# X3

# Thermal Reference Design

**Rev. 1.1**

**March 31, 2021**

# Revision History

This section tracks the significant documentation changes that occur from release-to-release. The following table lists the technical content changes for each revision.

| Revision | Date | Description |
|---|---|---|
| V 0.1 | 2020-08-07 | Initial Draft |
| V 0.2 | 2020-08-19 | Adding LPDDR thermal simulation data |
| V1.0 | 2021-03-21 | Adjusting the Temperature limitation. Official release. |
| V1.1 | 2021-03-31 | Add literal expression about power consumption number. |

# Contents

Revision History ........ 1

Contents ........ ii

Figures ........ 3

Tables ........ 4

1 Introduction ........ 5

1.1 Definitions ........ 5

2 Specifications ........ 6

2.1 Thermal Specifications ........ 6

2.1.1 X3 Thermal Specifications ........ 6

3 Design Guidance ........ 6

3.1 Thermal Information ........ 6

3.1.1 X3 Thermal- Resistance ........ 6

3.1.2 X3 Power Consumption ........ 6

3.2 X3 Thermal Design Details ........ 7

3.2.1 PCB Thermal Design ........ 7

3.2.2 Mechanical Thermal Design ........ 8

3.3 X3 Thermal Design Example ........ 9

3.3.1 Example of PCB Thermal Design ........ 9

3.3.2 Example of Mechanical Thermal Design ........ 11

3.4 X3 Thermal Design Example of IPC ........ 12

# Figures

Figure 1-1 Simplified thermal resistance model for a typical chip ........ 5
Figure 3-1 Thermal stack up schematic ........ 7
Figure 3-2 Location of X3 thermocouple ........ 7
Figure 3-3 X3 top view ........ 9
Figure 3-4 X3 side view ........ 9
Figure 3-5 X3 thermal solution assembly example ........ 10
Figure 3-6 Surface temperature cloudy map of X3 and PCB ........ 11
Figure 3-7 Space temperature cloudy map( Y axe) ........ 11
Figure 3-8 X3 thermal solution assembly example - exploded view ........ 12
Figure 3-9 X3 thermal solution assembly example- side view ........ 12
Figure 3-10 X3 thermal solution assembly example in IPC ........ 13
Figure 3-11 X3 thermal solution assembly example in IPC-side view ........ 13
Figure 3-12 X3 thermal solution assembly example in IPC-exploded view ........ 14
Figure 3-13 Surface temperature cloudy map of X3 and PCB ........ 15
Figure 3-14 Space temperature cloudy map(Y axe) ........ 15
Figure 3-15 Surface temperature cloudy map of top view ........ 16
Figure 3-16 Surface temperature cloudy map from bottom to top ........ 16

# Tables

Table 1-1 Definition of terms ..... 5
Table 2-1 X3 thermal specifications..... 6
Table 3-1 X3 thermal resistance..... 6
Table 3-2 X3 Power Consumption..... 6
Table 3-3 Thermal simulation parameters ..... 10
Table 3-4 Thermal simulation parameters ..... 14

# 1 Introduction

With the development of modern society, electronic equipment has been widely used in various fields of people's production and life. In the background of miniaturization and high power of electronic products, heat dissipation of electronic equipment is very important to improve the reliability of equipment. Reasonable thermal design can improve the service life of electronic devices and prevent them from failure due to overheating.

This document provides thermal and mechanical specifications and the thermal reference design for X3.

## 1.1 Definitions

Table 1-1 Definition of terms

| Term | Description |
|---|---|
| $T_A$ | Temperature ambient |
| $T_J$ | Junction temperature for working |
| $\theta_{JA}$ | Junction-to-ambient thermal resistance, Defined as ($T_J$- $T_A$)/Power consumption |
| $\theta_{JB}$ | Junction-to-board thermal resistance |
| $\theta_{JC}$ | Junction-to-case thermal resistance |
| TIM | Thermal Interface Material |
| IPC | IP Camera |

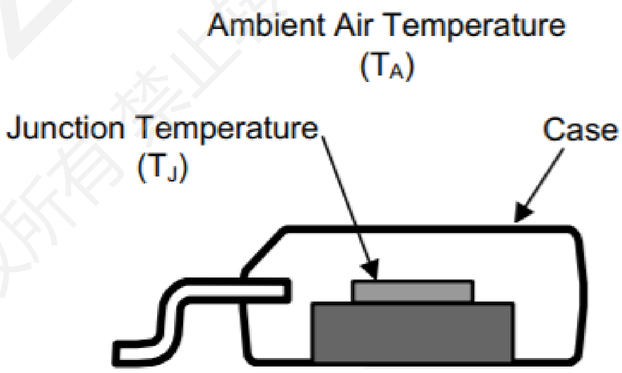


Figure 1-1 Simplified thermal resistance model for a typical chip

# 2 Specifications

## 2.1 Thermal Specifications

### 2.1.1 X3 Thermal Specifications

Table 2-1 X3 thermal specifications

| Symbol | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $T_A$ | Temperature ambient | -25 | | 85 | ℃ |
| $T_J$ | Junction temperature for working | 0 | | 105 | ℃ |

# 3 Design Guidance

This chapter provides some thermal design guideline, which mainly describes heat-sink and mechanical design considerations that should be understood for thermal solutions.

## 3.1 Thermal Information

### 3.1.1 X3 Thermal- Resistance

Table 3-1 X3 thermal resistance

| Symbol | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $\theta_{JA}$ | Junction-to-ambient thermal resistance | | 13.71 | | ℃/w |
| $\theta_{JB}$ | Junction-to-board thermal resistance | | 3.72 | | ℃/w |
| $\theta_{JC}$ | Junction-to-case thermal resistance | | 1.16 | | ℃/w |

### 3.1.2 X3 Power Consumption

The power consumption of X3 is highly dependent on the customer application scenario, which includes the CPU&BPU's loading. Customer should evaluate the power consumption of X3 based on the real application's situation. Discuss with Horizon FAE for the detail number.

Table 3-2 X3 Power Consumption

| Scenario | Power $T_J$=50℃ | Power $T_J$=100℃ |
|---|---|---|
| 1. Dual 4K Camera input, BPU loading 70%, CPU loading 40% | TBD | TBD |

| | | |
|---|---|---|
| 2. | TBD | TBD |
| 3. | TBD | TBD |

## 3.2 X3 Thermal Design Details

### 3.2.1 PCB Thermal Design

The heat generated by electronic equipment makes the temperature of equipment rise rapidly. If the heat is not dissipated in time, the device will continue to heat up, the device will fail due to overheating, and the reliability of electronic equipment will decline. X3 is the main heat source on PCB. In order to ensure the normal operation of X3 and other component on PCB, it is necessary to design a thermal solution to dissipate the heat from X3 to ambient quickly and effectively.

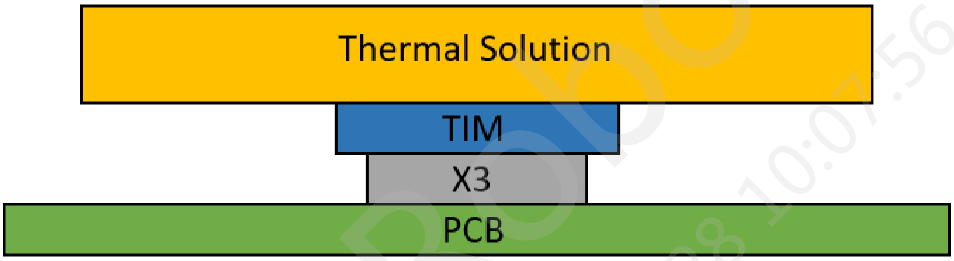


Figure 3-1 Thermal stack up schematic

The X3 product is designed for integration with a product-level thermal solution which could be a passive heat-sink, an active heat-sink, etc. The thermal solution must attach to the top surface of the X3 case. The 7.6 × 7.6 mm area on the top surface of the X3 case, as shown in Figure 3-2, is the key contact area for efficient cooling performance. Full contact with the entire top surface of the X3 is suggested for maximum cooling.

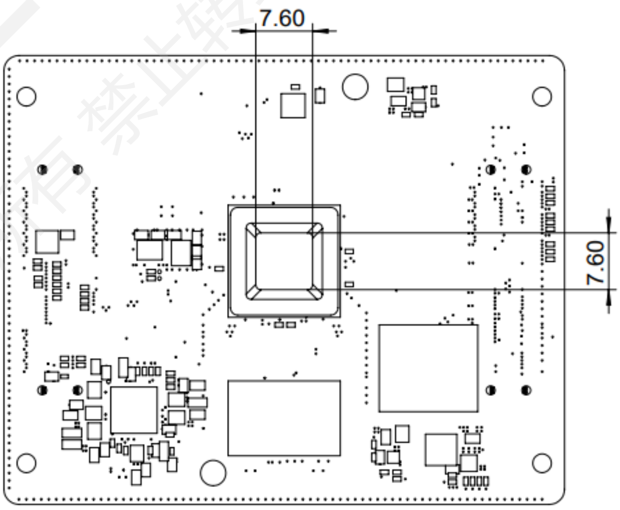


Figure 3-2 Location of X3 thermocouple

The main way of heat dissipation from the X3 to the ambient is by conducting heat out of the X3 case and into the surrounding air through fins attached to the heat-sink base.

To dissipate the heat of the X3 quickly, the following suggestions on the selection and use of the heat-sink should be considered for developing the thermal solution.

- Select heat-sink with high thermal conductivity as far as possible within the cost constraint according to the customer's actual use environment. Thermal conductive materials play an important role in thermal design. The higher the thermal conductivity of the material, the better the heat transfer.
- Avoid breaks in the thermal path. There are air gaps and voids between the top surface of X3 case and the bottom surface of heat-sink. Because air has a very low thermal conductivity, it will seriously hinder the heat transfer between the contact surfaces. In order to reduce the thermal contact resistance between the X3 surface and the heat-sink surface and ensure the smooth thermal path, it is suggested that the air gap between X3 and the heat-sink should be filled with thermal interface material (TIM) with high compression performance and high thermal conductivity.
- Increase the area of the surface on which the heat transfer takes place. Under the condition of meeting the limitation of installation space, properly increasing the area of the heat-sink base and fins, can effectively improve the thermal performance of the heat-sink.

### 3.2.2 Mechanical Thermal Design

For best thermal performance, the TIM should provide low thermal impedance within the mechanical, reliability, and cost constraints of the customer's product.

The following considerations should be referenced to ensure good mechanical and thermal contact between the X3 case and the heat-sink.

- The applied force to the heat-sink base should maintain the desired pressure on the TIM. The TIM is a kind of heat conducting medium, which is used to reduce the contact thermal resistance between the surface of heat source and the contact surface of heat-sink. At the same time, it also plays the role of insulation, damping and sealing. However, with extremely poor heat-sink interface flatness or roughness, TIM may not adequately fill the gap. The TIM thermal performance depends on its thermal conductivity and the pressure applied to it: In the compression limit range, the higher the pressure, the greater the compressibility, the smaller the thermal resistance, the shorter the conduction path, the better the thermal conductivity. The distance between the top surface of X3 and the bottom surface of heat-sink should consider not only the compression ratio of TIM, but also the height tolerance of X3 package.
- Ensuring system electrical, thermal, and structural integrity under shock and vibration events. The mechanical requirements of the heat-sink attach mechanism depend on the mass of the heat-sink and the level of shock and vibration that the system must support. The overall structural design of the motherboard and the system should be considered in designing the heat-sink attach mechanism.
- The heat-sink should be held in place under mechanical shock and vibration events.

The following figures provide X3 product dimensions to let customers determine how to interface the X3 case with the heat-sink and ensure mechanical compatibility in system. The specific installation dimensions are shown in Figure 3-3 and Figure 3-4.

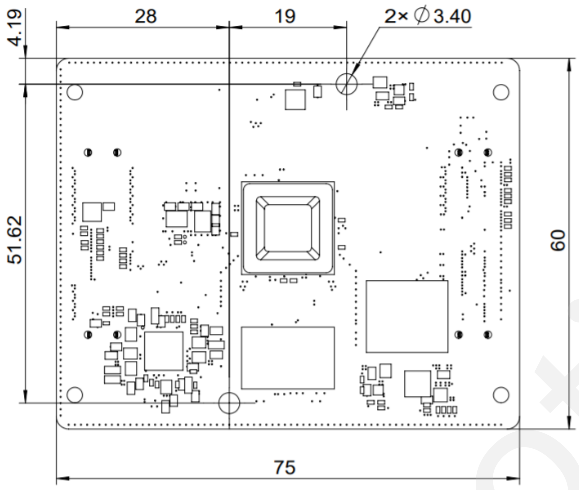


Figure 3-3 X3 top view

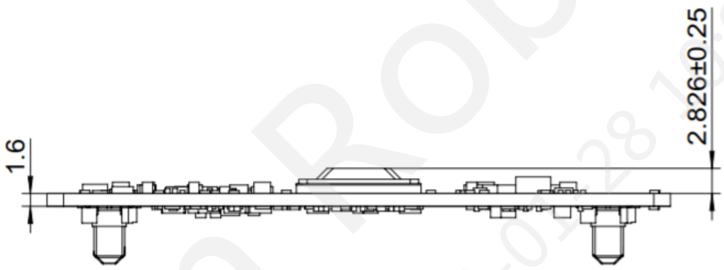


Figure 3-4 X3 side view

## 3.3 X3 Thermal Design Example

In this section, the thermal simulation result of X3 on PCB with a passive heat-sink and the connection mechanism design of heat-sink are taken as examples to illustrate the thermal design of X3.

Caution: The example only illustrates the thermal simulation process of X3 embedded product. The simulation result is highly dependent on the multiple inputs, such as customer product mechanical structure, thermal interface material, PCB size, and the real power consumption of X3 in customer scenario.

### 3.3.1 Example of PCB Thermal Design

This section provides a typical thermal design reference example with a passive heat-sink for X3, as shown in Figure 3-5.

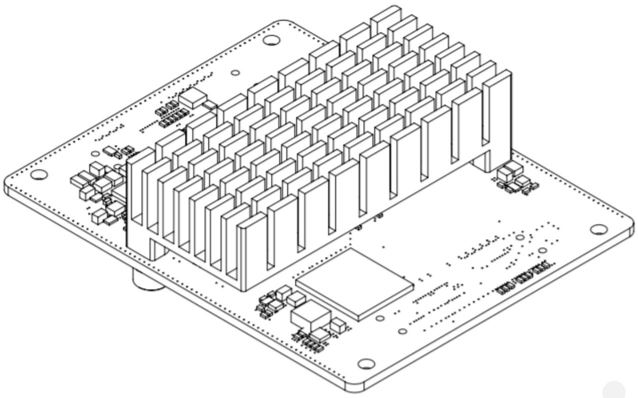

Figure 3-5 X3 thermal solution assembly example

Based on the simplified model in the above thermal design reference example, the thermal simulation of X3 is carried out according to the parameters in Table 3-3.

Table 3-3 Thermal simulation parameters

| Parameter | Description | Value | Unit |
|---|---|---|---|
| $T_A$ | Temperature ambient | 55 | ℃ |
| $T_{JM}$ | Maximum X3 Junction Temperature | 105 | ℃ |
| $P_1$ | Power Consumption of X3 | 3.6 | $W$ |
| $P_2$ | Power Consumption of LPDDR | 0.45 | $W$ |
| $\lambda_{Al}$ | Thermal conductivity of heatsink | 210 | $W$/(m·K) |
| $\lambda_{TIM}$ | Thermal conductivity of TIM | 6 | $W$/(m·K) |
| V | Volume of space | 125000 (50×50×50cm) | $cm^3$ |

**Caution: the X3 power consumption of 3.6W is only a reference number to demonstrate the simulation process. Discuss with Horizon FAE for the detail power consumption number in customer scenario.**

Based on the simulation parameters of table 3-3, the maximum simulated junction temperature of X3 is 97.3℃, which is lower than 105℃(Maximum X3 Junction Temperature in table 3-3). Figure 3-6 and Figure 3-7 show some simulation results: surface temperature cloudy map of X3 and PCB, Space temperature cloudy map(Y axe).

The customer should design a thermal solution based on the thermal design reference examples provided in this section and in combination with the actual operating ambient temperature.

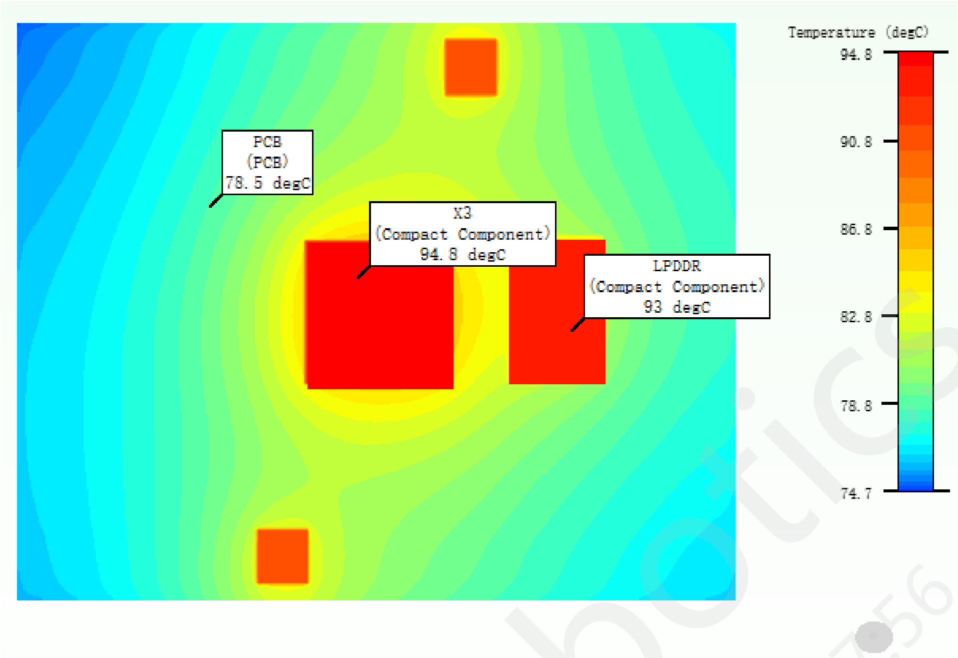


Figure 3-6 Surface temperature cloudy map of X3 and PCB

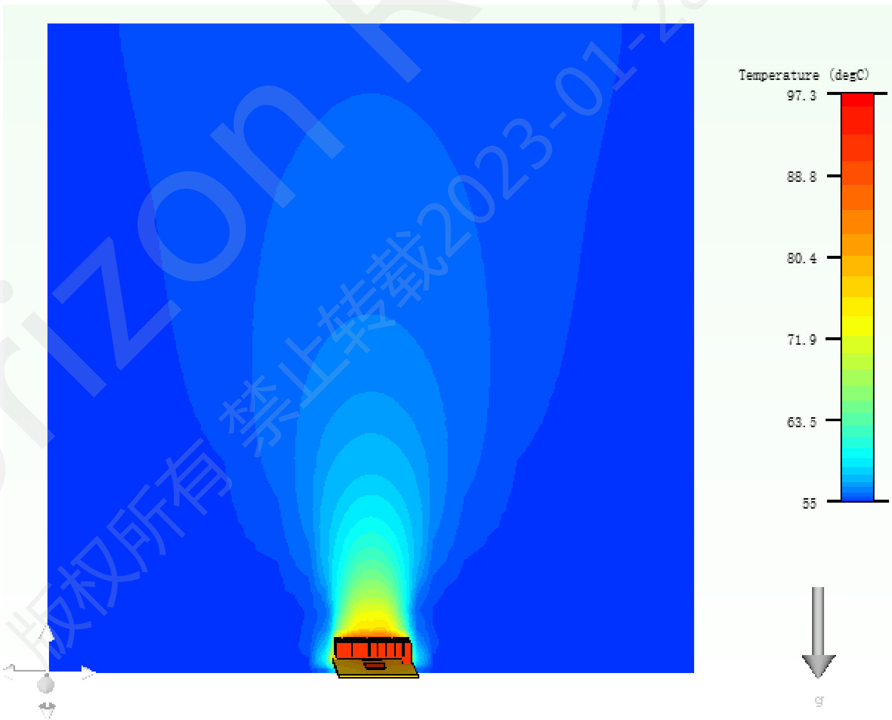


Figure 3-7 Space temperature cloudy map( Y axe)

### 3.3.2 Example of Mechanical Thermal Design

As shown in Figure 3-8, the heat-sink is installed on the top surface of the X3 case, which can continuously transfer the heat on the surface of the X3 case in time by TIM. Between the X3 case and the heat-sink, there is a thermal interface material with high thermal conductivity and high compression performance.

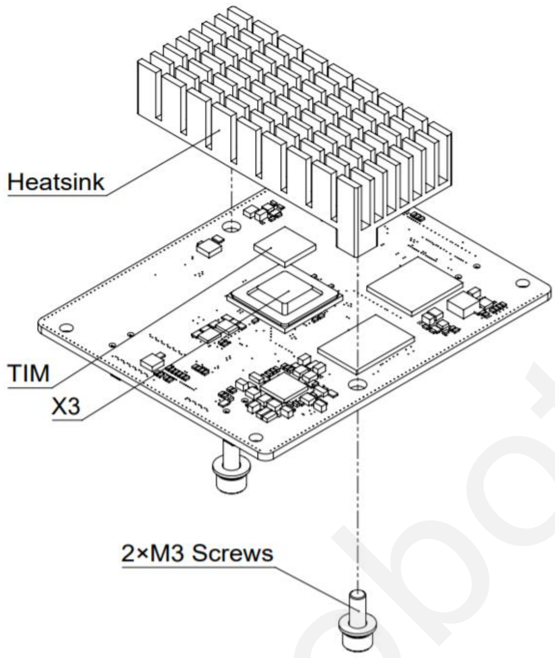


Figure 3-8 X3 thermal solution assembly example - exploded view

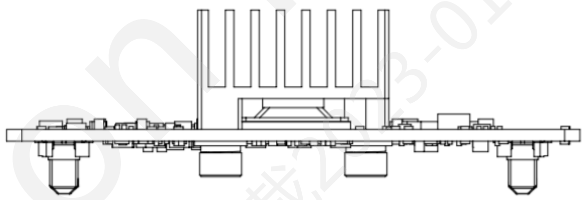

Figure 3-9 X3 thermal solution assembly example- side view

In order to ensure good contact between the heat-sink and X3, the distance between the top surface of X3 and the bottom surface of the heat-sink base should be adjusted according to the height tolerance of X3 package and the thickness deformation of the TIM. The thickness compression ratio of the TIM is generally controlled at 60% ~ 80% after the M3 screws are screwed on.

When the thickness compression ratio of the TIM is controlled at 60%~ 80%, the gap between the X3 case and the heat-sink is fully filled, and the thermal resistance is also significantly reduced to achieve the purpose of heat dissipation. At the same time, the shock and vibration of the X3 system will also be buffered.

## 3.4 X3 Thermal Design Example of IPC

This section provides a typical thermal design reference example with a passive heat-sink for X3, which is installed in IPC, as shown in Figure 3-10.

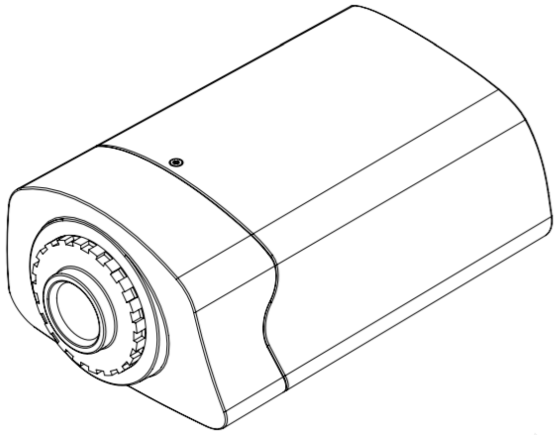

Figure 3-10 X3 thermal solution assembly example in IPC

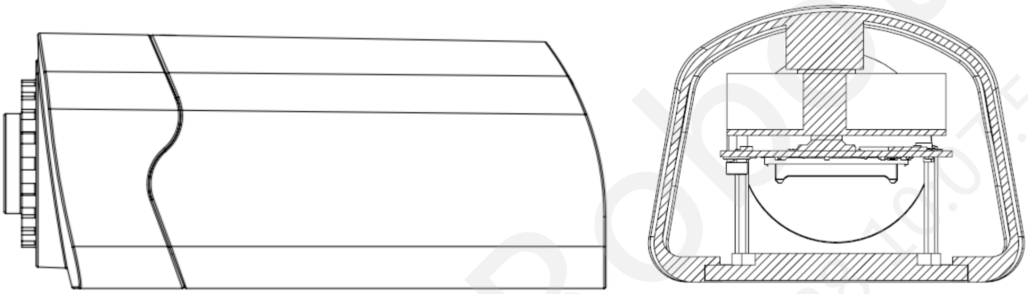

Figure 3-11 X3 thermal solution assembly example in IPC-side view

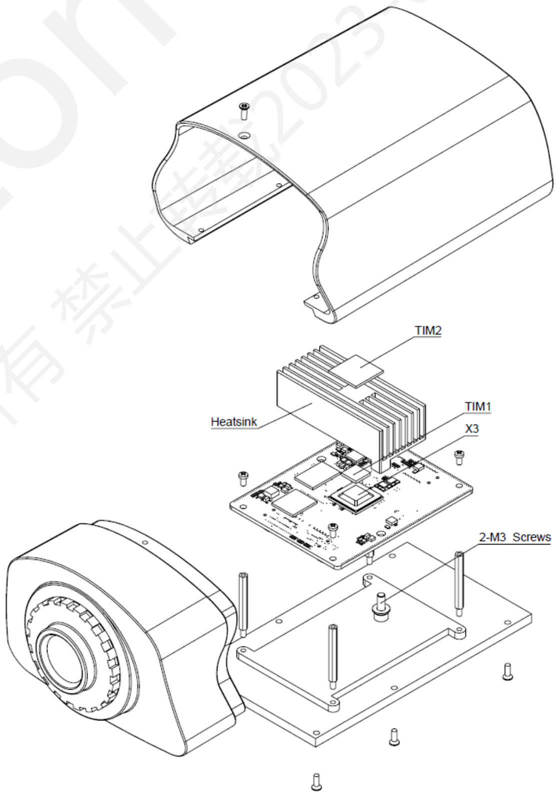

Figure 3-12 X3 thermal solution assembly example in IPC-exploded view

Based on the simplified model in the above thermal design reference example of IPC, the thermal simulation of X3 is carried out according to the parameters in Table 3-4

Table 3-4 Thermal simulation parameters

| Parameter | Description | Value | Unit |
|---|---|---|---|
| $T_A$ | Temperature ambient | 55 | ℃ |
| $T_{JM}$ | Maximum X3 Junction Temperature | 105 | ℃ |
| $P_1$ | Power Consumption of X3 | 3.6 | $W$ |
| $P_2$ | Power Consumption of LPDDR | 0.45 | $W$ |
| $\lambda_{Al}$ | Thermal conductivity of heatsink | 210 | $W/(m·K)$ |
| $\lambda_{TIM}$ | Thermal conductivity of TIM | 6 | $W/(m·K)$ |
| $\lambda_{IPC}$ | Thermal conductivity of IPC shell | 120 | $W/(m·K)$ |
| V | Volume of IPC | ≈600 | $cm^3$ |

**Caution: the X3 power consumption of 3.6W is only a reference number to demonstrate the simulation process. Discuss with Horizon FAE for the detail power consumption number in customer scenario.**

Based on the simulation parameters of table 3-4, the maximum simulated junction temperature of X3 is 93.5℃, which is lower than 105℃(Maximum X3 Junction Temperature in table 3-4). Figure3-13 to Figure 3-16 show some results of simulation. The thermal simulation results indicate that the thermal solution is reasonable which can meet the requirements of X3 heat dissipation.

The customer should design a system thermal solution of IPC based on the thermal design reference examples provided in this section and in combination with the actual operating ambient temperature.

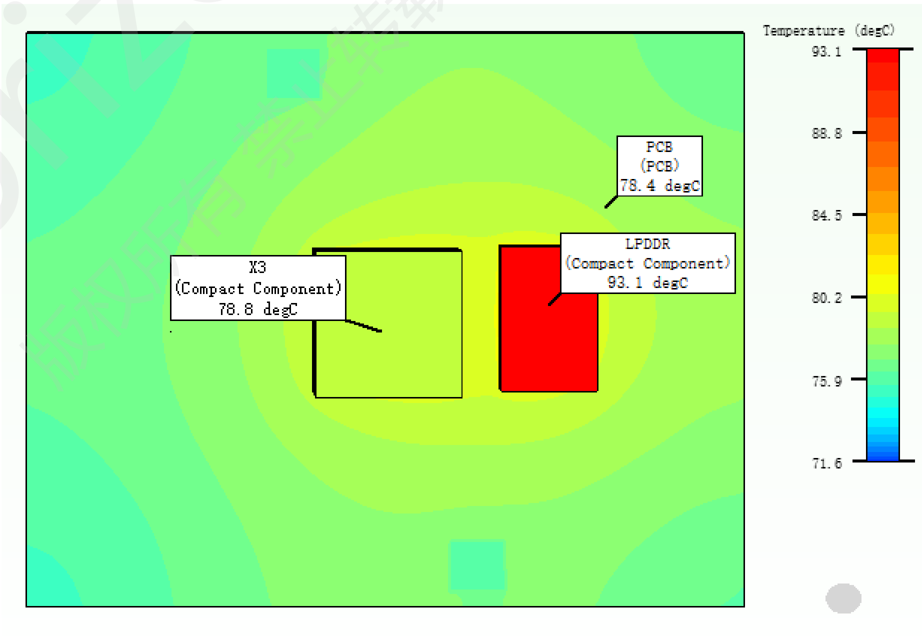

Figure 3-13 Surface temperature cloudy map of X3 and PCB

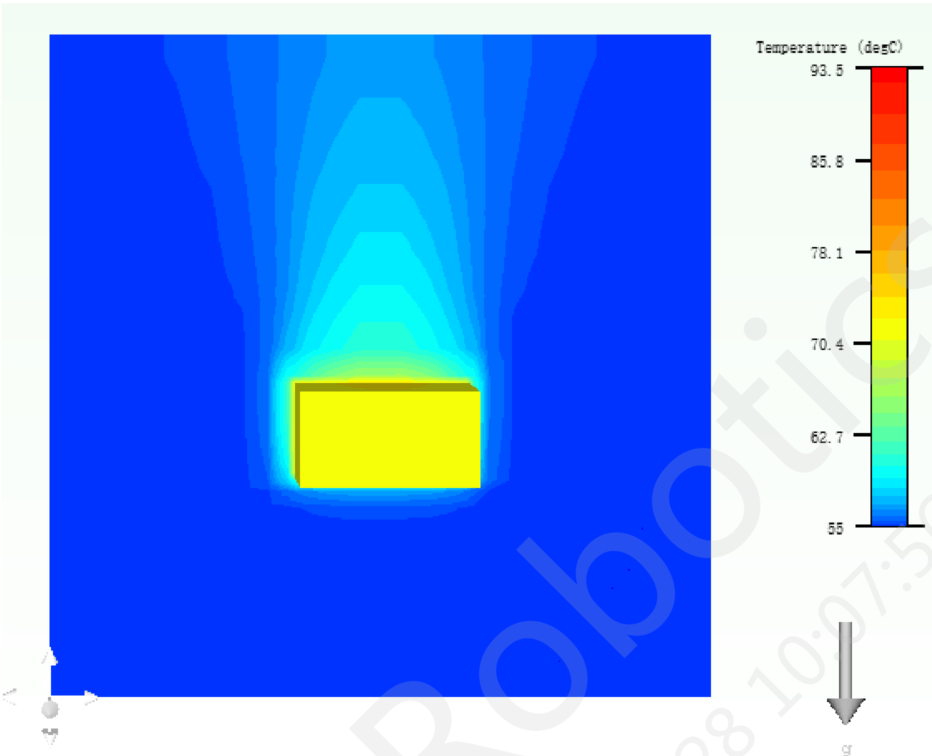


Figure 3-14 Space temperature cloudy map(Y axe)

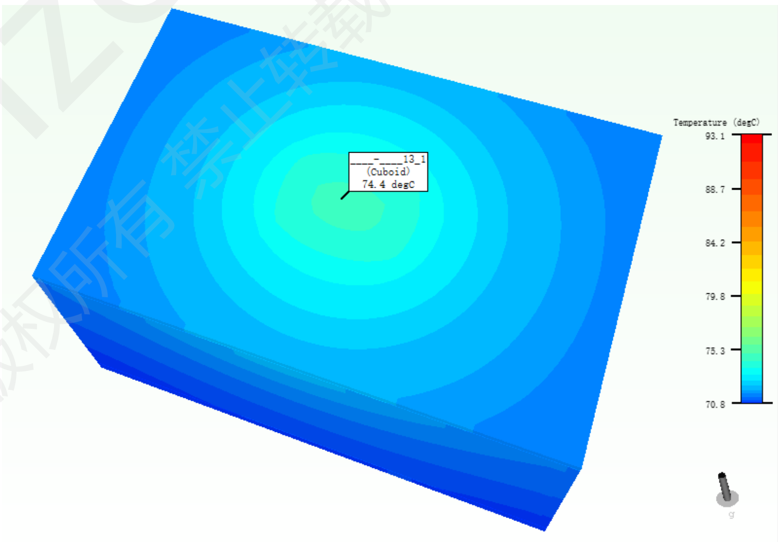

Figure 3-15 Surface temperature cloudy map of top view

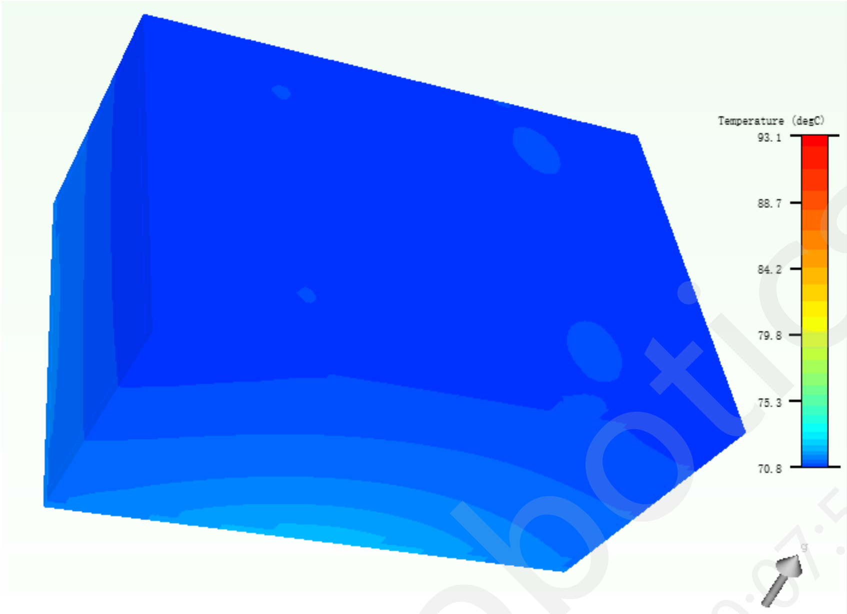


Figure 3-16 Surface temperature cloudy map from bottom to top