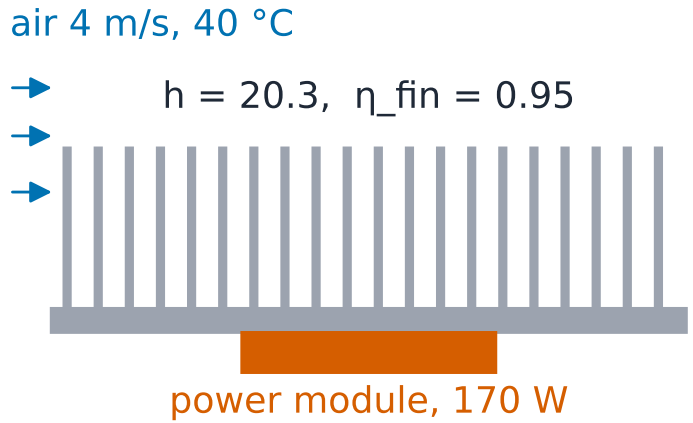
Exercise walk-through

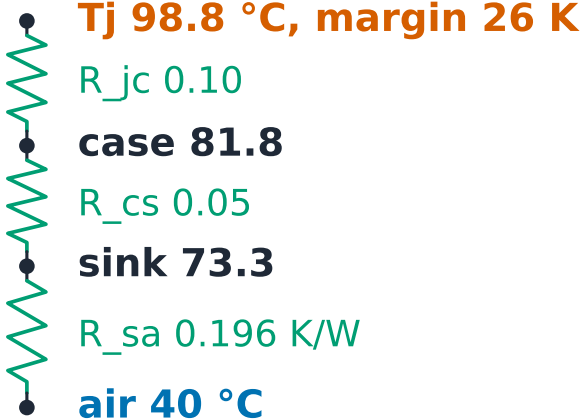
10.6
Thermal design

University Mechanical Engineering

Cooling the drive electronics

20 fins, 40 × 2 mm, 150 mm long junction to air: limit 125 °C





Allowed $R_{sa} \le \mathbf{0.35}$ K/W; 20 **fins** give $\eta_f = 0.95$, $R_{sa} = \mathbf{0.196}$ K/W, $T_j = \mathbf{98.8}$ °C.

Margins and assumptions

1. **Options** 30 **fins** $\rightarrow$ 88.6 °C; 60 mm fins $\rightarrow$ 89.8 °C.
2. **Sensitivity** h is $\pm 25\%$ uncertain; at $h = 15$, $T_j = 110$ °C, still below 125.
3. **Conservative** Radiation from the sink (about 10%) ignored.
4. **Not covered** Fan failure - needs a thermal trip.

Decision

A thermal design is a number, a margin and the assumption that could break it.

Check yourself

- The wall and the pipe? (0.1437 K/W, 188 W; 17.5 W/m insulated, 170 W/m bare with radiation.)
- The ball and the shaft? (Bi 0.019, 34 s; Bi 1.05, 15.6 s, lumped 10.4 s.)
- The two h values? (Air plate 20.3; loop water about 10 000 $\mathrm{W/m^2K}$.)
- The shield, the exchanger, the sink? (170 $\mathrm{W/m^2}$; 2.89 $\mathrm{m^2}$, 4.33 $\mathrm{m^2}$ fouled; 0.196 K/W, 98.8 °C.)

Exercises 2.1·2.2

2.1 A 120 W module must keep $T_j \le 110$ °C in air at 35 °C, with $R_{jc} + R_{cs} = 0.23$ K/W. Find the largest allowed R_{sa} (three decimals, K/W). [2]

2.2 An aluminium fin ($k = 200$ W/(m · K)) is 30 mm high and 1.5 mm thick, with $h = 25$ W/(m^2 · K). Find m (two decimals, m^{-1}), mH and η_f (three decimals). [4]

Exercises 2.1·2.2

2.1 A 120 W module must keep $T_j \le 110$ °C in air at 35 °C, with $R_{jc} + R_{cs} = 0.23$ K/W. Find the largest allowed R_{sa} (three decimals, K/W). [2]

2.1

- $R_{sa,max} = (T_{j,max} - T_a)/P - (R_{jc} + R_{cs}) = 75/120 - 0.23 = \mathbf{0.395}$ K/W.

2.2 An aluminium fin ($k = 200$ W/(m · K)) is 30 mm high and 1.5 mm thick, with $h = 25$ W/(m^2 · K). Find m (two decimals, m^{-1}), mH and η_f (three decimals). [4]

2.2

- $m = \sqrt{2h/(kt)} = \sqrt{2 \times 25/(200 \times 0.0015)} = \mathbf{12.91}$ m^{-1}.
- $mH = 12.91 \times 0.030 = 0.387$; $\eta_f = \tanh(0.387)/0.387 = \mathbf{0.953}$.

Exercise 3.1

3.1 The sink of 2.1 has a base 100 mm by 120 mm carrying 25 of the fins of 2.2, each 100 mm long, $h = 25$ W/(m^2 · K). (a) Find the fin area (both faces) and the exposed base area. (b) Find R_{sa} (four decimals) and T_j (one decimal, °C); does it meet the limit? (c) A fan doubles h to 50: find the new η_f, R_{sa} and T_j, and explain why R_{sa} falls by less than half. [10]

Exercise 3.1

3.1 The sink of 2.1 has a base 100 mm by 120 mm carrying 25 of the fins of 2.2, each 100 mm long, $h = 25$ W/(m^2 · K). (a) Find the fin area (both faces) and the exposed base area. (b) Find R_{sa} (four decimals) and T_j (one decimal, °C); does it meet the limit? (c) A fan doubles h to 50: find the new η_f, R_{sa} and T_j, and explain why R_{sa} falls by less than half. [10]

3.1

- (a) $A_f = 25 \times 2 \times 0.030 \times 0.100 = \mathbf{0.150}$ m^2.
- $A_b = 0.100 \times 0.120 - 25 \times 0.0015 \times 0.100 = \mathbf{0.00825}$ m^2.
- (b) $hA_{eff} = h(A_b + \eta_f A_f) = 25(0.00825 + 0.953 \times 0.150) = 3.779$ W/K, so $R_{sa} = \mathbf{0.2646}$ K/W.
- $T_j = T_a + P(R_{jc} + R_{cs} + R_{sa}) = 35 + 120(0.23 + 0.2646) = \mathbf{94.4}$ °C, inside 110 °C.
- (c) $m = \sqrt{2 \times 50/(200 \times 0.0015)} = 18.26$, $mH = 0.548$, $\eta_f = \mathbf{0.911}$.
- $hA_{eff} = 50(0.00825 + 0.911 \times 0.150) = 7.244$ W/K, $R_{sa} = \mathbf{0.138}$ K/W; $T_j = 35 + 120(0.23 + 0.138) = \mathbf{79.2}$ °C.
- A larger h steepens the temperature fall along the fin, so the tips run cooler and η_f drops: the conductance less than doubles, and $R_{jc} + R_{cs}$ do not change at all.