Thermal Homework Problems

April 11, 2009

For problems involving transistors, use the chart on page 4 of the Thermal Analysis notes for data.

1. A heated block of metal has a thermal resistance of 5 C/W to ambient. How much heater power is required to hold the block at 80 C if ambient is 25 C? Answer: 11 watts.

2. It takes 20 watts of heater power to hold a block of metal at 60 C when the ambient temperature is 25 C. What is the thermal resistance to ambient? Answer: 1.75 C/W.

3. How much power would be required to hold the block in problem 2 at 60 C if the ambient temperature was -10 C? Answer: 40 watts.

4. A resistor is rated at 0.25 watts maximum dissipation at 25 C. Its maximum operating temperature is 125 C (i.e. it can dissipate zero power at that temperature). What is the maximum power dissipation of the resistor if the ambient temperature is 60 C? Answer: first note that the thermal resistance to ambient of the resistor is 400 C/W!!! Then, the maximum power dissipation is 0.16 W

5. It is desired to operate the resistor in problem 4 at no more than 80 C device temperature (ambient remains at 60 C) to enhance the lifetime. What is the allowable power dissipation for this situation? Answer: 0.05 watts – note how small!

6. How much power can a 0.25 watt rated resistor dissipate if the ambient temperature is 0 C? Answer: only 0.25 watts in most cases although consult manufacturer's data sheets. This is typically a consequence of maximum allowable current density and localized heating effects.

7. What is the maximum power a transistor in a TO-92 package can dissipate with an ambient temperature of 50 C and so that the junction temperature is no more than 100 C? Answer: note that the thermal resistance from junction to ambient is 60 + 240 = 300 C/W. Then, Pmax = 0.167 watts.

8. The voltage between the collector and emitter of a transistor in a TO-92 package is 5 volts and the collector current is 50 mA. What is the junction temperature if the ambient temperature is 25 C and no heat sink is used? Answer: the power dissipation is 0.25 watts and the junction temperature will be 100 C.

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9. A power transistor in a TO-220 package is typically rated at 25 watts dissipation when attached to an infinite heat sink at 25 C. How much power can it dissipate in free air at an ambient of 25 C? Answer: note that the thermal resistance from junction to ambient (no heat sink) is 3 + 45 or 48 C/W. The maximum junction temperature in the infinite heat sink case is 125 C (3 + 1 = 4 C/W total). Thus, the maximum no heat sink power dissipation is 2.08 watts {(125 – 25) / 48}.

Refer to Figure 2 (Typical heat sink data) on page 5 of the thermal analysis notes for the following problems. Data read from the chart is only approximate so consider that if your answer is similar but not exactly as given.

10. A transistor in a TO-220 package mounted to the heat sink will be dissipating 10 watts. What will be the temperature of the heat sink when the ambient temperature is 40 C and there is no forced air? Answer: 70 C. What will the temperature of the transistor case be if the mounting thermal resistance is 1 C/W? Answer: 80 C. What is the junction temperature? Answer: 110 C. What is the effective thermal resistance of the heat sink? Answer: 3 C/W.

11. Repeat problem 10 if air is blowing across the heat sink at a rate of 150 feet per minute? First determine the effective thermal resistance of the heat sink – answer: ~ 1.8 C/W – much better than in free air. Heat sink temperature will be 58 C. Case temperature will be 68 C. Junction temperature will be 98 C.

12. What is the temperature rise of the heat sink if a transistor is dissipating 20 watts and the air flow is 300 feet per minute? Answer: thermal resistance is ~0.9 W/C resulting in a temperature rise of 18 C. What would the temperature rise be without forced air? Answer: ~59 C.

The following are some good general questions to know the answers to.

13. What is the thermal resistance of an “infinite” heat sink? Answer: 0 C/W.

14. Do heat sinks eliminate heat? Answer: No, they only assist in transferring heat.

15. Is air a good conductor of heat? Answer: No, air is a terrible thermal conductor.

16. What is the purpose of substances generally known as heat sink compound that are used between the surface to surface mating of a transistor and a heat sink? Answer: to displace the small air gaps from imperfect surface finish thus enhancing thermal conductivity.

17. If an “infinite” heat sink were actually available then could a transistor attached to it dissipate infinite power? Answer: No, because there is finite thermal resistance between the junction and the case resulting in a thermal gradient. The maximum power rating of a transistor already assumes mounting to an “infinite” heat sink.