Smart Dual-Hook System V2.0 Prototype

-- Engineering Contribution Statement

Developer: Muyang Ni
Period (Phase 1): May 2025 – October 2025
Organization: Xuzhou iHook Smart Device Co. Ltd.

1. Executive Summary

This document serves as a supplementary technical explanation detailing my engineering contributions to the Phase 1 development of the Smart Dual-Hook System V2.0 Prototype.

The Smart Dual-Hook System (Core IP protected by ZL202323648312.7, ZL202330870916.2, ZL202420531585.9) is a mission-critical device designed for high-altitude industrial safety applications, such as power grid pylon maintenance and construction work. The system innovatively integrates intelligent sensors and wireless communication into a traditional mechanical safety hook, transforming it into a real-time reliability monitoring solution.

The V2.0 prototype aimed for a substantial upgrade in three key areas: performance, power efficiency, and connectivity. During the Phase 1 development, my primary responsibility was the complete platform migration and the establishment of the foundational firmware on the new, highly efficient hardware platform.

My work successfully achieved the following core milestones:

1. **Platform Migration:** Successfully ported the V1.0's legacy ARM architecture to the more efficient RISC-V architecture (ESP32-C3), optimizing the platform for low-power consumption.
2. **Power Optimization:** Implemented system-wide power management strategies that resulted in a power consumption reduction of over 15% for the prototype.
3. **Enhanced Reliability:** Developed the core signal acquisition and processing firmware for the new sensor, achieving a zero failure phenomena rate during initial PC-based evaluation tests (analyzing hundreds of complete collected records). This work laid the groundwork for reducing the target false detection rate to below 0.5%.

The following pages include a formal attestation from the Chief Technology Officer (CTO) of Xuzhou iHook (page 2), followed by detailed technical descriptions of the hardware architecture (page 3-4) and software framework (page 5-6) developed during my tenure.

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Supplemental Background Material on Mr. Muyang Ni's Work

I. Company and Business Overview

Xuzhou iHook Smart Device Co. Ltd. specializes in the research and development and promotion of Industrial Automation and Intelligent Safety Systems. Our core business covers critical sectors including Power (smart operations and maintenance), Construction (high-altitude safety), and Industry (equipment/personnel safety monitoring).

II. Core Product: Smart Safety Hook

The Smart Safety Hook is our company's pioneering safety device. It integrates intelligent sensors with traditional mechanical structure to achieve real-time detection, instant alerting, and data logging of the hook's secure attachment status.

- Technical Advantage: Overcomes the limitations of traditional mechanical hooks. It holds multiple patents and significantly enhances operational safety.
- Application & Promotion: Successfully implemented in Hubei Grid, Hebei Grid, and construction sites in Jiangsu.
- V1.0 Reliability: Achieves a high level of detection reliability, with a failure rate of only a few percent.

III. Mr. Muyang Ni's Contribution to the V2.0 Prototype (May – Oct, 2025)

Mr. Muyang Ni was responsible for the early V2.0 Smart Safety Hook Prototype development, focusing on platform migration, power reduction, and performance upgrades.

Scope of Work	Key Achievements
Platform Upgrade	Ported the V1.0 ARM architecture to the more efficient RISC-V architecture (ESP32-C3) and adapted new sensors, communication chips, and low-power MCUs.
Power Optimization	Successfully reduced the prototype system's power consumption by over 15%.
Prototype Evaluation	Based on signal acquisition and PC-based evaluation, hundreds of complete collected records showed no failure phenomena, demonstrating excellent functional performance.

Project Outlook: The company is proceeding with mass production development based on this prototype. The V2.0 product is expected to launch and enter real-world application in the second half of 2026.

For any further information regarding this project or Mr. Ni Muyang's contribution, please feel free to contact me via email at: zyj@ihook.freeqiye.com

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张雁军 / Zhang Yanjun

Zhang Yanjun
Chief Technology Officer and Director of Smart Devices
Xuzhou iHook Smart Device Co. Ltd.

Hardware Architecture (My Contribution)

2. System Scope and Focus

The complete Smart Dual-Hook System is comprised of three key components: the Operator Hook Unit, the Ground Control Station, and the Remote Monitoring Terminal. This technical documentation, and specifically the subsequent hardware description, focuses exclusively on the internal architecture of the Operator Hook Unit which is the core sensing and communication device worn by the worker.

3. Operator Hook Unit Block Diagram

The overall functional block diagram of the Operator Hook Unit is illustrated in Figure 1. This hardware description primarily details the components that were either newly integrated or managed as part of the Phase 1 platform migration , including the MCU/Bluetooth chip (ESP32-C3) , the Optical Sensors , the IMU Sensor , and the Hall Sensor.
It should be noted that this description does not include details regarding other proprietary or confidential hardware components related to the mechanical structure, charging system, or battery management systems developed by Xuzhou iHook Smart Device Co. Ltd..

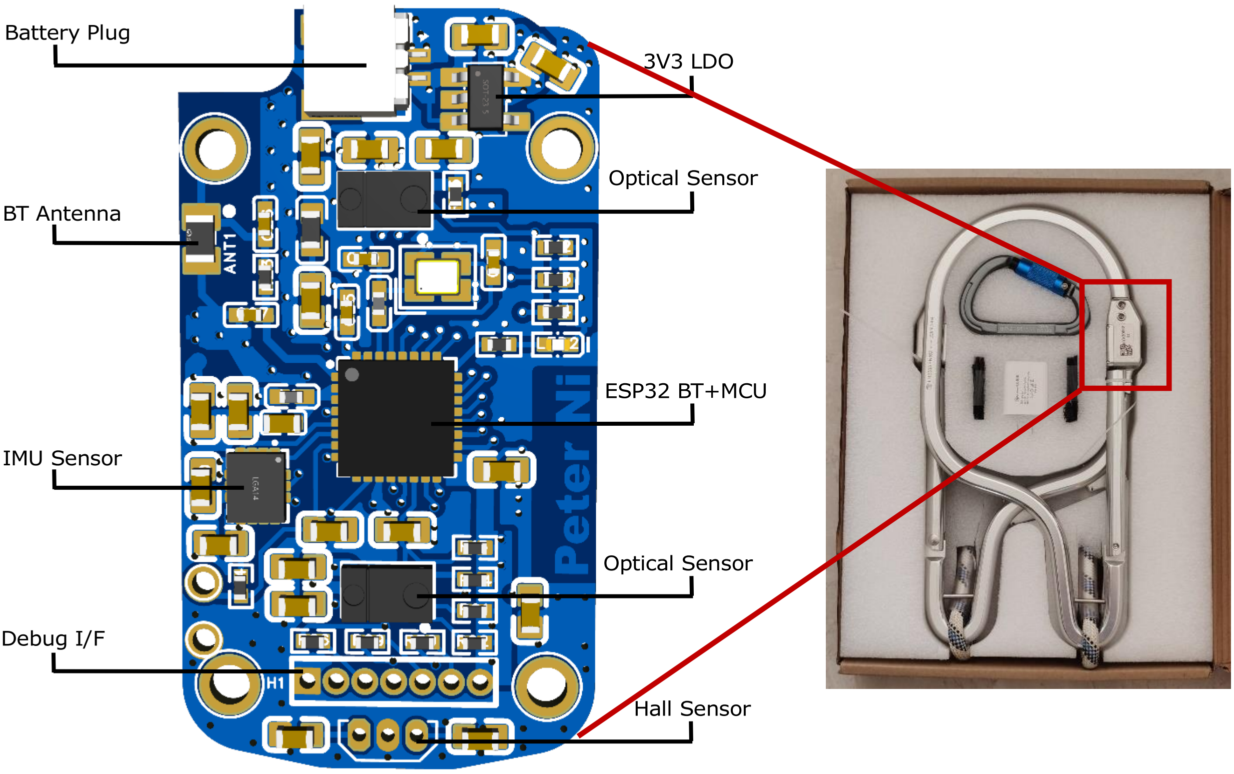

Figure 1: Block Diagram of the Operator Hook Unit

4. Hardware Development and Manufacturing Process

As the primary platform migration engineer, I completed the full hardware development cycle for the V2.0 Operator Hook Unit prototype:

- Schematic and PCB Design: I utilized the lceda-pro tool to finalize the circuit schematic design and the corresponding Printed Circuit Board (PCB) layout.
- Manufacturing Procurement: I was responsible for coordinating the external procurement and manufacturing for the Solder Stencil, PCB fabrication, and PCB assembly/soldering (PCBA).

5. Initial Hardware Verification and Transition to Software

Upon receiving the assembled prototype boards, I performed a critical series of initial hardware verification tests to ensure the platform was ready for firmware development:

- Power System Test: Comprehensive system power testing was conducted to validate the voltage regulators (LDOs) and overall power integrity.
- Boot-up and Communication Check: Basic boot-up functionality and core communication integrity (e.g., initial BLE check) were verified.
- Transition to Firmware: Following successful hardware verification, the project transitioned into the software development phase, focusing on platform migration and foundational firmware establishment.

Software Framework and Key Algorithms (My Contribution)

My core responsibility in Phase 1 was to build a robust, modular, and real-time operating system (RTOS) framework to manage concurrent tasks, high-speed data acquisition, and reliable communication.

6. RTOS-Based Firmware Architecture (FreeRTOS)

The firmware was built upon the FreeRTOS kernel. I implemented a basic level of multi-priority task scheduling where the Sensor Data Acquisition task is the highest priority to ensure timely and precise signal capture.
Phase 1 Implemented Functions:

- System Foundation: Implemented System Boot-Up and Deep Sleep states.
- Data Acquisition: Implemented the core acquisition task for the two Optical Sensors and one Hall Sensor.
- Connectivity: Full implementation of BLE 5.0 base communication and the Over-the-Air (OTA) update protocol.

7. Advanced Signal Processing and Data Validation

My key contribution was ensuring signal quality and integrity from the new V2.0 sensor array, which is critical for the superior performance of the company's proprietary safety algorithm.
A. Noise Reduction and Pre-processing
Operating in harsh industrial environments required effective signal cleaning. I implemented digital filtering routines to address common signal integrity issues:

- Jitter Noise Elimination: Implemented digital sampling and averaging techniques to smooth out high-frequency temporal noise (jitter).
- Spike Noise Mitigation: Developed a simple, robust outlier detection and replacement mechanism (spike/impulse noise filter) to eliminate transient electrical noise spikes.

B. Data Validation
The core safety decision logic is proprietary. My role was to validate that the pre-processed data stream from the new V2.0 platform was compatible with, and improved the performance of, this existing proprietary algorithm.

- Validation Process: I collected hundreds of complete, high-quality sensor records and analyzed them off-device (on a PC platform) by interfacing with the company's algorithm library.
- Validation Result: This process successfully demonstrated the platform’s stability by achieving zero false failure phenomena across all collected records, confirming V2.0's viability for mass production and supporting the goal of reducing the false detection rate to below 0.5%.

8. Remote Device Management (Over-the-Air Updates)

I designed and implemented a highly reliable Over-the-Air (OTA) firmware update protocol over BLE, a critical feature for field maintenance.

A. Data Integrity and Transport Protocol Design

To guarantee reliable binary transfer, I engineered a robust, two-phase protocol:

1. Integrity Check: Each firmware data chunk is appended with a Cyclic Redundancy Check (CRC) checksum. The device verifies the integrity of every packet received.
2. Flow Control: I implemented a Stop-and-Wait acknowledgment (ACK/NACK) mechanism. If corruption is detected, the device signals the sender precisely which chunk was successfully processed, requiring the client to re-transmit only the failed data onward. This prevents unnecessary data resends and ensures resilience to wireless interference.

9. Project Scope and Future Work (Post-Phase 1)

My work established the foundational platform and verified the core sensing concept. The following crucial system features were deferred to subsequent development phases (Phase 2 by other team members):

- Safety-Critical Logic: On-device implementation of the Detached (Insecure) / Alert (Fault) FSM states.
- Algorithm Implementation: Embedded implementation of the core proprietary safety algorithm.
- Power Management Systems: Implementation of the charge and discharge management system firmware.
- Memory Management: Implementation of garbage collection and long-term flash memory management.

Authorization and Responsibility Statement

I, Muyang Ni, confirm that the technical documentation provided in this submission (Pages 1, 3, 4, and 5) has been explicitly **authorized for public disclosure** to university admissions bodies by Xuzhou iHook Smart Device Co. Ltd. This authorization was granted on **November 10, 2025**.

The content accurately details my personal engineering contributions to the Smart Dual-Hook System V2.0 Prototype (Phase 1) and **does not include any confidential company proprietary information**.

I attest to the accuracy of the technical descriptions and take full personal responsibility for this disclosure for the purpose of my academic application.

Date:
Nov 14th 2025 Nov 14, 2025

Signature:
Muyang Ni Muyang Ni