Spreading Resistance Estimation Tool for Heat Spreader Design

Fast, visual MATLAB-based method for early-stage thermal design

Problem and Solution

PROBLEM

- Designers need to size heat spreaders for ICs and power devices, but full 3D simulations are time-consuming.
- **Spreading resistance (R_sp)** is a key metric, and engineers need quick ways to visualize how geometry and material properties affect it.

SOLUTION

- This tool estimates **thermal spreading resistance** using the closed-form model by **Lee et al.**, popularized by **Simons (2004)**.
  - Accepts heat source dimensions, material properties, and spreader geometry ranges
  - Computes R_sp for different **thicknesses and areas**
  - Outputs a clean **R_sp vs Area** plot
  - Helps identify optimal spreader size for target R_sp

References:
Simons, R.E., *Simple Formulas for Estimating Thermal Spreading Resistance*, Electronics Cooling, 2004
Lee et al., 1995: Constriction/Spreading Resistance Model for Electronics Packaging

Methodology

- Core Principle: Estimate **spreading resistance** from a heat source into a larger heat spreader using **closed-form equations** derived from a circular area transformation.
- Geometry Mapping: Rectangular source → equivalent **circular radius**

$$r1 = \sqrt{\frac{A_{source}}{\pi}},\ r2 = \sqrt{\frac{A_{spreader}}{\pi}}$$

- Applicable to non-square spreaders using area-equivalence

- Parameters:
  - Inputs:
    - Heat source length & width
    - Spreader length, width, and thickness range
    - Thermal conductivity k, effective heat transfer coefficient h_eff
  - Computed:
    - Biot Number, Bi = h*r2/k
    - Spreading Resistance: $R_{sp} = \frac{1}{k \times r1 \times \sqrt{\pi}} \times \left[\frac{E \times \tau}{\sqrt{\pi}} + \frac{(1-E)}{\sqrt{\pi}} \times \phi\right]$

$$where, E = \frac{r1}{r2}, \tau = \frac{t}{r2}, and$$

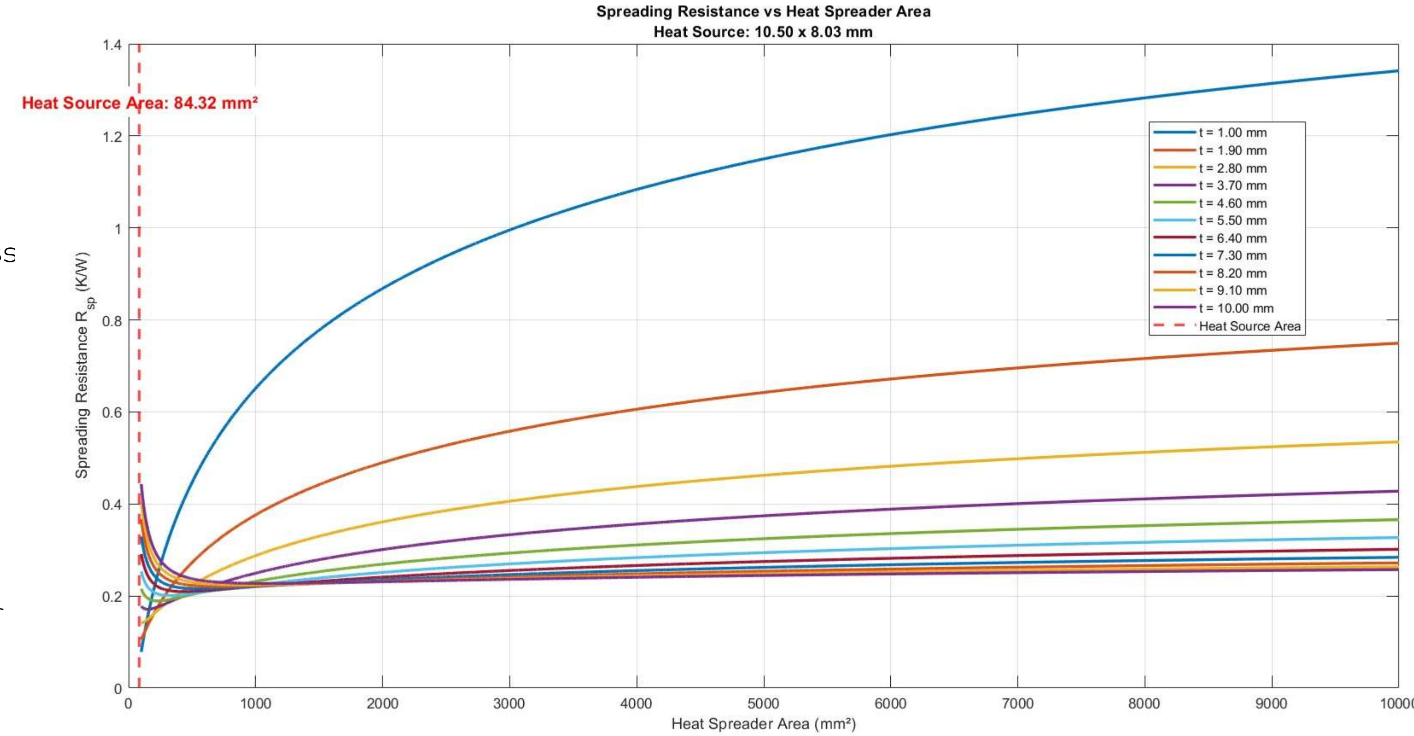
$$\phi = \frac{\tanh(\lambda \times \tau) + \left(\frac{\lambda}{Bi}\right)}{1 + \left(\frac{\lambda}{Bi}\right) \times \tanh(\lambda \times \tau)}, \qquad \lambda = E + \frac{1}{E\sqrt{\pi}}$$

Tool Features:

- Fast MATLAB implementation
- Handles thousands of spreader combinations
- Outputs design chart: R_{sp} vs Area, color-coded by thickness

Output: R_sp vs Heat Spreader Area

- This plot shows how spreader area and thickness affect thermal spreading resistance (K/W).
- Curves correspond to different thickness values (1 mm to 10 mm).
- Red dashed line indicates actual heat source area (84.32 mm²)
- Key Takeaways:
  - Increasing thickness reduces R_sp, especially at small areas.
  - After a certain point, increasing area or thickness yields diminishing returns



This chart enables engineers to select an optimal spreader size and thickness to meet target R_sp values , no FEA required.

Application Example: Choosing a Spreader

Design Scenario:

- You're packaging a 10.5 mm × 8.03 mm chip dissipating high power.
- Your target: keep spreading resistance R_sp < 0.25 K/W

Heat Source Area:

$$A_{source} = 84.32\ mm^2$$

What spreader dimensions and thickness meet the target?

Using the Tool:

- Use the chart from Slide 3
- Follow the red dashed line (84.32 mm²)
- Check which curves fall below 0.25 K/W

Design Decision:

- At t ≥ 5.5 mm, R_sp< 0.25 K/W
- Suggested geometry: Area ≥ 300 mm²
- Thickness ≥ 5.5 mm
- Material: Use high-k

Result:

You've quickly eliminated infeasible spreaders and focused on efficient thermal designs, without FEA.