PERFECT WIRELESS EXPERIENCE

Module General

Thermal Design Guide

V1.2

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This document serves as a guide for the use of products. Customers must design their products according to the information provided in the document. The Company shall not be liable for any damage caused by failure to comply with relevant operation or design specifications or safety rules. Due to product version upgrade or other reasons, the Company reserves the right to modify any information in this document at any time without prior notice and any responsibility. Unless otherwise agreed, all statements, information and suggestions in this document do not constitute any express or implied guarantee.

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Safety Instructions

Do not operate wireless communication products in areas where the use of radio is not recommended without proper equipment certification. These areas include environments that may generate radio interference, such as flammable and explosive environments, medical devices, aircraft or any other equipment that may be subject to any form of radio interference.

The driver or operator of any vehicle shall not operate wireless communication products while controlling the vehicle. Doing so will reduce the driver's or operator's control and operation of the vehicle, resulting in safety risks.

Wireless communication devices do not guarantee effective connection under any circumstances, such as when the (U) SIM card is invalid or the device is in arrears. In an emergency, please use the emergency call function when the device is turned on, and ensure that the device is located in an area with sufficient signal strength.

Contents

Applicable Model

No.	Applicable Model	Description
1	Applicable to all projects	--

Change History

V1.2 (2024-01-10)	Example Modify the description of the temperature control policy
V1.1 (2022-11-21)	The specific heat dissipation scheme and temperature control strategy of the module are re-established.
V1.0 (2022-06-16)	Initial version.

1 Heat Conduction

When there is no macroscopic relative motion between various parts of an object, the heat transfer caused by the motion of microscopic particles such as molecules, atoms and ions is called thermal conductivity. Fourier's law of thermal conductivity:

$$Q = -\lambda A \frac{\partial T}{\partial x} \qquad \mathrm{W}$$

Q is thermal power, in W; A is the cross-sectional area perpendicular to the direction of heat flow, in m^2; λ is the thermal conductivity of the material, in W/(m·°C), which is a physical property parameter characterizing the thermal conductivity of the material, and **∂**x is the thermal conduction distance, in m. Heat flux q:

$$q = \frac{Q}{A} \qquad \mathrm{W/m^2}$$

By integrating Fourier's law under the condition of one-dimensional heat conduction:

$$Q = \frac{\Delta T}{R_t}$$

The calculation formula of thermal conductivity resistance is:

$$R_t = \frac{\delta}{\lambda A} \qquad \mathrm{K/W}$$

The methods to improve thermal conductivity in engineering include:

- Increase the area A of the thermal conductive object.
- Shorten heat transfer distance between heat source and cold end.
- Choose materials with higher thermal conductivity.

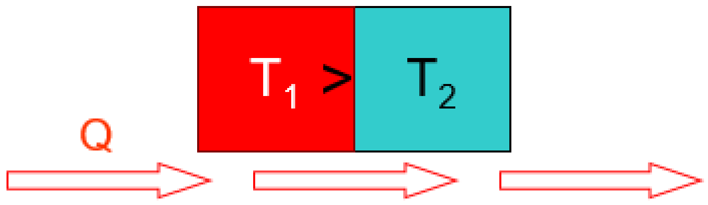

Figure 1. Example diagram of thermal conduction

2 Thermal Conductivity of Common Materials W/(m·°C)

Solid > Liquid > Gas

Thermal conductivity of common materials (under normal temperature and pressure):

Pure copper: 400 W/m x °C

Pure aluminum: 236 W/m x °C

Pure water: 0.6 W/m x °C

Air: 0.025 W/m x °C

ADC12: 68 W / m x ℃

AL5052: 150 W / m x ℃

AL6061: 180 W / m x ℃

AL6063: 203 W / m x ℃

Stainless steel: 17 W/m x ℃

Cupronickel: 33 W/m x °C

PCB: Anisotropic material

Soldering tin: 80 W/m x °C

3 Thermal Contact Resistance

During two-phase solid surface contact, the actual contact is only the area of some discrete parts due to limit of the material processing procedure. The gap between the non-contact surfaces is filled with air, and generates a large thermal resistance.

Main measures commonly used in engineering to reduce contact thermal resistance:

- Increase the pressure between contact surfaces;
- Improve the machining accuracy of two contact surfaces;
- Add thermal gasket or thermal grease, thermal paste between the contact surface;
- Soft metal materials are selected to make the shell of radiator or device under the condition that the structural strength permits.

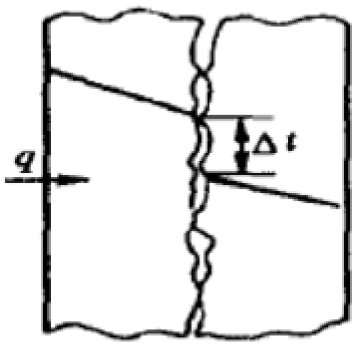

Figure 2. Thermal resistance scheme

4 Thermal Convection

Convective heat transfer refers to the heat exchange process when moving fluid flows through solid surfaces at different temperatures. According to the causes, convective heat transfer can be divided into forced convection heat transfer and natural convection heat transfer. Forced convection heat transfer usually has external power sources, such as pumps and fans, while natural convection heat transfer mainly runs because of different densities caused by different temperatures. Newton's cooling formula:

$$Q = \alpha A \Delta T$$

Where α is the convective heat transfer coefficient in W/(m2·K), which represents the average convective heat transfer capacity of the heat transfer surface.

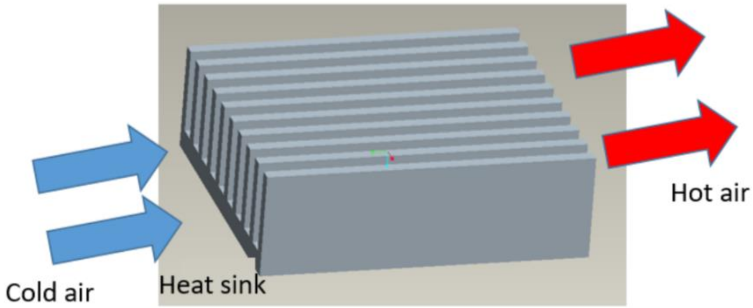

Figure 3. Heat dissipation diagram of heat sink

The methods to improve convective heat transfer capacity in engineering include:

- Appropriately increase the surface area A of heat sink;
- Increase fluid velocity and convective heat transfer coefficient α;
- Change fluid working medium and improve convective heat transfer coefficient α.

5 Thermal Radiation

The research wavelength of thermal radiation ranges from 0.1μm to 100μm, and the radiation energy of most electronic devices is concentrated in infrared band. Thermal radiation mainly depends on the surface temperature. The actual object temperature is generally lower than 1800℃. At this temperature, thermal radiation is invisible infrared radiation. The emission and absorption of infrared radiation by the object can be considered as the same, which has nothing to do with the color of the object surface (the surface color is related to the visible radiation of high temperature). Radiation force of actual object:

$$E = \varepsilon E_b = 5.67\varepsilon\left(\frac{T}{100}\right)^4 \qquad \mathrm{W/m^2}$$

The temperatures in the above two formulas are absolute, not Celsius. Blackness ε (emissivity): depends on the temperature, type and surface condition of the object, and has nothing to do with color.

The methods to improve radiation heat transfer capacity in engineering include:

- Anodic oxidation
- Surface painting

6 Purpose of Thermal Design

There are four main goals in the thermal design of the whole machine:

- Meet the TJ temperature requirements of IC devices;
- Meet ergonomic requirements;
- Good heat dissipation can enhance the reliability of IC devices;
- Good heat dissipation can reduce the performance degradation of IC devices caused by overheating.

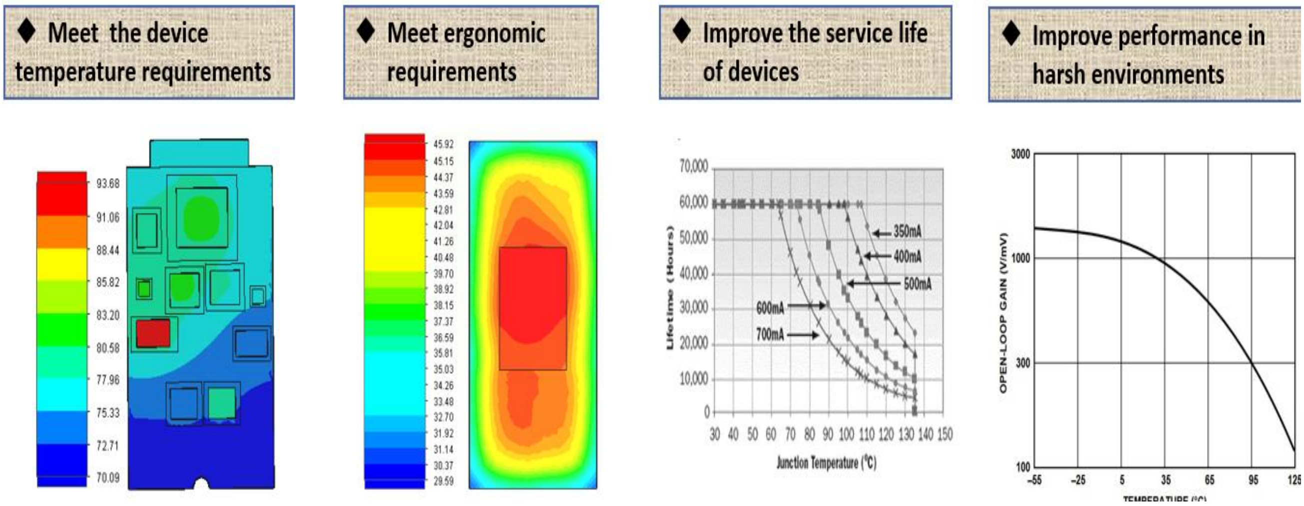

Figure 4. Purpose of thermal design

7 PCB Thermal Design Suggestions

IC devices are directly soldered on the PCB. Good PCB thermal design can greatly improve the heat dissipation capacity. The suggestions for improving heat dissipation of PCB are mainly as follows:

- Under the premise of the cost, the PCB board design with the number of layers and the amount of copper as much as possible is preferred;
- Increase the area of PCB. In the case of insufficient heat dissipation, the area of PCB can be increased as much as possible based on the design size of the whole machine. The larger the heat dissipation area, the better the heat dissipation performance.
- Add PCB hole design, as shown in Figure 2, the purpose of PCB hole design is to increase the heat dissipation capacity in the thickness direction. According to research, when the number of holes per unit area (1cm^2) reaches 600 (laser hole with aperture of 0.08 mm), the heat dissipation performance of PCB is excellent, and increasing the number of holes has a low cost performance for heat dissipation improvement. (For 0.2 mm mechanical hole, the thickness of copper plating in the hole is 0.025 mm, and the number of holes drilled is 36% of that of 0.08 mm laser holes. When the copper plating thickness of mechanical holes is 0.015 mm, the number of holes drilled at this time is about the same as that of 0.08 mm laser holes);
- Proportion of copper in thickness direction: n = (d1+d2)/L, the larger the ratio of n, the better the heat dissipation of PCB.

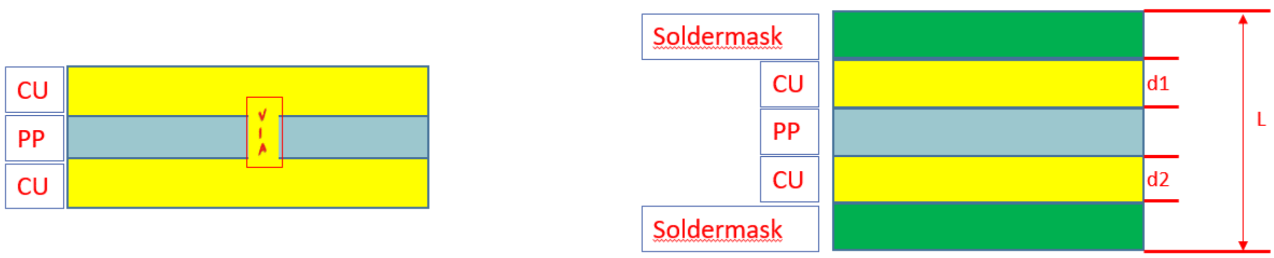

Figure 5. PCB thermal design

8 Heat Sink Design Suggestions

For heat sink design, the main suggestions for improving heat dissipation are as follows:

- The more the number of heat sink fins, the better the heat dissipation effect. If the number of fins is too large, the convection heat dissipation of heat sink will occur. When designing heat sink, customers can get the appropriate number of heat sink fins based on calculation or simulation analysis;
- The heat dissipation can be increased by increasing the fin length of the heat sink. When designing the fin length, customers can determine the fin with appropriate length through calculation or simulation analysis based on the processing technology of different materials;
- The material of heat sink is usually aluminum alloy or copper. The radiation coefficient of metal surface is relatively low, and the radiation heat transfer is directly proportional to the absolute value of temperature. The surface treatment mainly plays a role in the case of natural convection.
- When choosing the heat sink, the structure with small thermal resistance should be chosen reasonably, that is, trapezoidal fin thermal resistance > triangular fin thermal resistance > streamline fin thermal resistance.

Table 1. Recommended heat sink design

Thermal Capacity Study					
Fin No.	Tj (℃)	Fin Length	Tj (℃)	Surface Treatment	Tj (℃)
4	71.3	30	73.6	No	72.9
8	68.4	44	68.6	Surface oxidation or painting	68.2

9 Selection of Thermal Interface Materials

Currently, there are three kinds of thermal interface design in common use, which mainly improve heat dissipation by reducing the air thermal resistance between two solids. In the design of thermal interface materials, the thermal interface materials should be fully contacted with two structural components, and 20% redundancy should be reserved in the design. Of course, when designing the heat dissipation of the whole machine, the thicker the thermal interface material is not the better. The thermal resistance is proportional to the thickness, so the thermal resistance of the heat dissipation path from the heat source to the external environment shall be reduced as much as possible.

- In the process of dispensing glue in the module, it is mainly to open up the heat dissipation path from the IC device to the top of the shielding cover. If there is no heat sink designed above the shielding cover or no connection with the whole machine shell for heat dissipation, then the gluing in the module has little influence on heat dissipation.
- When a heat sink is designed above the shielding cover or is connected with the shell of the whole machine for heat dissipation, gluing in the module can play a great role in heat dissipation.

Type	Service Life	Processing Technology	Application Scenario
Thermal gasket	Excellent	Hand paste	Clearance 0.3 to 3 mm
Thermal silicone grease	Poor	Dispenser	No clearance
Thermal grease	Good	Dispenser	Clearance 0.1 to 1 mm

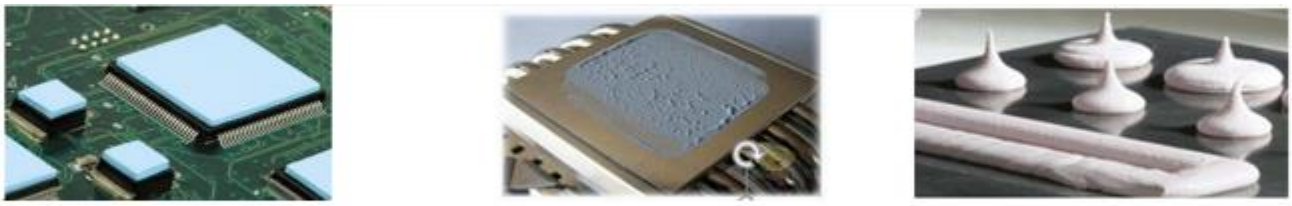

Figure 6. Thermal interface material design

10 Suggestions on Overall Thermal Design of LGA Package Module

When using LGA package module for thermal design of the whole machine, the main suggestions are as follows:

- The LGA package module will be soldered on the customer's motherboard. At this time, it is preferred to use the whole machine shell for heat dissipation, and use thermal interface material between the module and the shell for connection;
- The corresponding position of the module under the customer motherboard can be selectively filled with thermal interface materials according to the actual situation;
- When selecting shell materials, metal shell is preferred, among which aluminum alloy material has better heat dissipation effect;
- When plastic shell is selected, graphite sheet can be pasted on the inner side for temperature equalization to eliminate local hot spots;
- When the shell is far away from the module, heat dissipation can be achieved by adding a heat sink on the module.

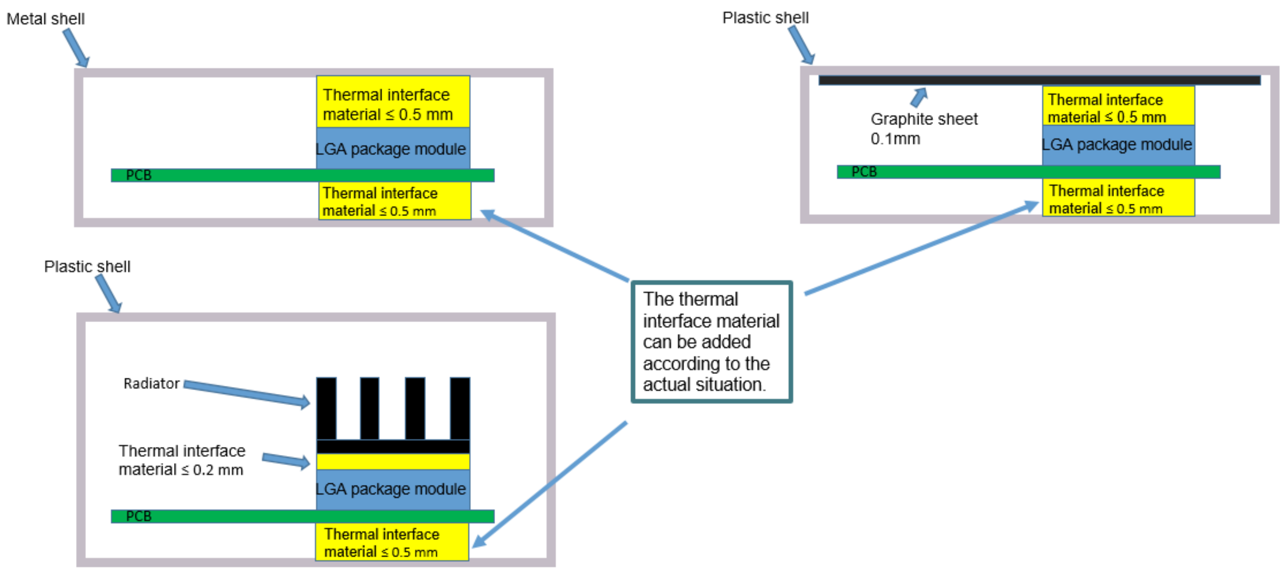

Figure 7. LGA package module heat dissipation structure stack

11 Suggestions on Overall Thermal Design of M.2 Package Module

When using M.2 package module for thermal design of the whole machine, the main suggestions are as follows:

- For the M.2 module, due to the plug-in installation, the same design scheme as the LGA package can be adopted above the shielding cover. On this basis, the thermal interface material can be filled between the exposed copper area at the bottom of the module and the PCB of the main board of the customer for heat dissipation.
- For details, refer to Figure 8.

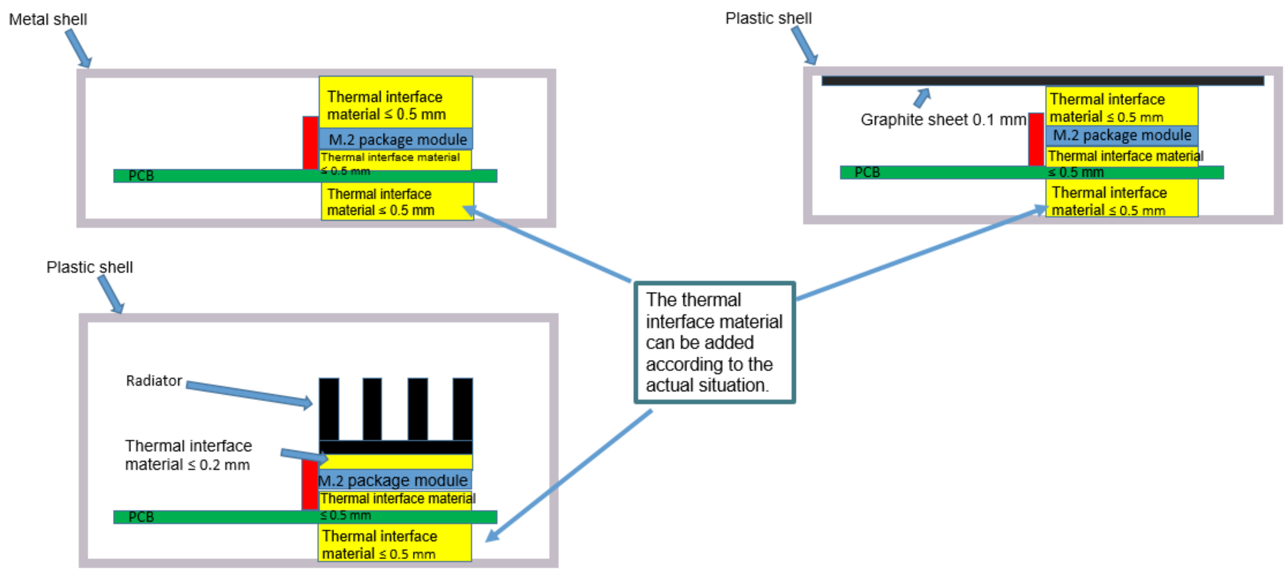

Figure 8. M.2 package module heat dissipation structure stack

12 Temperature Control Strategy

Due to different models and platforms of module products, their specific temperature control measures often vary. For specific temperature control measures, please refer to the detailed temperature control document of the module product.

13 Thermal Design Support

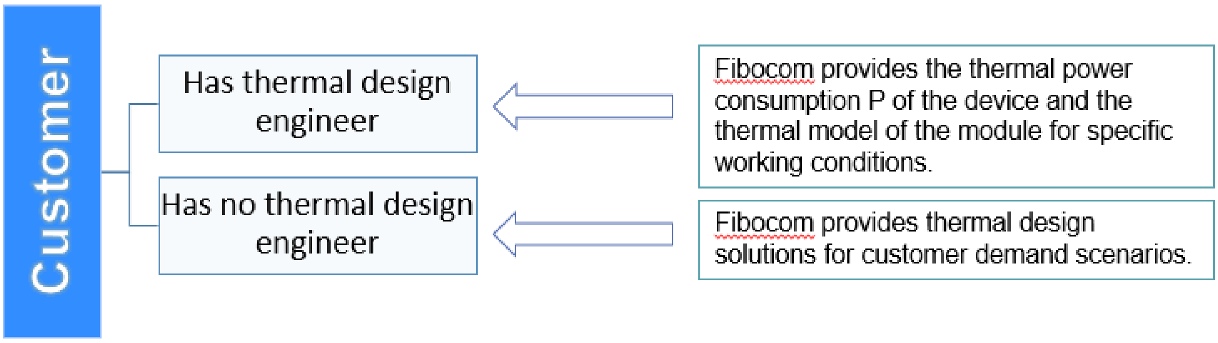

Figure 9. Thermal design assistance process for customers

Customer thermal design related promotion:

- Fibocom high temperature test without shell;
- Fibocom provides customers with thermal design support, and customers can fill in the relevant information of the whole machine according to the demand table;
- Fibocom can provide PDML or STP thermal model files for customers with thermal design engineers.