Peltier device

One notable application of Peltier devices is in portable cooling systems for medical use, particularly in vaccine transport. In regions lacking reliable refrigeration, maintaining the cold chain for temperature-sensitive vaccines is critical. Peltier modules, being compact and solid-state, offer a viable solution for such portable cooling needs.

In a recent experimental study, a TEC1-12706 Peltier module was tested within an electronic cooling assembly as shown in Fig. 7.1. The system operated from a regulated 12 V DC power source, with a current draw of approximately 6 A. To optimize thermal management, aluminum heat sinks and DC-powered fans were employed on both sides of the module.

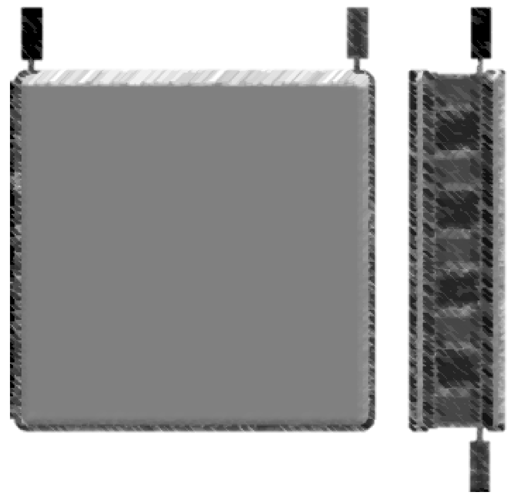

Fig. 7.1

Experimental data indicated that the hot-side temperature of the Peltier module stabilized at approximately 328 K, while the cold-side effectively maintained electronic component temperatures below 303 K, crucial for electronic stability and performance. The observed efficiency of the Peltier module was approximately 0.40, highlighting a practical efficiency suitable for high-precision electronic cooling.

From an electrical perspective, controlling the current and voltage supplied to the Peltier device significantly influences its cooling performance and efficiency. PWM-based DC controllers are often employed to finely regulate power input, thus managing thermal output and improving the longevity of both the Peltier device and cooled electronic components.

The cooling power Q_c at the cold side of Peltier module depends on the current I through the Peltier module and the absolute temperature of the cold side T_c. The Seebeck coefficient α which the cooling power depends on is constant. Ignoring internal resistive and conductive losses, a simpler and commonly used basic formula for a Peltier module that focuses on the thermoelectric cooling effect is given by

$$Q_c = \alpha I T_c$$

Fig. 7.2 shows the process of operating the Peltier module that requires the absolute temperature of the cold side to be 293.15 K.

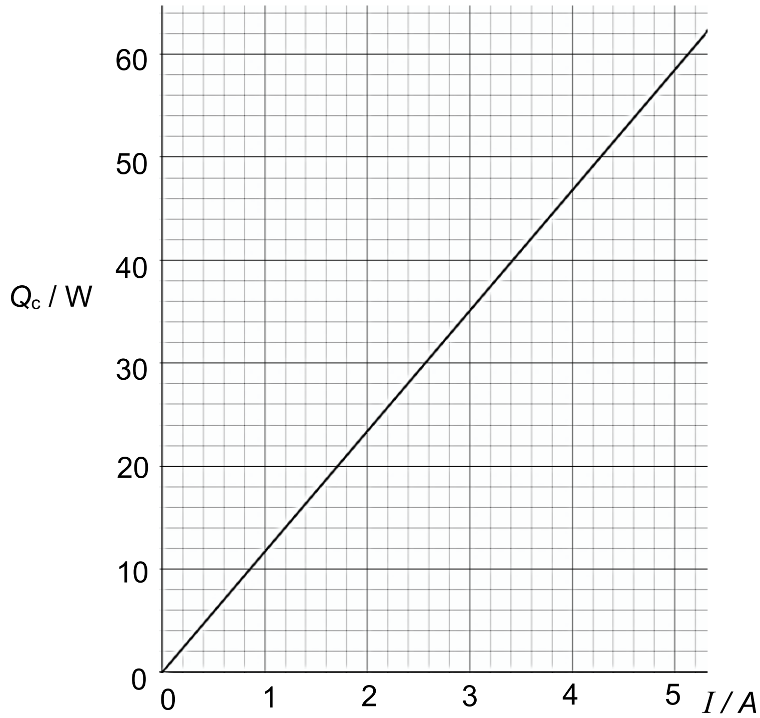

Fig. 7.2

Ultimately, the integration of Peltier modules within electronic cooling systems provides reliable temperature management crucial to modern electronics. Continued research is focused on improving electrical control strategies and thermal management techniques to enhance overall efficiency and effectiveness in high-performance electronic applications.

(a) State one advantage and one disadvantage of using Peltier modules compared to traditional refrigeration methods.

Advantage: ....

....

....

Disadvantage: ....

....

.... [2]

(b) State and explain if the multiple Peltier modules should be connected in series or parallel to the power supply to maximise the cooling output of the cooling assembly.

....

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....[2]

(c) Suggest what happens to the hotness of the sides when the polarity of a Peltier device is reversed.

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………[1]

(d) A potential divider can be used to provide necessary voltage and current to the Peltier module as shown in Fig. 7.3.

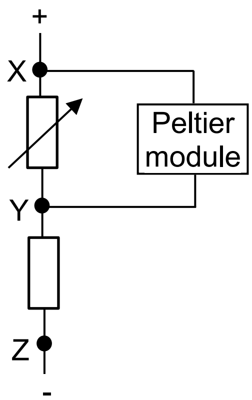

Fig. 7.3

Explain how the potential divider can turn on the Peltier module.

………

………

………

………[2]

(e) Using Fig. 7.2,

(i) determine the Seeback coefficient of α,

α = ………………………………………… V K^{-1} [2]

(ii) determine the amount of charges flowing through the Peltier module for 2 hours at the cooling power of 40 W.

amount of charges = ……………………………………C [3]

(iii) calculate the potential difference across the Peltier module at the cooling power of 40 W.

[The efficiency of the Peltier module is given as efficiency = $\dfrac{\text{Cooling Power}}{\text{Input Power}}$]

potential difference = ……………………………..……V [3]

(f) A student suggested that an a.c. power supply can be used to power the Peltier module.

Explain how the suggestion from the student can be implemented with some modifications.

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……[2]

(g) On Fig. 7.4, sketch a graph that shows the variation with time *t* of the output potential difference (p.d.) of a 50 Hz sinusoidal 230 V a.c. power supply. Add a scale to the y-axis.

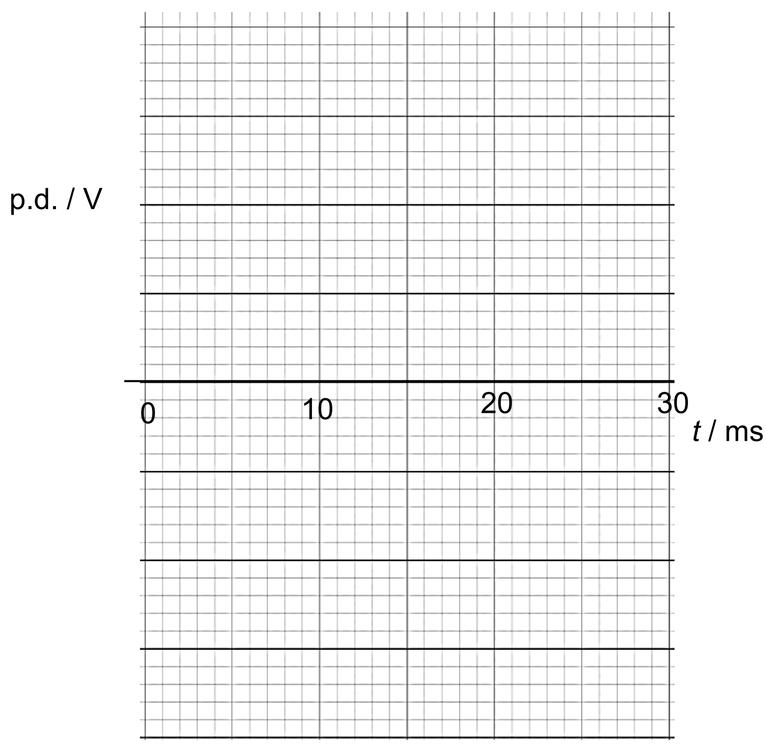

Fig. 7.4

[3]

[Total: 20]