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RADAR Computer Unit (RCU)

Introduction

In the recent times, RADAR signal processing has become one of the most demanding embedded computing applications in aerospace and defense systems. A high density of sensor signals received, are translated into the digital domain, and vice-versa for transmission, storage and analysis.

An RCU (RADAR Computer Unit) is one of the main sub-systems of a RADAR, responsible for RADAR operations such as RADAR Control, Pre-Processing, Target Detection and Tracking, and Post-Processing. All these operations need to be completed with real-time constraints laid by the scenario or application.

This Case Study showcases Mistral's expertise in design and development of a high-performance RADAR Computer Unit that addresses the high-speed signal and data processing challenges of modern-day military RADARs.

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The Customer

The customer is a leading Defense Laboratory working in the field of RADAR and RADAR Sub-systems.

The Requirement

The customer approached Mistral to design, build and integrate a Liquid Cooled Hybrid VPX system that functions as a Signal Processor Unit. The Signal Processor Unit forms one of the main sub-systems of a vehicle mounted multi-antenna RADAR that executes all RADAR signal processing algorithms including Pre-Processing, Detection and Post-Processing, based on defined situational parameters.

Mistral conducted a requirement analysis, followed by a feasibility study to identify all the control and computational requirements of the unit to meet the expectations of the customer. The customer was keen on a compact system with 8 card slots to house multiple compute intensive cards to perform signal processing and enable high bandwidth communication for the large amount of data that is to be processed.

Solution Provided

Based on the detailed requirement analysis, Mistral architected a state-of-the-art RADAR Computer Unit. Considering the high functional significance of the Unit and the critical data it had to handle, Mistral paid special attention while designing, sourcing and integrating various components that went into the Unit.

The RCU architecture comprises of multiple Intel i7 Processors along with GPGPU implemented on a standard VPX bus architecture, with high speed Ethernet switch fabric & PCIe connectivity for Communication, Processing and I/O Elements of the system.

As per the customer requirements, the unit is designed to record raw data and has an in-built data generation capability for independent verification of RADAR chain from signal processor. Considering the large amount of data that the unit had to receive and process, we opted for Multi-core GPGPU accelerators with a total of 960 Cores. To handle the amount of heat dissipation, primarily from the graphics cores, we implemented a liquid cooling methodology. The unit is also provided with SATA based Flash Disk with each of these SBCs to record and replay data. The RCU is designed to communicate with other RADAR sub-systems over LAN and external systems through Serial FPDP and 10G Fiber Optic interconnect.

System Highlights

- Rugged, Liquid cooled 8-slot VPX chassis
- High Speed VPX backplane designed to support PCIe and 10G Ethernet communication
- Intel SBC to process input data and enable communication over PCIe with GPGPU
- Intel SBCs enable communication between cards over 10G Ethernet via VPX Backplane
- GPGPU card for RADAR data processing
- sFPDP Card to capture the RADAR data for processing
- 10G Fibre Optic card for communication across subsystems
- Frame grabber card for security & surveillance purpose
- Display Ports implemented on backplane to facilitate High Resolution graphics
- Multiple High Capacity SATA modules for each Intel SBC to ensure data recording & replay
- 1.5 KW PSU to power all electronics within the system.

System Design, Integration and Testing

Hardware Design

Key phases of Hardware design included:

- Custom Rugged Liquid-cooled Enclosure
- High-speed VPX Backplane
- IO Panel Cards and Cable Harness
  - IO Panel for Debug Ports
  - Display Ports, Ethernet, USB & DIO Ports, and Video capture input (frame grabber input)

Software Design

Software design for the system included:

- Remote BIT [Built in Test] Application
- GUI Application/Framework for Acceptance Test Plan

System Design

The system is designed to withstand extreme environmental conditions. The system design process included:

- Structural Analysis using ANSYS Mechanical Enterprise
- Thermal Analysis using ANSYS ICEPAK
- Signal Integrity Analysis of the Backplane using Hyperlynx by Mentor Graphics
- Reliability Analysis
- Power Requirement Analysis
- Compliance to MIL-STD-461F & MIL-STD-810F

System Integration

The System was integrated to meet all quality and regulatory standards for a Radar sub-system. Each component that formed a part of the system underwent thorough testing and validation.

- Intel SBCs & GPGPU tested for seamless operation with Windows & Linux OS
- Tested sFPDP and 10G Fibre optic communication between cards within the system & between sub-systems on both Windows and Linux
- PCIe communication between Intel SBCs & GPGPU for both Windows and Linux OS
- Tested Frame Grabber with online data capture/monitoring in both Windows OS and Linux
- Enabled DP ports for both Windows and Linux OS along with extended DP capability
- EMI/EMC and Environmental Qualification of the system
- Integrated functional tests and Endurance tests.

The Challenges

Thermal Management:

Effective cooling of the high-power Unit [1KW] was one of the key challenges. The 960 Cores GPGPU Cards dissipates a large amount of heat which demanded the need for an effective cooling mechanism. This was addressed right from the design stage, where the heat loads were distributed evenly, and by providing efficient Liquid cooling mechanism.

Qualifying Tests:

Environmental/Mechanical Tests (Vibration, Shock and Bump) for a system of this nature, and in the absence of shock mounts was a design challenge and it was addressed by suitably ruggedizing the PSPU enclosure and thereby allowing hard-mounting of the Unit within the RADAR shelter.

Key Achievements

- Applied an effective cooling mechanism for the high-power system, ensuring, continuous operation with zero downtime and increased reliability (high MTBF)
- Inlet/outlet pipes of coolant system designed to be independent of I/O panel. This enabled rectification of any issues w.r.t cooling to be handled externally, without opening the front panel
- High resolution RADAR display of up to 2K was attained by successfully implementing Display Port technology in the system
- System was realized using two Operating Systems, vis-a-vis Microsoft Windows and Red Hat Enterprise Linux.

Customer Benefits

- A high-end computing, control and display system, in a compact form factor to meet all the platform constraints and processing requirements
- Multiple High-Resolution RADAR Display for a 360^0 surveillance
- Inter system communication readiness for assisting centralized Battle Management
- Situational awareness with line of sight perimeter surveillance
- Mistral technical expertise, with testimonials of field proven, high reliability, and cutting-edge technology.

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