Thermal Minutes

Thermal Management of Telecom and Datacom Equipment

Because of their unique product offerings, communications and computing industries drive a large segment of the technology market. The power dissipation of equipment doing faster data transmission and processing is on the unwavering rise. For that reason, proper thermal management of this gear has a central role in its successful deployment and operation.

End-users insist that their telecom and datacom equipment meet compliance and performance standards. For the manufacturers, one of the most difficult requirements to satisfy is effective thermal management.

The basis of this thermal challenge resides in several parameters:

- Thermal coupling within the system and surrounding equipment
- System standardization (e.g., the ATCA Standard)
- Constrained space
- EMI/EMC requirements for high frequency devices, boards and packaging
- Acoustic noise
- Limited air flow
- Rigid performance standards (e.g., 72 hours operation at 55°C)
- Non-uniform power distribution and congested PCBs
- Field serviceability (e.g., system operational within 4 hours of failure)

A successful thermal design requires that the junction temperatures of all critical devices in a system be sufficiently below their critical level in the worst-case ambient temperature. Otherwise, higher temperatures may result in data transmission bit errors and/or a decrease in a system's life expectancy. Thermal coupling and non-uniform PCB layout make this determination a complicated process. Figure 1 shows an example of thermal coupling from environment to the device.

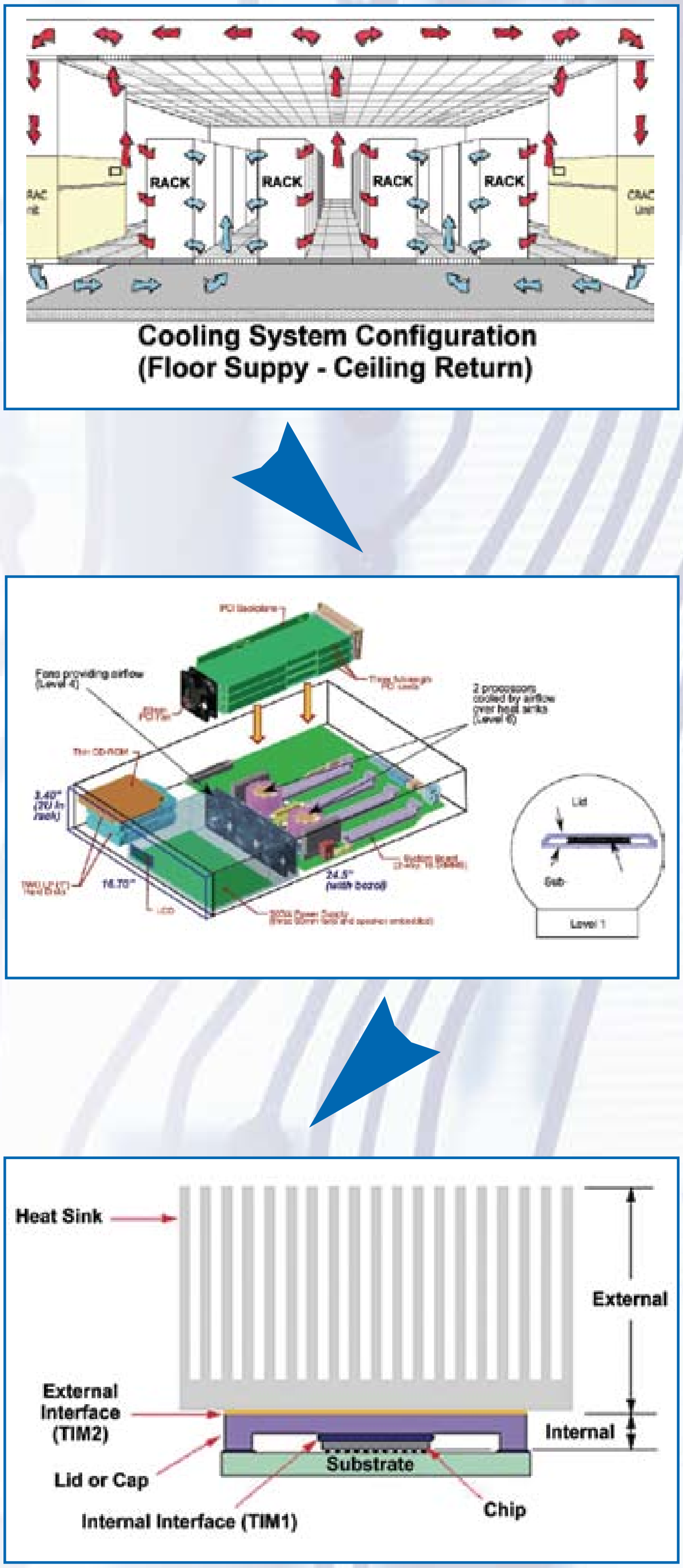

Figure 1. Thermal coupling in telecom and datacom equipment, from the central office (data center) to the component.

Solution Order	Package Level	Requirements and Tools	Requirements and Tools
First	System	System flow distribution and boundary conditions for the card racks, T, V, and Pressure	Measurement or Simulation (CFD)
Second	Card Rack (chassis)	Boundary conditions for the PCB, and thermal coupling between the board and the rack	Measurement or Simulation (CFD) and solid modeling (temperature gradient in the solid)
Third	Board (PCB)	Boundary conditions for the component on heat transfer and fluid flow	Measurement of fluid flow distribution and board properties and board level solid modeling
Fourth	Component (device or module)	Boundary conditions for the Die (Tj) and its cooling solution	Fluid flow and temperature measurement equipment; Heat sink; Interface materials and their properties; Solid modeling; Package material properties

Table 1. Solution hierarchy for thermal analysis.

In telecom and datacom equipment, to calculate the junction temperature of a device residing on a PCB, all parameters impacting its magnitude must be accounted for. See Figure 2.

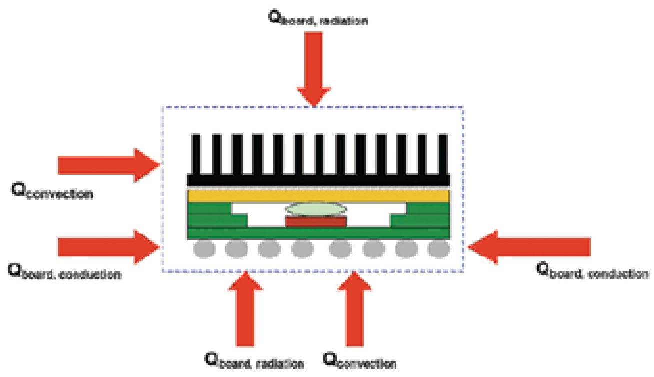

Figure 2. Thermal coupling at the device level.

The junction temperature (T_j) is a function of following parameters:

$$T_j = f(V_{fluid}, k_{board}, k_{component}, k_{spreader}, k_{interface\ material}, h_{heat\ sink}, T_a, P_{device}, \varepsilon, Q_{upstream})$$

Where V is the air velocity, k is the thermal conductivity, and ε is the emissivity.

Table 1 shows the approach, domain, anticipated results, and the needed tools to successfully obtain the junction temperature of a device in the system.

Once the junction temperature is obtained by using two independent methods, it must be ensured that there is at least a 10% margin of safety in the design. Therefore, the following equation must be satisfied:

$$\eta = (T_{j,\ calculated} - T_{a,\ reference})/(T_{j,\ spec} - T_{a,\ reference}) \leq 90$$

Where

$T_{j,\ calculated}$ = junction temperature as the result of above calculation.
$T_{j,\ spec}$ = critical junction temperature specified by the manufacturer.
$T_{a,\ reference}$ = reference ambient or approach air temperature.

With a properly determined junction temperature in hand, a cooling method can be selected for maintaining the desired performance. Depending on the data obtained from Table 1, we can choose from these options:

- Natural convection
- Forced convection (air-mover)
- Active air cooling (not very common)
- Jet impingement (air or liquid)
- Advanced systems (liquid or refrigeration)

Although cooling by air is the most common and preferred system, liquid cooling has been used in unique circumstances. Regardless of the method selected, every cooling decision should consider the following parameters:

- **Cooling capacity** – Does it satisfy the junction temperature requirements?
- **Size** – Does it comply with the packaging requirements?
- **Regulatory requirements**– Does it meet the system and site implementation requirements (e.g., NEBS)?
- **Reliability** – Does it meet the expected life requirements?
- **Budget**– Does it comply with the cost constraints imposed on the system?
- **Market availability** – Is it readily available? Can supply-chain requirements be met?

Obtaining a successful cooling solution is made possible by combining methodical thermal analysis (as delineated in Table 1) with the results from at least two independent approaches, and by taking into account the above system parameters.

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