Thermal Analysis of Remote Interface Unit Control

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Abstract- "This project presents a comprehensive thermal analysis of a Remote Interface Control Unit (RICU) utilized in embedded systems for remote control and communication. The RICU's thermal behavior is investigated under various operating conditions, including extreme temperatures, humidity, and load variations. Through simulation modeling and experimental validation, this study aims to identify critical hot spots, evaluate heat distribution, and propose design improvements to enhance thermal performance and reliability. The analysis employs advanced simulation tools to model heat transfer mechanisms, thermal interfaces, and material properties. The results provide valuable insights into the RICU's thermal behavior, enabling the development of optimized design solutions to mitigate thermal-related issues. This project contributes to the advancement of embedded systems design, particularly in applications where thermal management is crucial, such as aerospace, automotive, and industrial control systems. The findings and methodologies presented in this study can be applied to improve the reliability, efficiency, and performance of RICUs in various industries."

1 INTRODUCTION

General Overview

The comprehensive thermal analysis of the RICU is designed to thoroughly assess its performance under both typical and extreme operating conditions, meticulously identifying temperature hotspots and potential risks of thermal failure due to excessive heat flux, thermal gradients, and convection limitations. By precisely pinpointing areas of high thermal stress, practical and effective design improvements can be strategically implemented to significantly enhance heat dissipation through optimized thermal conductivity, radiation, and convection, ensuring the RICU's safe, efficient, and reliable operation.

These targeted improvements are crucial for validating the feasibility of RICU deployment in elevated ambient temperatures, where thermal management is particularly challenging due to increased thermal loads and reduced heat transfer coefficients. Ultimately, this rigorous analysis enables the development of a more robust reliable, and high-performance RICU design, capable of withstanding a wide range of environmental conditions while maintaining optimal functionality, safety, and operational efficiency. Furthermore, the insights gained from this analysis can inform future design iterations, enabling the creation of even more advanced and thermally optimized RICU solutions that meet the evolving demands of complex systems and applications.

By leveraging advanced thermal modeling and simulation techniques, such as xt thermo and finite element analysis (FEA), engineers can optimize the RICU's thermal performance, reduce the risk of thermal-related failures, and ensure the long-term reliability and durability of the system, thereby enhancing overall system performance and minimizing downtime.

OBJECTIVE OF THE WORK OF THIS PROJECT

To analyze the thermal performance of the RICU under typical and extreme conditions.

To identify temperature hotspots and potential risks of thermal failure.

To provide practical design improvements for better heat dissipation.

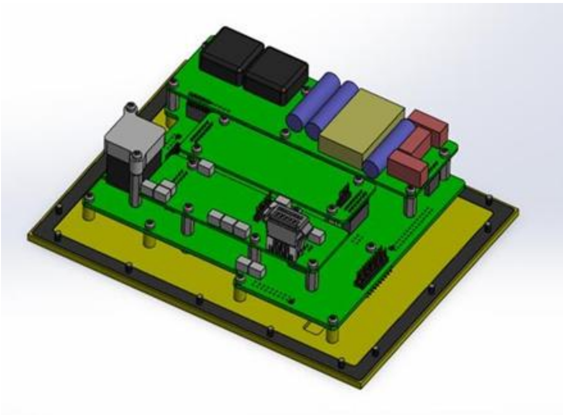
To validate the feasibility of RICU deployment in elevated ambient temperatures

Ensure safety and operational efficiency.

The RICU (Dimensions of unit: 255 (W) X 162.5 (D) X 85.5(H) mm) is an essential embedded system Component used to interface sensors, actuators, and communication modules in remote environments. As electronics become more compact and powerful, thermal management has emerged as a critical aspect in ensuring system stability, longevity, and performance.

Without proper thermal control, the RICU may face overheating issues, leading to degraded performance or component failure. Thus, this study aims to assess and improve the thermal characteristics of the RICU through simulation-based analysis

MAJOR COMPONENTS IN RICU (REMOTE INTERFACE UNIT CONTROLLER):
1. BASE BAND PCB
2. AUDIO CARD
3. VO CODER PCB
4. DC-DC PCB
5. RHS SIDE PCD (RSP INTERFACE CARD
6. LHS SIDE PCB (CRYPTO INTERFACE)
7. FRONT PANEL EXTENSION PCB



LITERATURE SURVEY

Muhammad Awais et al:
This study investigated the thermal resistance of a clothing system consisting of a full-sleeve shirt and trousers made from R/L knitted fabric and woven fabric. Thermal simulation and wear trials were conducted using a thermal manikin, "CHARLIE". The results showed that the simulation values of thermal resistance were higher compared to the wear trial values, likely due to the inability of the simulation to account for air permeability and air exchange. The study highlights the importance of considering air gaps and clothing openings in clothing design, which significantly impact thermal resistance. The findings suggest that simulation software needs to be improved to accurately predict thermal resistance, and further research is needed to understand the complex interactions between clothing, air gaps, and thermal resistance.
The study used a combination of thermal simulation and wear trials to evaluate the thermal resistance of the clothing system. The simulation was conducted using Theseus-FE software, while the wear trials were performed in a climate chamber under controlled conditions. The thermal manikin "CHARLIE" was used to measure the thermal resistance of the clothing system.
The results showed that the simulation values of thermal resistance were higher compared to the wear trial values. This discrepancy was attributed to the inability of the simulation to account for air permeability and air exchange between the microclimate and outer environment. The study highlights the importance of considering air gaps and clothing openings in clothing design, which significantly impact thermal resistance.
The study demonstrates the importance of considering thermal resistance and air gaps in clothing design. The findings suggest that simulation software needs to be improved to accurately predict thermal resistance, and further research is needed to understand the complex interactions between clothing, air gaps, and thermal resistance. The study contributes to the development of high-performance clothing systems that balance functionality, comfort, and sustainability.

Lorenzo Codecasa et al:
semiconductor devices demonstrates exceptional efficiency and accuracy. By utilizing a Dynamic Compact Thermal Model (DCTM) constructed through the Multi-Point Moment Matching (MPMM) algorithm, the tool achieves significant gains in CPU time and memory storage compared to traditional Finite Element Method (FEM) simulations. The tool's ability to reconstruct the space-time distribution of temperature rise and heat flow within the device makes it a valuable asset for device designers. The validation of the tool's efficiency and accuracy through the analysis of a state-of-the-art multifinger GaAs heterojunction transistor (HBT) highlights its potential for widespread adoption in the field of semiconductor device design.
The tool developed for dynamic thermal and electrothermal analysis of integrated semiconductor devices showcases remarkable efficiency and accuracy, leveraging a Dynamic Compact Thermal Model (DCTM) constructed via the Multi-Point Moment Matching (MPMM) algorithm. This approach yields substantial gains in CPU time and memory storage, making it an invaluable asset for device designers. The tool's capability to reconstruct the space-time distribution of temperature rise and heat flow within the device further enhances its utility. Validated through analysis of a state-of-the-

art GaAs heterojunction transistor, this tool holds significant promise for advancing semiconductor device design

Yanan Zhang et al:
This study created a special box (vacuum box) to mimic the temperature conditions inside a specific part of a system called FOA (Final Optics Assembly). The box is designed to simulate the temperature inside the FOA by removing air (creating a vacuum) and controlling the heat. Researchers used computer simulations (with two different models: DO and S2S) to predict the temperature inside the box and compared these predictions to actual temperatures measured in experiments. They found that the box effectively simulates the FOA's temperature conditions and that the S2S model is more accurate and efficient for these simulations.

Key Points about RICU:
1. Vacuum Box Design: The box is designed to mimic the FOA's internal temperature conditions.
2. Simulation Models: Two models (DO and S2S) were used to simulate temperature, with S2S being more accurate and efficient.
3. Air Pressure Impact: The air pressure inside the box affects the temperature, with heat radiation becoming more significant in a vacuum.

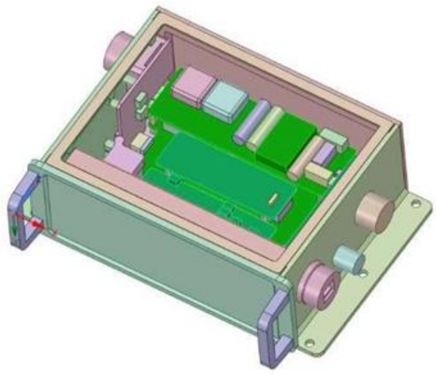
Bin Chen et al:
Our comprehensive analysis of the thermal performance of high-speed motorized spindles demonstrates the efficacy of utilizing a uniform temperature shell comprising carbon fiber and Peltier thermoelectric material. By harnessing the Peltier material's thermoelectric properties and the carbon fiber's thermal management capabilities, we achieve a significant reduction in thermal deformation. The simulation results reveal a substantial decrease in radial temperature gradient, from 47.4°C to 29.6°C, and a notable reduction in component temperatures. Specifically, the spindle shell temperature decreases by 20.45°C, while the stator and cooling jacket temperatures exhibit reductions of 16.9°C and 18.97°C, respectively. These findings underscore the potential of our proposed approach to enhance the thermal performance of high-speed motorized spindles, thereby improving machining accuracy, reliability, and overall system efficiency.

3.OBJECTIVE OF THE WORK

This project focuses on a theoretical analysis of the Remote Interface Unit Controller (RIUC), examining potential problems it may encounter during usage. The analysis will be conducted prior to manufacturing, utilizing thermal analysis tools to assess the performance and consumption of individual components.

4.METHODOLOGY

Modelling and Simulation:
1. A 3D CAD model of the RICU was created, including PCB layout, enclosure, and component placement And generated CFD domain using Sloid works.
2. Mesh generated using floTherm-XT mesh, having count of 1.512 millions of cells.
3. Simulations were conducted using SolidWorks and FloTher XT Simulation



CFD APPROACH

STEP1: Preprocessing
1. import CAD Geometry which is created in solid works
2 Geometry dean -up (removing unwanted features)
3. save the file.
4. open in solver software
5. define materials for all components
6. define boundary condition
7. Mesh generation

STEP 2: Solve
1. Define solver settings
2. Define number of iterations
3. solve

STEP 3: Post Processing
1. scalar contours (temperature plots)
2. collect required data.

MATERIAL & BOUNDARY CONDITIONS DETAILS

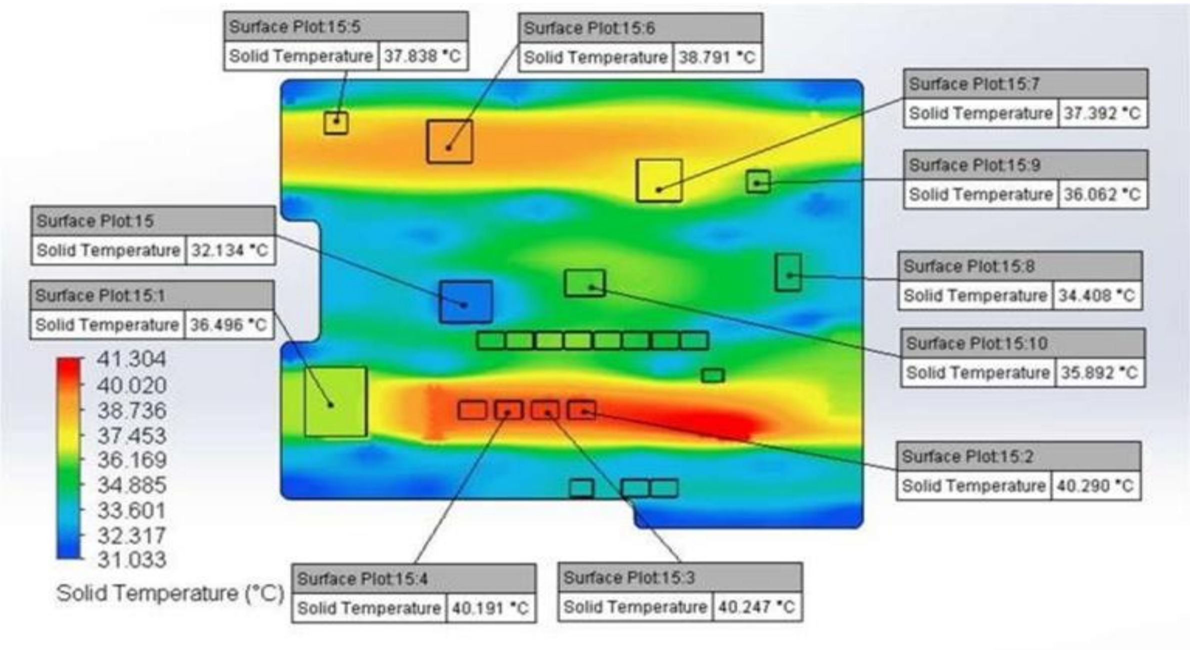
Boundary Conditions:

- Ambient Temperature: 25°C
- Enclosure: limited airflow (passive cooling)
- Power Sources: High-power ICs, voltage regulators, communication modules
- Convection Mode: Natural convection, no forced airflow
- Gravity considered (Y-direction)
- Radiation considered (Emissivity is 0.85)

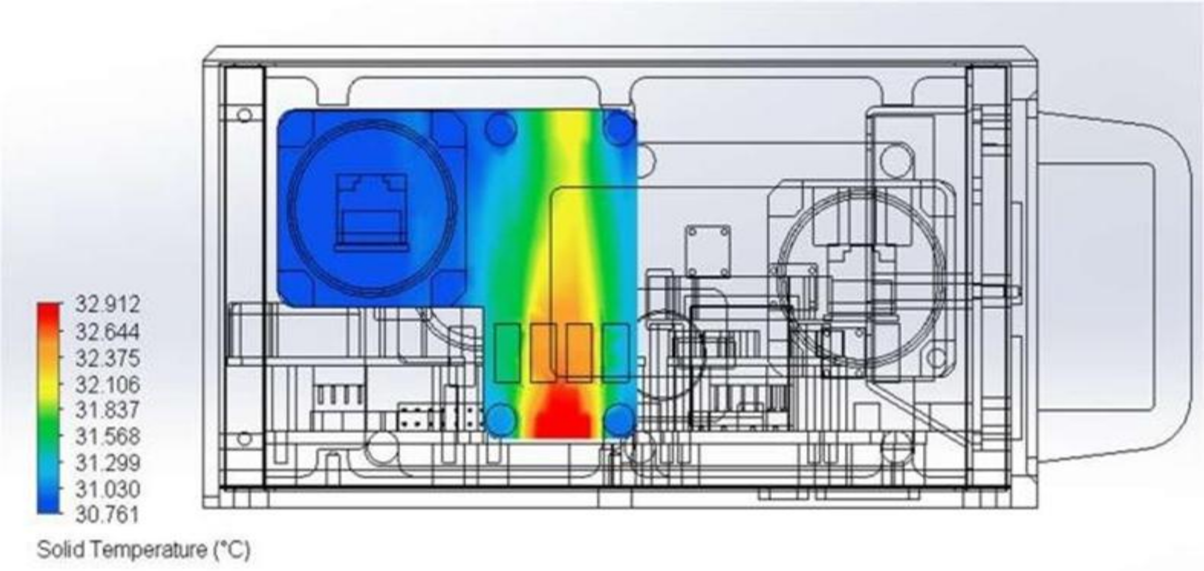
Sl. No	Module name	Section	Input Voltage (V)	Input Current (A)	Input power (W)	Output power (W)	Efficiency (%)	Power Dissipation (W)	
								Section	Module
1	BB&ARX	Baseband & Audio RX card	12	0.1	1.2	NA	NA	1.20	3.70
			5	0.3	1.5	NA	NA	1.50	
			-5	0.2	-1	NA	NA	1.00	
2	ATX	Audio TX card	12	0.1	1.2	NA	NA	1.20	2.20
			5	0.1	0.5	NA	NA	0.50	
			-5	0.1	-0.5	NA	NA	0.50	
3	VPC	Voice Process card	5	0.2	1	NA	NA	1.00	1.00
4	Crypto Interface card	Crypto Interface card	NA						
5	RSP Interface Card	RSP Interface Card	NA						
6	Front Panel Interface	Front Panel Interface	NA						
7	DC-DC Converter	12V DC-DC Converter	28	0.10	2.82	2.40	85	0.42	1.22
		5V DC-DC Converter 28V	28	0.19	5.29	4.50	85	0.79	
8	RIU M-II	Total dissipation Transmission	28	0.29	8.12	NA		8.12	8.12

I	ITEM DESCRIPITION	MATERIAL
01	RIU FRONT PANEL	AL IS: 736-86Gr 24345 WP
02	LHS SIDE PLATE	
03	RHS SIDE PLATE	
04	TOP PLATE FOR RIU	
05	BASE PLATE FOR RIU	
06	RIU REAR PANEL	
07	HANDLES	
08	COVER FOR FRONTPANEL	SS 316
09	SPACER FOR 37 PIN CONNECTOR	AL IS :736-86 Gr 64430 WP
10	SPACER FOR 3 PIN CONNECTOR	
11	SPACER FOR ETH CONNECTOR	
12	HEXAGONAL STUDS	SS 304
13	SUPPORT CUP FOR PICO	NYLON
14	GASKETS	PURE SILVER FILLED SILICON
	PCB DETAILS	MATERIAL
01	BASE BAND PCB	GLASS EPOXY
02	AUDIO CARD	
03	VO CODER PCB	
04	DC-DC PCB	
05	RHS SIDE PCB (RSP INTERFACE CARD)	
06	LHS SIDE PCB (CRYPTO INTERFACE)	
07	FRONT PANEL EXTENSION PCB	

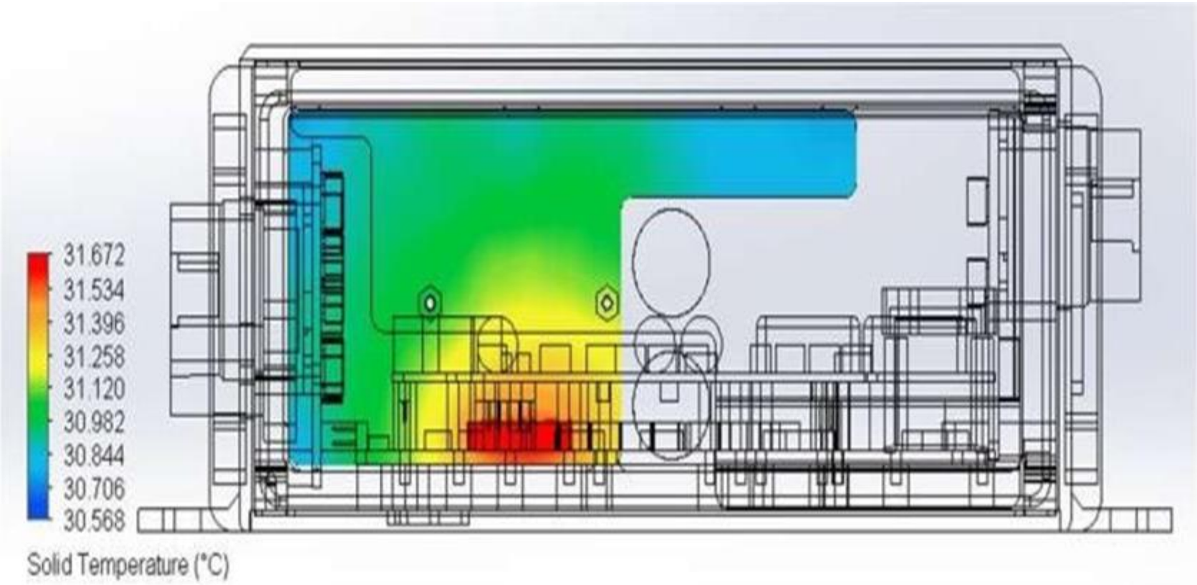
4: RESULTS: TEMPERATURE CONTOURS



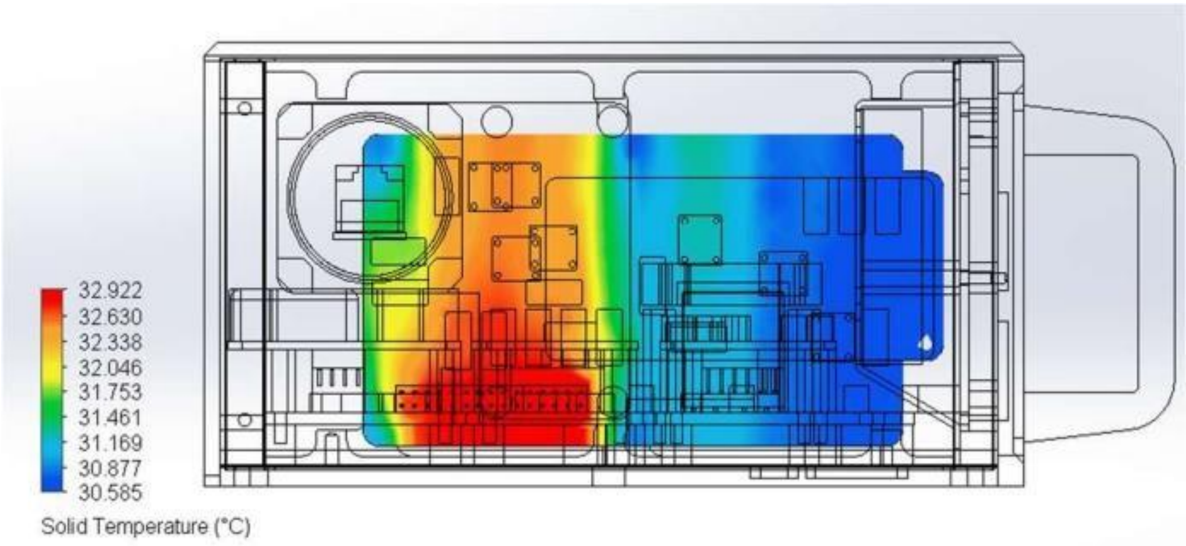
Maximum Base band & Audio RX temperature is 41.3 deg C



Maximum LHS side PCB temperature is 32.9 deg C



Maximum Front panel PCB temperature is 31.7 deg C



Maximum RHS side PCB temperature is 32.9 deg C

If the simulation shows the entire surface area of the RIUC in red, it indicates that the current cooling system is insufficient. To address this, we may need to:

- Implement additional forced cooling systems
- Change the cooling medium to improve heat dissipation

RESULTS AND OBSERVATIONS

[1] Peak temperature: ~47°C at 25°C ambient, indicating marginal thermal margin.
[2] Surface temperature of the enclosure remained within safety limits (<50°C).
[3] Hotspots detected near Audio card and VO Coder PCB.
[4] Inner PCB regions experienced higher temperatures due to restricted airflow.
[5] Temperature gradient showed that most of the heat was conducted through copper planes and vias.

Components	Maximum Temperature(^{0} C)
BASE BAND PCB	41.3
AUDIO CARD	46.1
VO CODER PCB	46.8
DC-DC PCB	38.3
RHS SIDE PCB (RSP INTERFACE CARD)	32.9
LHS SIDE PCB (CRYPTO INTERFACE)	32.9
FRONT PANEL EXTENSION PCB	31.7

5: CONCLUSION

The thermal analysis of the RICU confirms its safe operation in standard ambient conditions, but highlights the need for improvements in thermal design to ensure reliable performance in high-temperature or enclosed environments. By implementing suggested modifications, such as enhancing cooling mechanisms, optimizing component selection, and redesigning the enclosure, the RICU can achieve better thermal efficiency, operational safety, and increased device longevity. These improvements can enable the RICU to operate effectively in a wider range of environments, reducing the risk of overheating and associated damage or failure. By prioritizing thermal design, the RICU can be made more robust and reliable, ultimately leading to improved performance, extended lifespan, and reduced maintenance costs. Furthermore, a well-designed thermal management system can also enhance the overall system reliability, reduce downtime, and increase user satisfaction, making it a critical aspect of the RICU's design and development. Additionally, a robust thermal design can also provide a competitive advantage, as it can enable the RICU to operate in harsh environments, making it suitable for a broader range of applications and industries. By investing in thermal design improvements, the RICU can achieve increased performance, reliability, and longevity, ultimately leading to increased customer satisfaction and loyalty.

REFERNCE

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