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Design and Development of IoT Network for Motor Monitoring in Industrial and Agricultural Systems

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Abstract - *This paper details the hardware design and architectural implementation of a low-cost, wireless Condition Monitoring System (CMS) for induction motors. addressing the limitations of expensive, wired legacy systems, we propose a distributed dual-microcontroller architecture. The system utilizes an **ESP32** based transmitter node to acquire real-time vibration, temperature, and current data, and transmits it via the **ESP-NOW** protocol to a central receiver. This paper focuses on the sensor integration, signal conditioning circuits, and the robust wireless communication framework required for reliable industrial telemetry*

***Key Words*: Condition Monitoring, Industrial IoT, ESP32, ESP-NOW, Vibration Analysis, Wireless Sensor Network, Predictive Maintenance, Induction Motors.**

1.INTRODUCTION

The operational reliability of induction motors is critical to industrial productivity. Failures in these machines are often preceded by gradual changes in physical parameters such as vibration intensity, surface temperature, and current consumption. While Continuous Condition Monitoring (CCM) is the industry standard for predictive maintenance, commercial solutions are often cost-prohibitive for small-to-medium enterprises (SMEs) and require invasive wiring.

This study presents the design of a standalone Wireless Sensor Node (WSN) capable of retrofitting onto existing motors. The system prioritizes modularity, utilizing off-the-shelf components to reduce costs while maintaining sufficient accuracy for fault detection.

2.SYSTEM ARCHITECTURE

The system adopts a Master-Slave topology to ensure that data acquisition is never interrupted by data processing tasks.

- **The Transmitter Node (On-Field):** Responsible solely for high-speed sensor sampling and data packet transmission.
- **The Receiver Node (Base Station):** Responsible for data aggregation, display, and logging.

This physical separation ensures that the critical sensing timing remains deterministic, unaffected by the latency of user interface operations.

3. HARDWARE IMPLEMENTATION

The core of the transmitter node is the ESP32 microcontroller, selected for its high-performance dual-core architecture and multiple Analog-to-Digital Converter (ADC) channels.

3.1 VIBRATION SENSING (ADXL345)

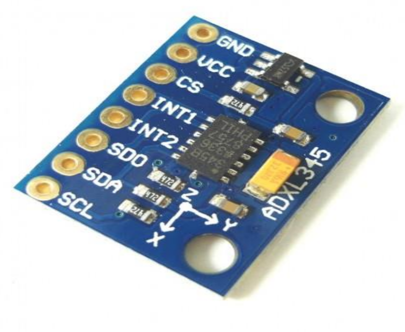

Fig -1: ADXL345

Vibration is the earliest indicator of mechanical faults (e.g., bearing wear, misalignment). We utilize the ADXL345, a MEMS-based 3-axis digital accelerometer. The sensor is configured for a measurement range of ±16g to capture high-intensity transient shocks. The ESP32 calculates the vibration magnitude vector (Vmag) using the Euclidean norm of the three axes (x, y, z).

3.2 THERMAL MONITORING (DS18B20)

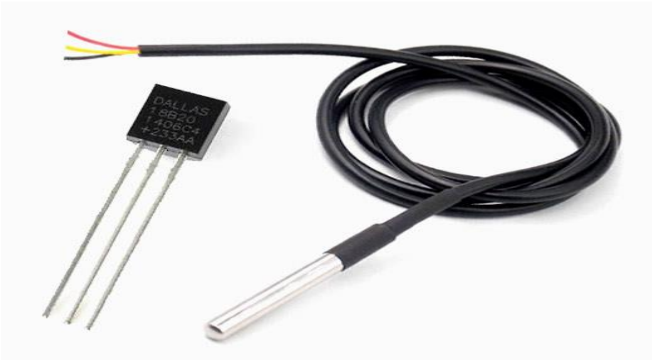

Fig -2: DS18B20 water resistant version

Motor overheating indicates overloading or ventilation failure. The DS18B20 digital thermometer was chosen for its immunity to noise over long cable runs. A 4.7kΩ pull-up resistor is required on the data line to ensure stable signal transitions. A waterproof, stainless-steel probe encapsulation is used to mount the sensor directly against the motor stator.

3.3 CURRENT MONITORING (SCT-013)

To detect electrical faults (e.g., phase imbalance, overloading), the system monitors AC current draw using an SCT-013-030 Non-Invasive Current Transformer (CT). The ESP32 ADC operates at 0-3.3V, but the CT outputs a pure AC signal (swinging positive and negative). A DC Biasing Circuit consisting of a voltage divider (two 10kΩ resistors) and a bypass capacitor (10μF) is implemented to offset the signal to a center point of 1.65V, allowing the microcontroller to read the full wave without clipping

Fig -3: SCT-013 Current Transformer

4. WIRELESS COMMUNICATION PROTOCOL

Reliable data transmission in an electrically noisy motor environment is a significant challenge. Standard WiFi (HTTP/MQTT) introduces high overhead and latency. To address this, the project utilizes **ESP-NOW**, a connectionless communication protocol developed by Espressif.

Fig -4: Wireless network web

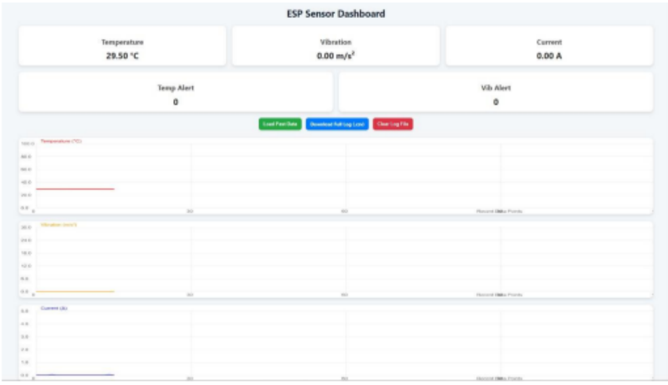

Fig -5: Website Dashboard

ESP-NOW uses low-level IEEE 802.11 Action Vendor Frames. It bypasses the traditional network stack (OSI layers), allowing devices to talk directly via MAC address pairing. Data is serialized into a rigid C++ struct format containing the sensor values. This protocol reduces transmission latency to under 10 milliseconds and significantly lowers power consumption compared to standard WiFi, making it ideal for the battery-constrained transmitter node.

5. CONCLUSION

The hardware design presented successfully integrates multi-parameter sensing into a compact, wireless unit. The use of the ESP32 alongside the ESP-NOW protocol provides a robust data link that functions independently of external router infrastructure. This architecture lays the foundation for a reliable predictive maintenance system, capable of operating in offline industrial environments. Future work will focus on the development of the receiver base station, including the real-time web dashboard, data logging algorithms, and user interface design.

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