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Thermal Management Solutions

Case Study

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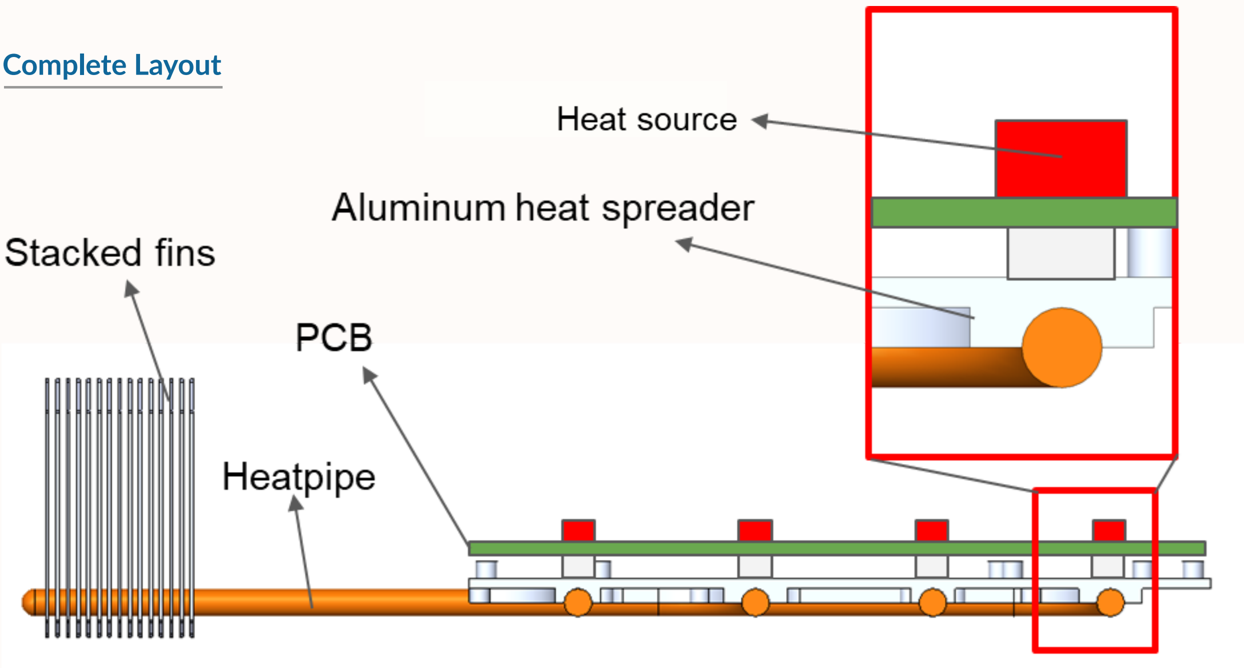
On maintaining safe temperatures of RF power amplifiers mounted on 5G Analogue Front End (AFE) Board

Client: IIT Madras 5G Test Bed

Challenge

- The AFE board housed 8 power amplifiers spread out at various locations on the board.
- Since the power amplifiers operate at a maximum efficiency of 30%, a lot of power was dissipated in the form of heat.
- Case temperature of each power amplifier dissipating 8 Watts of heat was to be maintained below 100 Deg C
- Since the AFE was sandwiched between the digital boards and the antenna patches, providing local heat sink was not possible, hence all the heat amounting to 64 W from 8 power amplifiers on the board was to be transported outside the enclosure and then rejected to air
- Maximum ambient temperature was considered to be 50 Deg C
- The complete system was to be mounted on a tower, hence providing means of forced convection such as fans was not possible due to reliability and serviceability issues. Therefore, heat was to be rejected to the air only through natural convection.

Complete Layout



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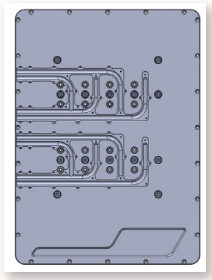
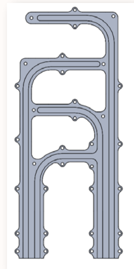
Solution

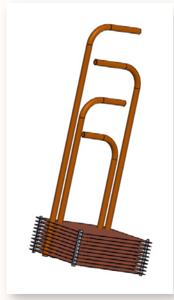
- Exact locations of all the power amplifiers were located on the board and heat pipe geometry was decided such that one heat pipe was placed below every two power amplifiers.
- Round heat pipes of 8 mm diameter were chosen for carrying the heat.
- The 4 heat pipes were routed through the heat spreader plate and outside the enclosure



Spreader Plate

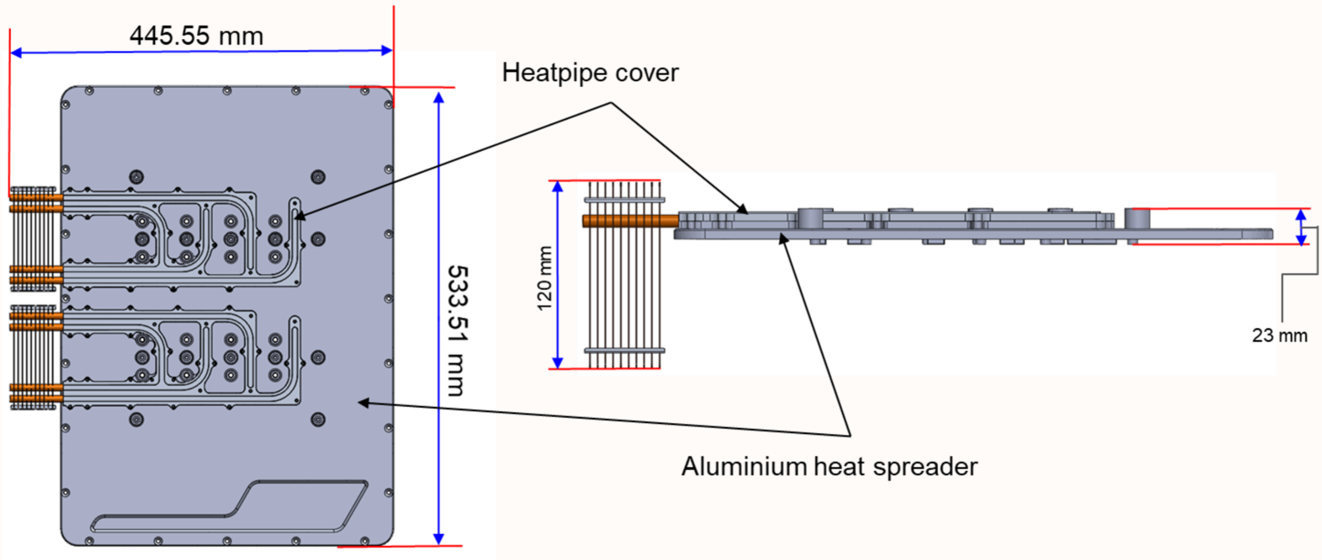


Clamping Plate



Heat Pipe Assembly

- Semi-circular grooves of 8mm diameter were made by machining the Aluminium spreader plate which was in contact with the board.
- A clamping plate with similar 8mm semi-circular grooves was used to mechanically clamp the heat pipes to the spreader plate.
- Sheet metal stacked fins of 0.7mm thickness were chosen as the heat sink since they could be closely stacked and would weigh much less as compared to other heat sinks for the same surface area.
- Required surface area was calculated based on the total heat dissipation and the temperature considerations.
- Based on the surface area, fin dimensions and number of fins were finalised.
- The sheet metal fins were press fitted on the condenser of the heat pipe and an additional thermally conductive epoxy was used to ensure proper fin contact.



Top View

Side View

Benefit

- Since all the heat was carried by the heat pipes with a minimal thermal resistance, the case temperature of the power amplifiers was maintained within 100 Deg C as was required.

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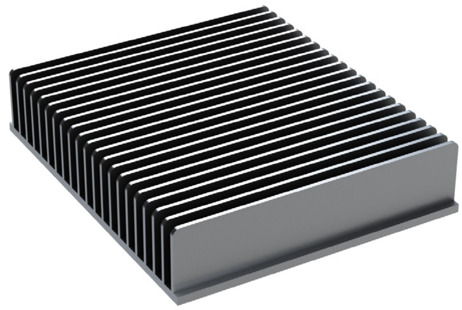
On reducing microprocessor chip temperature to acceptable levels using flat heat pipes embedded in a heat sink

Challenge

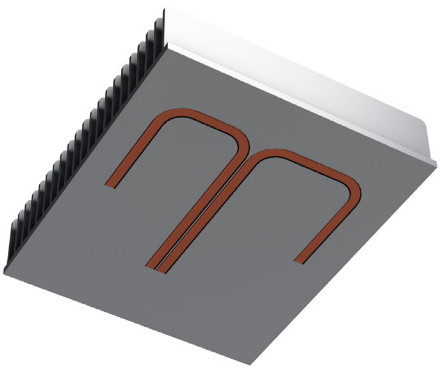
- Case temperature of a microprocessor with a size of 16.5mm x 9.1mm dissipating 45W of heat was to be maintained below 85 Deg C.
- The maximum ambient temperature was considered to be 45 Deg C.
- Heat rejection to the ambient was possible only through natural convection.
- The heat sink to be used was to form a part of the enclosure
- Heat sink size was limited to 240mm x 205mm x 50mm



Heat Sink Top

Solution

- A solid heat sink was chosen which could be manufactured through extrusion or pressure die casting process for large scale manufacturing
- This heat sink could form the top wall of the enclosure
- Number of fins, fin spacing and fin thickness was optimised to ensure maximum possible heat transfer to the ambient
- The location of the microprocessor on the heat sink was identified and a CFD analysis was conducted to identify the maximum case temperature of the microprocessor as well as the temperature spread across the heat sink



Heat Pipe Embedded Heat Sink Bottom

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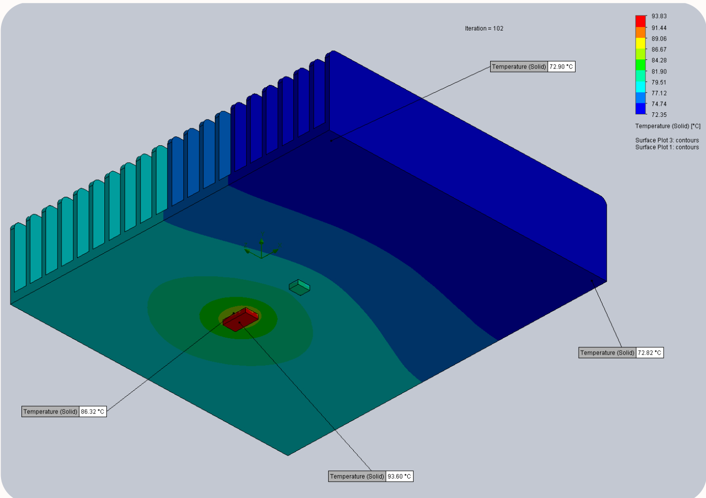
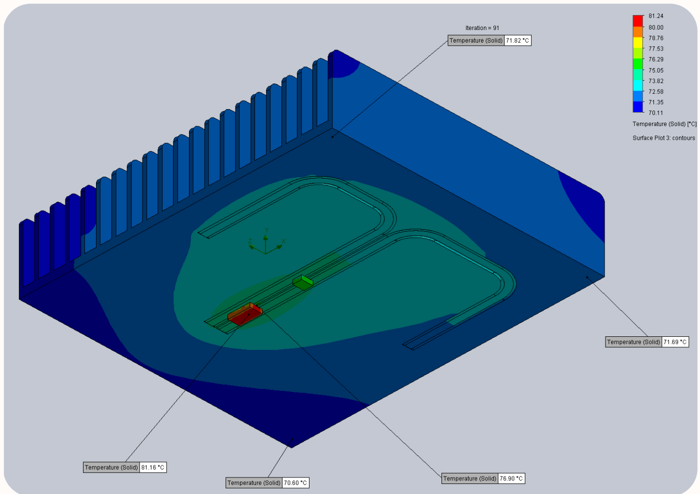
Solution

- It was noted that with all the optimisations, the microprocessor case temperature still exceeded the temperature limit of 85 Deg C
- It was identified from the heat map that the heat sink spreading resistance contributed to the excess temperature.
- This high spreading resistance was due to the high heat flux dissipation from the component 30 W/cm2.
- This in turn led to inefficient use of the complete heat sink area
- Coldest zones of the heat sink were identified and two flat heat pipes were chosen to transport the localised heat from the microprocessor to these zones.
- The bent and flattened heat pipes were embedded into the base of the heat sink by creating a groove in the shape of the heat pipes.
- A CFD analysis was run to recheck the heat spread and microprocessor case temperature.





Temperature comparison of microprocessor and heatsink without (left) and with (right) heat pipes

Benefit

- Temperature difference between the hottest and coldest zone of the heat sink dropped from 14 Deg C to merely 5 Deg C, reducing the heat sink spreading resistance
- Due to efficient utilisation of the heat sink using heat pipes, the microprocessor case temperature was maintained at 81 Deg C which was 4 Deg C lower than the desired maximum case temperature.

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