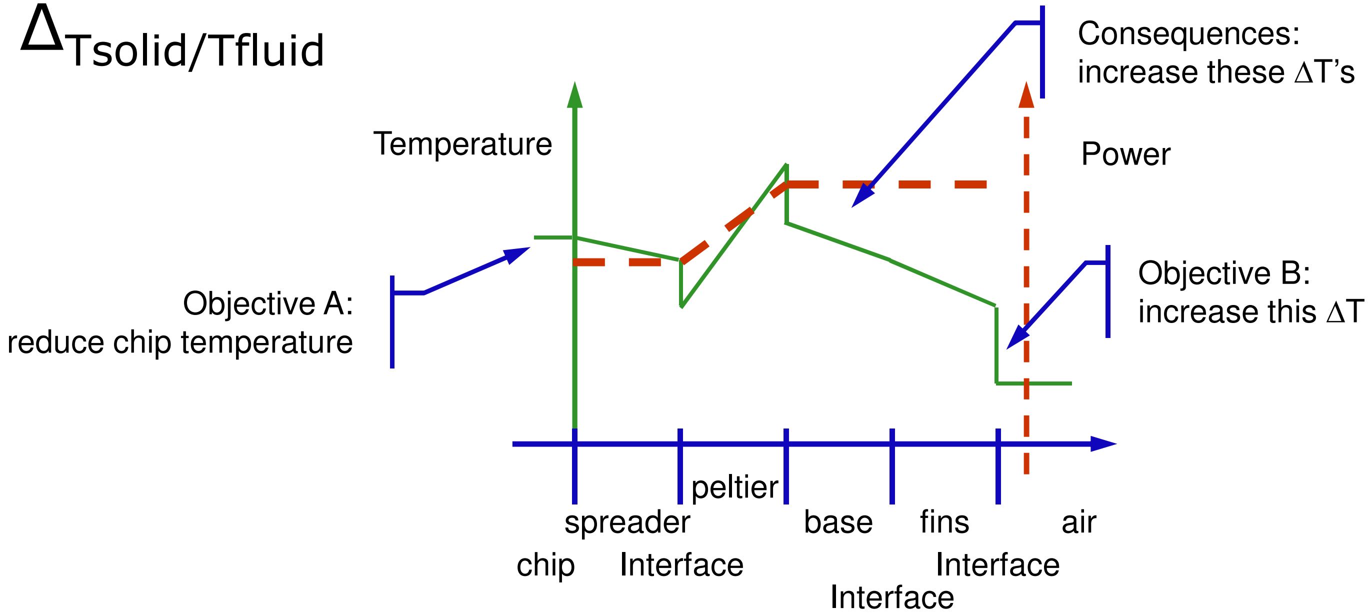
- Reducing Chip temperature &/or increasing $\Delta_{Tsolid/Tfluid}$



Power and temperature evolution from the chip to the fluid

From the Chip to the Fluid

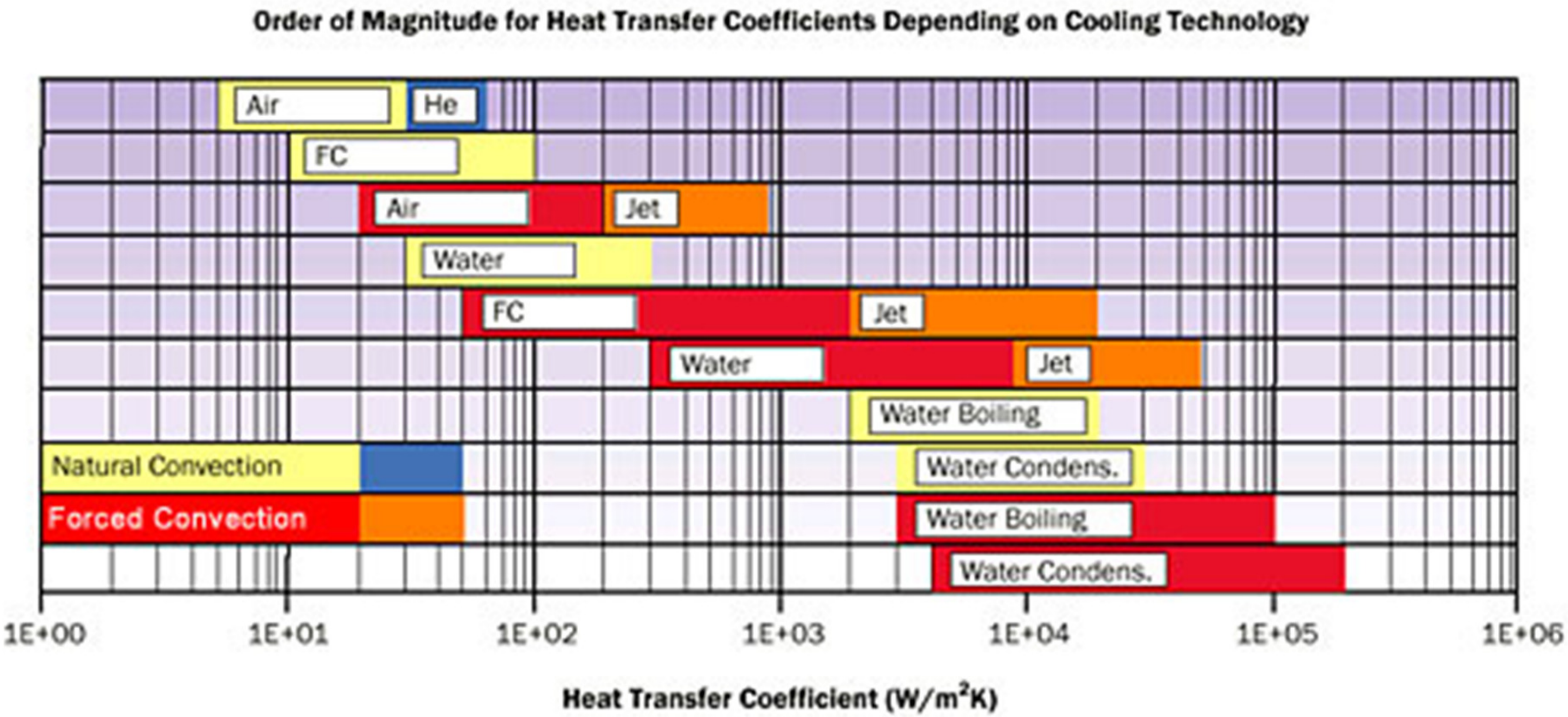
- Reducing Chip temperature &/or increasing $\Delta_{Tsolid/Tfluid}$



Power and temperature evolution from the chip to the fluid with a Peltier Cell

From the Chip to the Fluid

❑ Technologies and Heat Transfer coefficients



From Electronics Cooling

From the Chip to the Fluid

❑ Technologies and Heat Transfer coefficients

Flow	H (W/m².°C)
Air: natural convection	5 – 30
Air: forced convection	20 – 200
Air: jet impingement	200 – 900 Noisy!
Water: natural convection	30 – 300 Thermo Syphon
Water: forced convection	300 - 8.000
Water: jet impingement	8.000 - 50.000
Boiling water	2.000 - 100.000 Heat pipes

From Electronics Cooling

From the Chip to the Fluid

- Preliminary conclusion
  - It is often needed to spread the heat before moving it into a fluid
    - Some space is needed to allow this spreading => constrain on electronic design
  - Closer to the chip we are, less possibilities we have
    - Jet impingement and heat pipe become rapidly a must

From the Chip to the Fluid

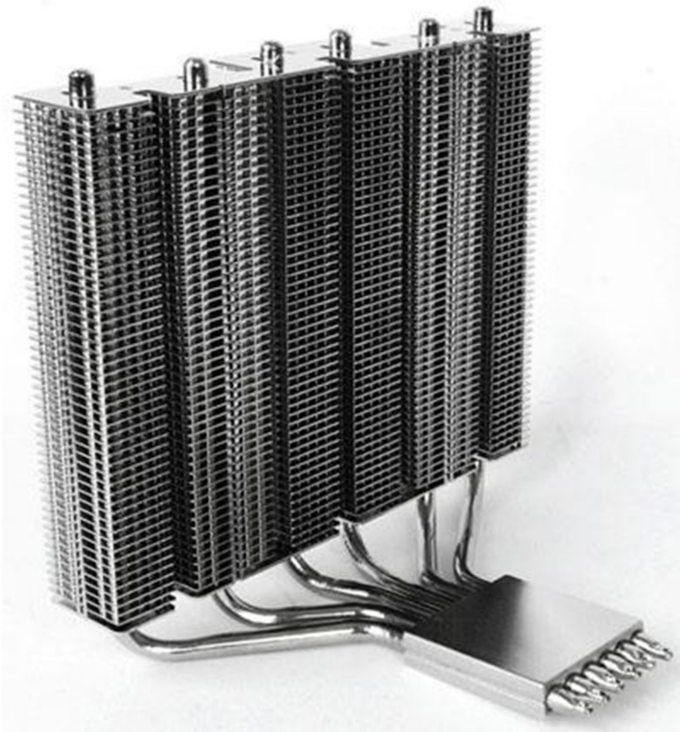
❑ Automotive Constrains

- Once again at the end we have to transfer the heat to the air => 2nd worst heat transfer coefficient: forced convection
  - ❑ Therefore all other solutions are only used to transfer the heat to the heat exchanger
- The air is dirty => Clogging does not allow high density fins without maintenance
- In Hybrid vehicles the water might be hot => high density fins required (low Δ_T)
- … dirty => high density fins in water may not be welcome (clogging)

From the Chip to the Fluid

Solutions:

- Heat Pipe are the best solution to catch efficiently high heat density very close to the chip



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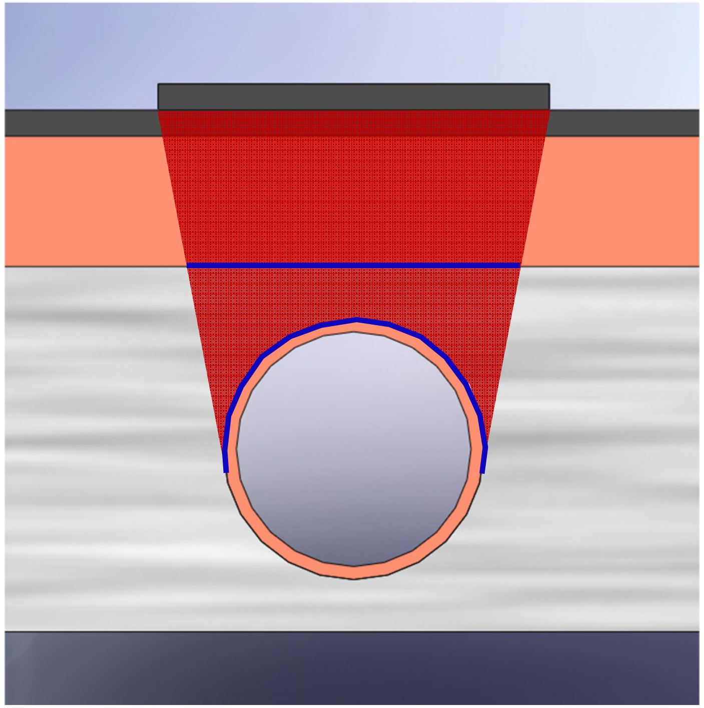
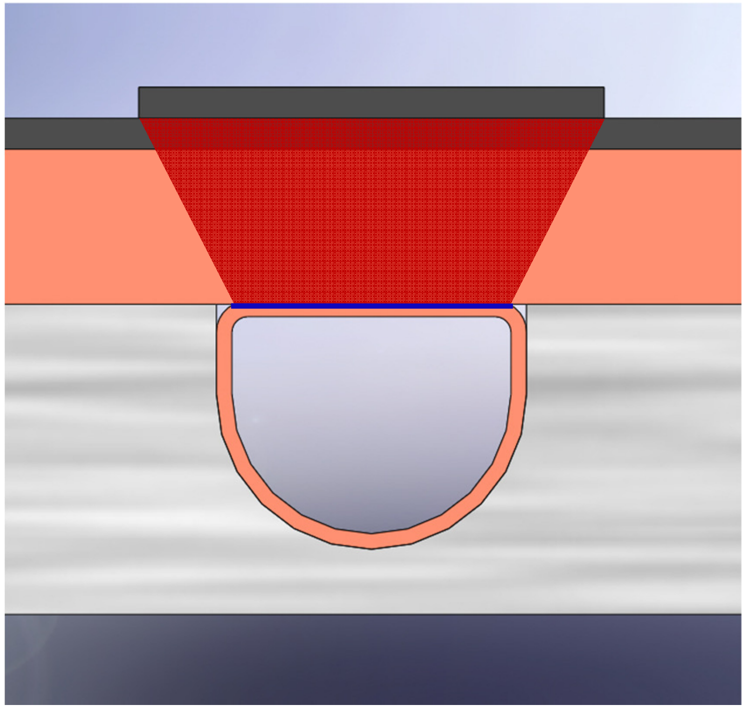
From the Chip to the Fluid

- Drawback:
  - High constrains on the thermal interfaces (chip to evaporator block, evaporator block to Heat Pipe)



From the Chip to the Fluid

- Drawback:
  - High constrains on the thermal interfaces is improved by direct contact



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From the Chip to the Fluid

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- Limited distance between heat source and heat exchanger (< 1m)
- Start up difficult
- Need special heat pipe for low temperatures (< 0°C)

From the Chip to the Fluid

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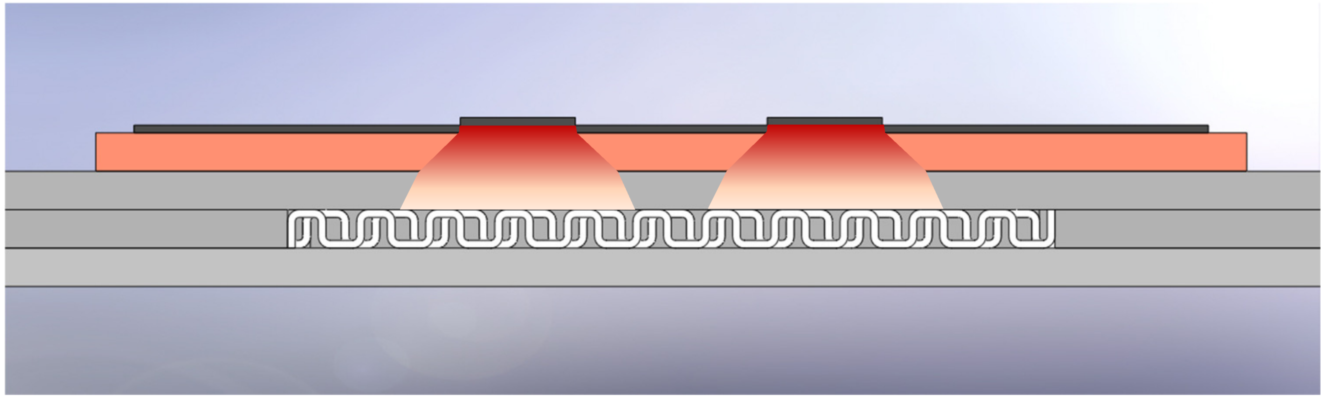
- LCP's including offset fins are a lot more efficient than LCP's using pipes they allow heat spreading with high heat exchange surfaces



❑ Risk of clogging

From the Chip to the Fluid

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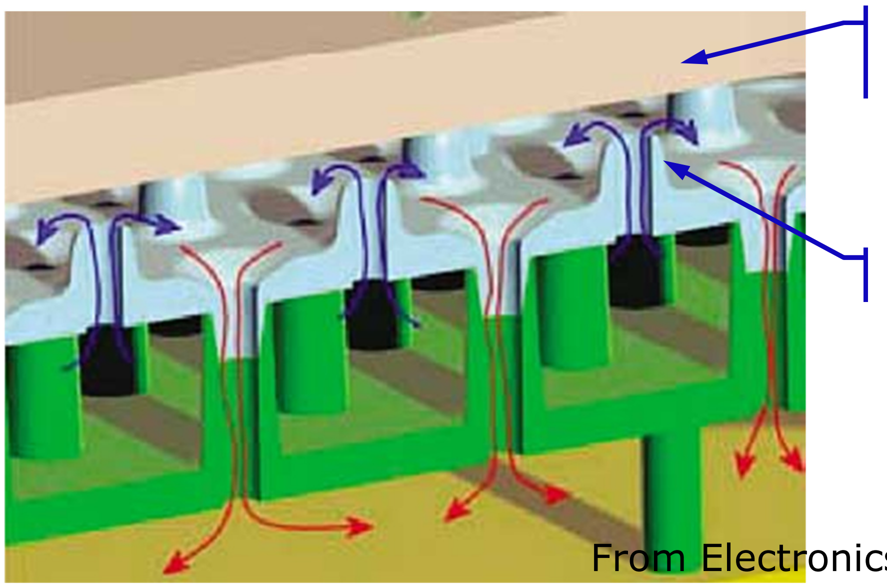
- Direct jet impingement cooling overcomes the clogging constrains and is compatible with hot water

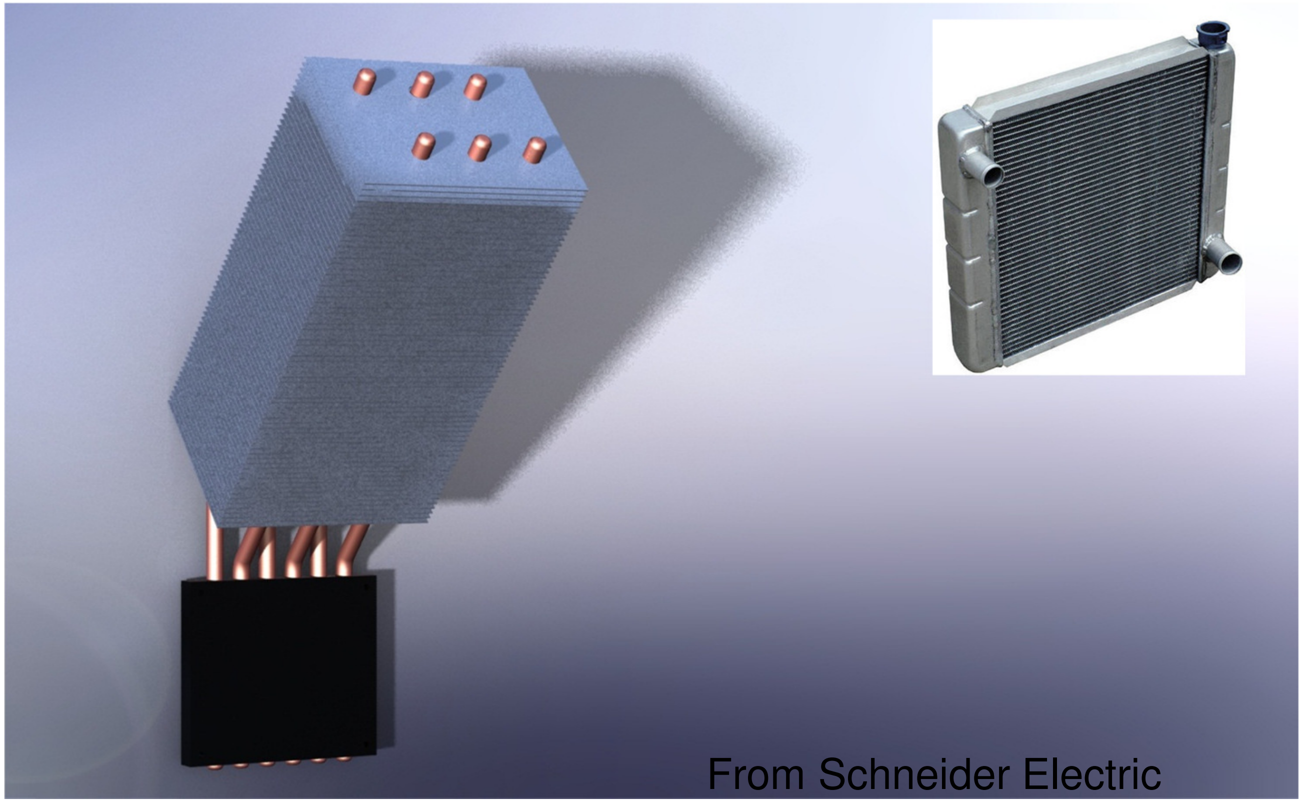


From Electronics Cooling

  - ❑ Less available surface
  - ❑ Chip position constrains to make an efficient Jet impingement solution

From the Chip to the Fluid

- The current water to air heat exchanger is quite perfect it has to be duplicated



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  - Can we store heat?
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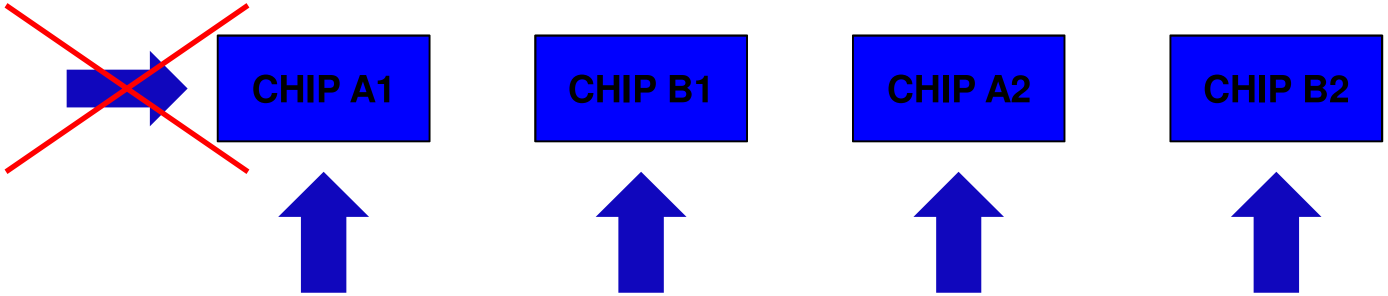
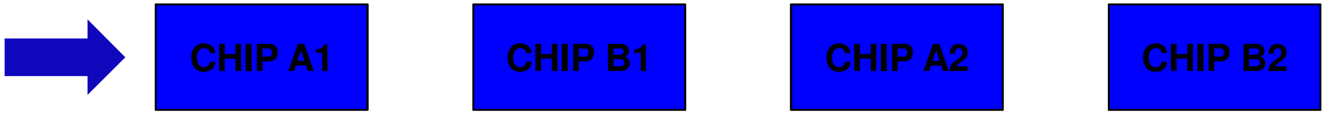
Balancing Chips Temperatures

- When we have multiple chips working together it is important, to balance loads an improve efficiency, that each kind of chip has the “same” temperature
- Because we use a mass flow to cool the ideal solution is that all components are // vs the flow



Balancing Chips Temperatures

- ❑ However it often impossible to do!
- ❑ Management of the Mass flow rate (air or liquid)



- $P\ [J/s] = H_c\ [J/kg\ °C]\ M\ [kg/s]\ \Delta_t\ [°C]$
- $M = P / H_c$ (0,5 or 1,5 or 3)

(H_c: Heat Capacity)

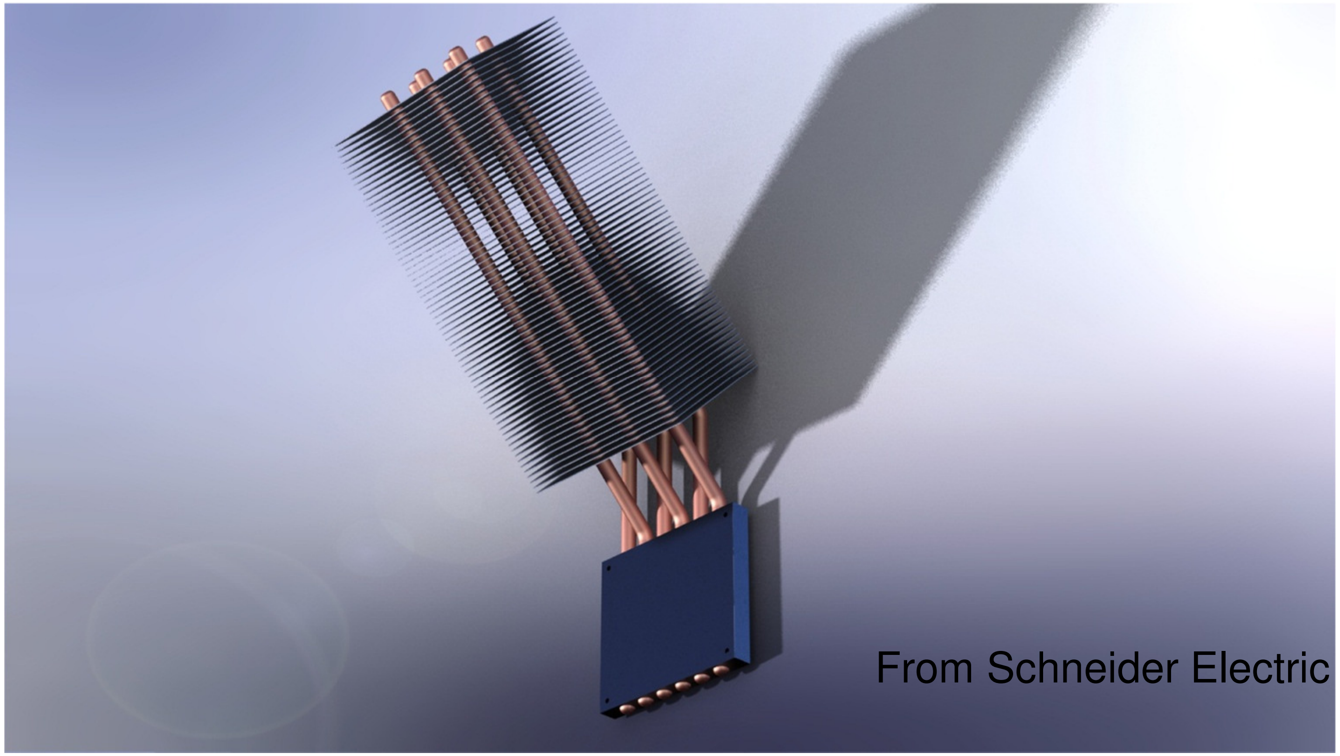
Balancing Chips Temperatures

Latent Heat

- When the phase change occurs the temperature is fixed and stable

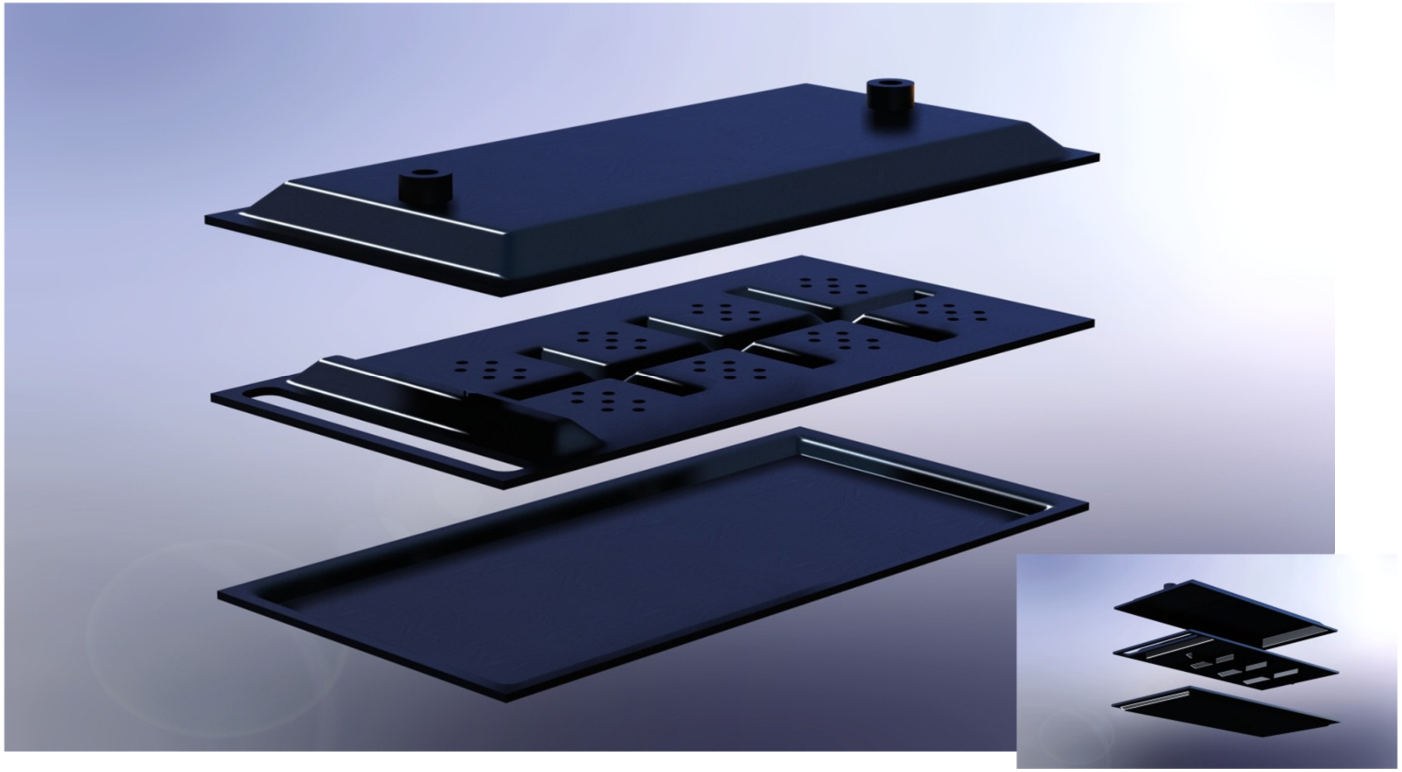
Balancing Chips Temperatures

- Solutions:
  - Latent heat: heat pipe (or hp loop, vapor chamber)



Balancing
Chips Temperatures

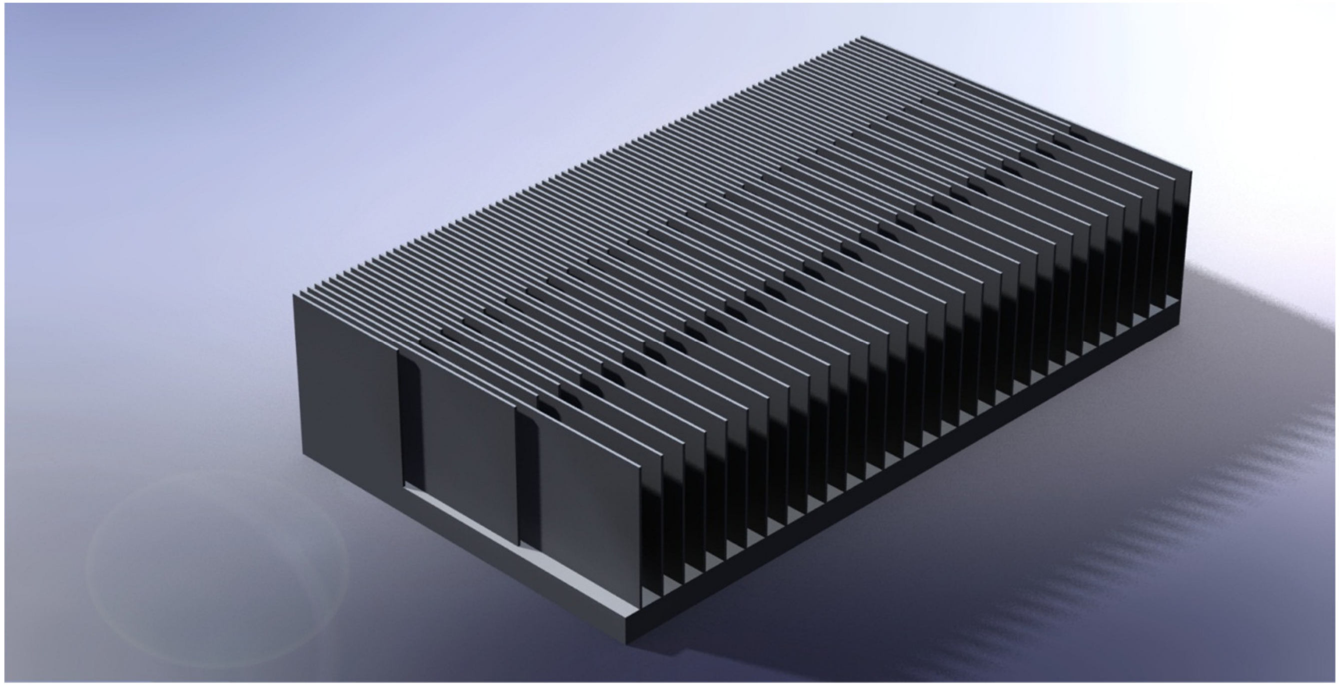
- Solutions:
  - Jet impingement allows to recreate a // cooling



Balancing Chips Temperatures

Solutions:

- Fin density variation (air)

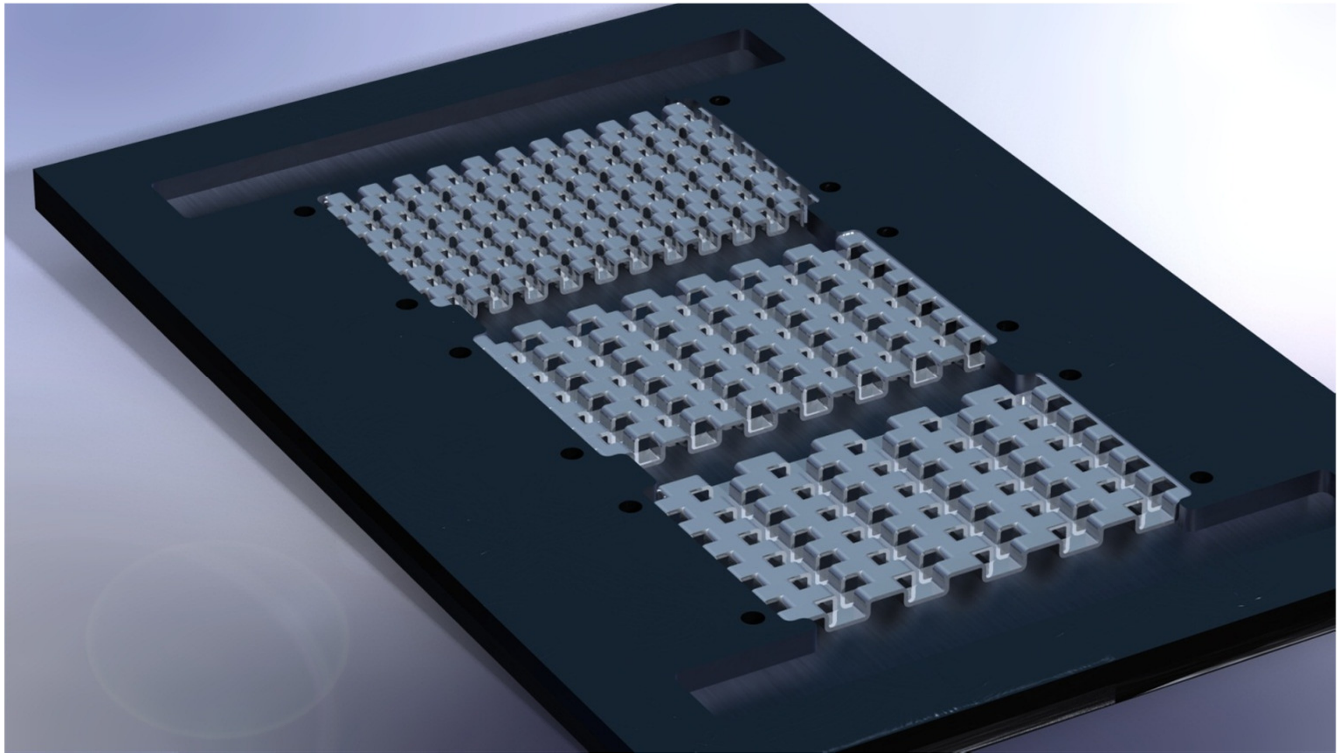


- Incompatible with low cost extrusions

Balancing
Chips Temperatures

❑ Solutions:

- Fin density variation (liquid)



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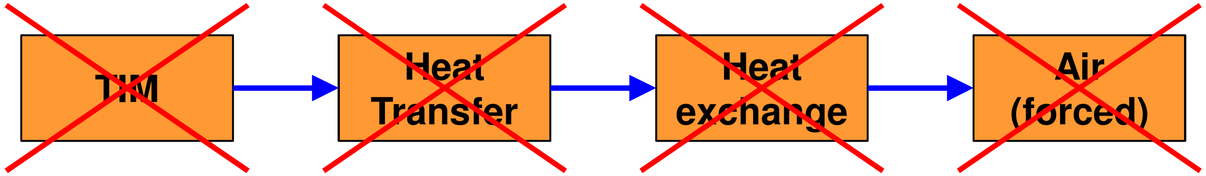
Emergency situations

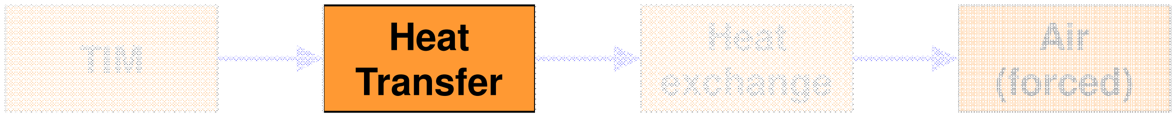
- What is an emergency situation?
  - As soon as a component of the cooling chain fails we face an emergency situation



  - Closer to the chip the failure is, higher the emergency is

Emergency situations

- Can we store heat?
  - Yes, the two possible functions able to store heat might be:



  - However it is theory:
    - the air is available, we just have to insure that it is always moving
    - in most of the cases the components are designed to be fully loaded by heat and the system works as a serial assembly

Emergency situations

- Solutions:
  - No TIM
    - Direct liquid/dual phase cooling
  - Mechanical high performance TIM
    - Mirror surface
    - High pressure mechanical assemblies
    - Welding, Soldering, Brazing

Emergency situations

- Use liquid transfer designed with storage capacities
  - High volume of liquid
  - Higher mass flow rate
- Implement backup Heat Pipes

Anyway this will result with margin in R_{th}

- Always allow natural convection and use as much as possible the movement of the car to generate backup forced convection