Lumped-Capacitance Thermal Model (Bi < 0.1): Conduction Inside Block ≫ Convection Outside

Material : Aluminum
ρ (Density) : 2700 kg/m³
Cp : 900 J/kg·K
Fin Type : Triangular

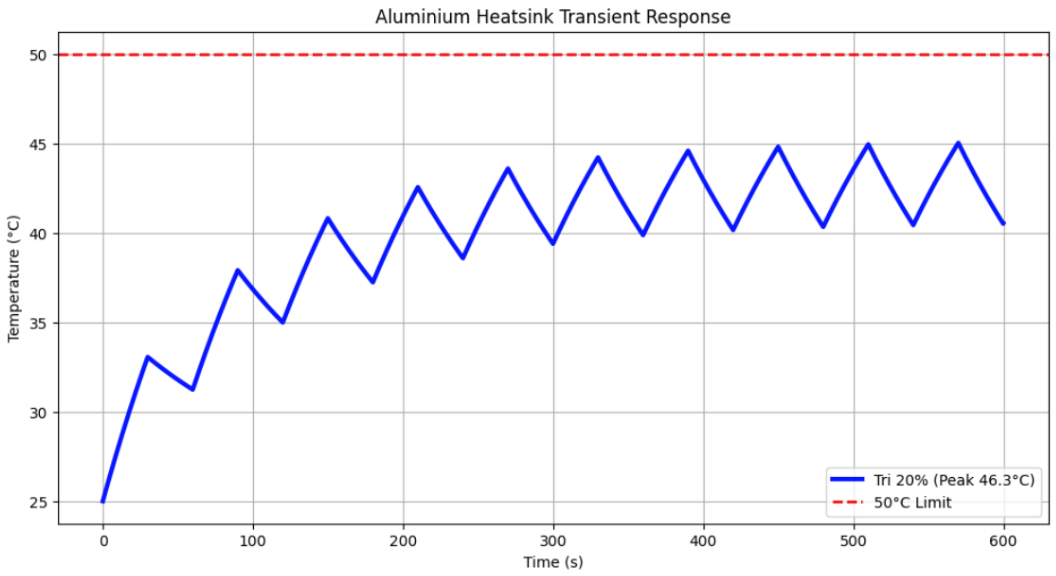
- **Energy Balance Equation:** $\mathrm{Q_{in}} - \mathrm{Q_{out}} = \mathrm{mc}\frac{dT}{dt}$
- **Thermal Energy Balance(ODE):** $\frac{\mathrm{dT}}{\mathrm{dt}} = \frac{Q(t)}{\mathrm{C_{th}}} - \frac{\mathrm{hA_{eff}}}{\mathrm{C_{th}}}(T - \mathrm{T_\infty})$
- **Heat Solution at Q:** $\mathrm{T(t)} = \mathrm{T_\infty} + (\mathrm{T_0} - \mathrm{T_\infty} - \frac{\mathrm{Q}}{\mathrm{hA_{eff}}})\mathrm{e}^{-\mathrm{t}/\tau} + \frac{\mathrm{Q}}{\mathrm{hA_{eff}}}$
- **Cooling Solution at Q=0 :** $\mathrm{T(t)} = \mathrm{T_\infty} + (\mathrm{T_0} - \mathrm{T_\infty})e^{-t/\tau}$
- Analysis implemented in Python to simulate transient heating/cooling cycles.

Fin Coverage vs Mass & Temperature - Simulation Result

- Fin comparison: temp, mass, efficiency
- Triangular fins = best performance

Fin Coverage vs Mass and Temperature Comparison Table

Fin Type	Coverage	Al Mass (g)	Al Temp (°C)	Efficiency η	Remarks
Rectangular	10%	63	42.5	0.912	OK
Rectangular	20%	129	45.0	0.884	OK
Rectangular	30%	194	55.2	0.842	Overheating
Triangular	10%	36	44.8	0.928	OK
Triangular	20%	73	46.3	0.892	OK
Triangular	30%	110	56.9	0.854	Overheating



- High coverage may exceed 50°C
- Tri 20% transient peak = 46.3°C (safe)

Final Thermal Performance Comparison

Triangular 20% fin was selected due to:

- ✓ Safe peak temperature (46.3°C)
- ✓ Lower material mass
- ✓ Lower manufacturing cost
- ✓ Stable transient response