PIQ Quiz Notes

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Thermal Quiz 1

Why are heatsinks needed to cool Power Semiconductors?

- Power semiconductors are highly efficient but not perfectly so. For example, a high power Insulated Gate Bipolar Transistor (IGBT) used in inverter equipment will dissipate thousands of watts while operating at full load.
- The silicon material used to manufacture power semiconductors has a typical maximum operating temperature of 125°C, which typically relates to a maximum heatsink temperature between 80°C to 90°C.
- The challenge is to remove the unwanted heat from the power semiconductor so that its junction temperature does not exceed 125°C. Junction temperature is the highest temperature inside the semiconductor, which determines its reliability and performance.
- Properly designed air cooled or liquid cooled heatsinks manufactured from either aluminum or copper are a critical component to the application when trying to maintain a stable junction temperature.

Question 1: Which cooling system is capable of removing the greatest amount of heat?

A. Air cooled

B. Liquid cooled

C. Oscillating air and liquid

D. All of the above

Explanation

Liquid cooling is the most effective means for removing heat, allowing the design engineer to optimize the semiconductor's performance.

Question 2: Which material has the highest thermal conductivity?

A. Aluminum

B. Tin

C. Zinc

D. Copper

Explanation

Copper has the highest thermal conductivity of the four metals, therefore transferring more heat away from viable components.

Question 3: What must the design engineer avoid in a liquid cooled system?

A. Leakage

B. Condensation

C. Different metals in the system

D. All of the above

Explanation

In a liquid cooled system, the design engineer should avoid fluid contact with electronic devices caused by leakage and condensation. In addition, using different metals in the cooling system will cause corrosion and should therefore be avoided.

Air cooled systems vs. liquid cooled systems

- From a cost standpoint, forced air cooling systems are generally preferred over liquid cooled systems. However, there are some factors to consider:
  - An air cooled heatsink requires a large surface area to dissipate the unwanted heat
  - In addition to the heatsink, a suitably sized fan is required to deliver sufficient air flow to remove heat from the heatsink.
- The most important characteristic of a heatsink is its thermal resistance, which is measured in Degrees Celsius per Watt (°C/W). The typical symbol for thermal resistance is either R_{Θ} or R_{th}. In general, an efficient heatsink will have low thermal resistance.

Understanding Thermal Resistance

- When thinking about "R" value, people often think of the R value of insulation used in a house. When selecting insulation for a home, the higher the R value, the better thermal protection the insulation will provide. This helps keep heat in the house during the winter and cool air inside during the summer.
- The opposite is true for a heatsink. A low value of R_{Θ} will allow the heat to flow freely from the semiconductor through the heatsink to the cooling medium, which might be air or water.

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Thermal Quiz 1 (continued)

Question 4: If a heatsink is to dissipate 1000 watts in an ambient temperature of 40°C and the maximum allowable heatsink temperature is 90°C, what is the required thermal resistance for the heatsink to meet this specification?

$$\frac{90 - 40}{1000} = \frac{50}{1000} = 0.05\ °C/W$$

Check the result: 1000 x 0.05 = 50, which is the allowable temperature rise.

In Summary

- A heatsink is a very important component for cooling the semiconductor. It extends its life and increases its reliability and performance by maintaining lower temperature.
- In heatsinks, the most common metals used are copper and aluminum. Of these two metals, copper has the higher thermal conductivity.
- An air cooled system is often less expensive than a liquid cooled system. However, a liquid cooled system allows more power dissipation and higher performance.

Additional Resources

- Solutions for Cooling of Power Electronics
- R-Tools 3D Heatsink Thermal Modeling Tool

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