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# A Multisensor Baseline and Abstention Architecture for Low Voltage Rotating Machine Condition Assessment

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**Abstract:** Condition assessment of small rotating machines is often demonstrated with a single sensor and a fixed threshold, although operating point, mounting and environment can alter measured signals. This paper presents NEXUS PRIME V1 as a documented design for a low voltage, ESP32 based bench instrument using device specific baselines, validity checks and corroborating channels. Its proposed rule set reports NORMAL when required measurements agree with calibrated healthy bands, ABNORMAL only for a coherent pattern in at least two independent condition channels, and INCONCLUSIVE when evidence is missing or contradictory. The design specifies vibration, current, voltage, temperature and RPM sensing, with distance serving primarily as a setup validity check; it also specifies local indication and a web dashboard. The supplied 71 page blueprint reports a design audit, including 18 distinct GPIO assignments and an estimated INR 1,894 parts budget. Hardware, firmware, diagnostic accuracy and reliability have not yet been measured. The contribution is an inspectable architecture and a preregisterable validation protocol, not an experimentally demonstrated diagnostic improvement.

**Keywords:** Rotating machinery; condition assessment; sensor fusion; device baseline; reject option; ESP32; prototype design.

## I. INTRODUCTION

Condition monitoring acquires machine signals to inform present state and maintenance decisions. The distinction between diagnosis and prognosis is established in machinery research [2]. Healthy only data and sparse fault examples also motivate novelty detection methods [3]. These approaches do not by themselves guarantee that a low cost instrument will detect faults reliably: its sensor placement, electrical limits, reference condition and decision policy still require verification.

NEXUS PRIME V1 is specified for one calibrated small DC rotating device supplied from a 5 V rail, within a 12 V DC safety ceiling [1]. The present paper studies the architecture and its testable design claims. It asks whether a baseline referenced, multisensor system can express uncertainty explicitly under missing or conflicting evidence. This is a design question here; comparative performance is an experimental question left open.

## II. RELATED WORK AND RESEARCH GAP

Jardine, Lin and Banjevic survey machinery diagnostics and prognostics and emphasize data acquisition, processing and decision making [2]. Pimentel and colleagues review novelty detection when normal examples are more accessible than abnormal examples [3]. Chow formalized the error and rejection tradeoff for statistical recognition [4]. NEXUS PRIME borrows the practical ideas of healthy reference and abstention, but it does not implement Chow's optimal probabilistic rule or claim a new fusion algorithm.

The bounded engineering contribution is to specify these concerns together for an inexpensive, one device bench setup: a documented acquisition chain, channel validity and quorum, per-device reference, physically interpretable corroboration, and an explicit third state. The literature establishes the value of monitoring and reject options; it does not establish the performance of this specific design. No systematic market or literature survey supports a world first claim.

## III. OBJECTIVES AND SOURCE METHOD

The objectives are to define a reproducible sensor and power architecture, prevent a single isolated excursion from becoming an abnormal verdict, expose the reasons behind each decision, and design a validation protocol that can quantify false alarms, misses and abstentions.

The primary source is the author supplied NEXUS PRIME V1 Engineering Build Blueprint, version 1.0, hardware revision A, software revision 0.1, dated 30 August 2026 [1]. It explicitly labels the project documentation stage and the physical build as pending. This paper evaluates what the design specifies and identifies unresolved measurements; it reports no experimental observation.

#### IV. PROPOSED SYSTEM ARCHITECTURE

The proposed ESP32 DevKit V1 hosts acquisition, feature processing, decision logic, local indications and a local network interface [1]. An MPU6050 measures acceleration for vibration features; an INA219 monitors motor current and supply bus voltage; a DS18B20 measures body temperature; an optical pulse sensor supplies RPM; and an HC-SR04 supplies distance or presence context. Distance and bus voltage are useful for setup validity and operating context, so they should not be counted automatically as independent fault corroboration. An SSD1306 OLED, RGB LED and buzzer indicate status. A DRV8833 drives the motor, and two servos position the sensing head. Component selections and the INA219 and DRV8833 roles are consistent with vendor documentation [5], [6].

A timed scheduler is specified to collect fast and slow channels into timestamped frames. The proposed pipeline then checks availability and plausible ranges, filters samples, extracts summaries such as vibration RMS and mean current, compares them with a healthy reference, and evaluates cross-channel consistency. Sensor-specific rates, buffer sizes, thresholds, tolerance bands and latency limits remain to be chosen from bench data. A local web server is specified to show readings and verdicts; the architecture is intended to work without cloud access [1].

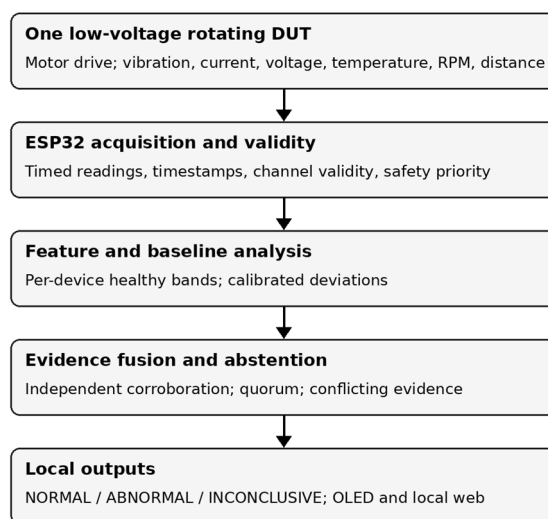


Fig. 1. Proposed logical acquisition and decision path [1].

| Subsystem  | Specified role                                                                              |
|------------|---------------------------------------------------------------------------------------------|
| Signals    | Vibration, current, bus voltage, temperature and RPM; distance checks geometry or presence. |
| Controller | ESP32 schedules sampling, validity, features and decision state.                            |
| Actuation  | DRV8833 drives one DC motor; two servos aim a sensor head.                                  |
| Output     | OLED, LEDs, buzzer and local web dashboard; scan history in volatile memory.                |

TABLE I. V1 design modules and their roles.

## V. CONDITION ASSESSMENT METHOD

### A. Device baseline and features

The blueprint proposes multiple healthy runs for the one reference device, with per-channel centers and allowed bands tied to a calibration identifier and timestamp [1]. Features may include acceleration RMS, average current, RPM stability and temperature trend. The bands must be derived under defined speed, load, mounting and ambient conditions; otherwise an operating point shift could be misread as damage. No numeric feature definitions, sampling schedule, calibrated band or confidence floor appears in the blueprint, so the paper cannot present an executable classifier or reproducible operating point.

### B. Three state decision policy

The specified policy can be restated without inventing parameters: let  $V$  denote whether the required channels and a relevant baseline are valid. If  $V$  is false, return INCONCLUSIVE. If the calibrated healthy bands and a normal confidence floor are satisfied without conflicting evidence, return NORMAL. Return ABNORMAL only if at least two independent condition channels exceed their calibrated limits, their direction forms a physically coherent pattern and the abnormal confidence floor is met. Return INCONCLUSIVE in every other case. Here “confidence” is a design score to be defined and calibrated; it is not a measured probability [1].

For example, a vibration rise alone is specified to produce INCONCLUSIVE, while increased vibration and current, falling RPM and a rising temperature trend may form an abnormal overload signature. Two apparently abnormal channels with no coherent pattern also remain inconclusive. Chow’s reject option gives theoretical context for abstention [4], but the  $V1$  policy requires its own empirical error versus abstention analysis.

### C. Data and interface handling

One active device profile and its baseline are planned for volatile ESP32 memory; the local scan history is also in memory. A restart therefore requires recapturing the healthy reference. The blueprint lists GET endpoints for the dashboard, live values and verdict, and POST endpoints for baseline capture, scan and stop [1]. These are planned interface contracts, not observed running services. It does not specify an authenticated web API. The network should be isolated during prototype testing, and remote exposure requires access control and a separate security review.

## VI. ELECTRICAL DESIGN AND SAFETY CONSTRAINTS

The design uses a regulated 5 V, 3 A external supply, fused input, reverse polarity protection and common ground. The motor and servos draw from the 5 V rail, while the ESP32 and 3.3 V devices use the board regulator in the proposed arrangement. The HC-SR04 5 V Echo is divided before GPIO35, and the buzzer is switched through a transistor. The frozen pin allocation uses 18 distinct GPIO assignments and reserves GPIO34/35 for inputs. Espressif confirms that GPIO34–39 are input only [7]. The exact purchased module and the 3.3 V regulator’s thermal and current margin still require measurement.

The blueprint gives an indicative INR 1,894 bill of materials under an INR 2,000 ceiling, not supplier quotations [1]. Its power analysis is conditional: the motor stall allowance and two stalled servos cannot be assumed to fit simultaneously within 3 A. Firmware must prevent peak motor and servo loads coinciding, and a bench current trace must verify the rail under startup, normal scan and fault conditions. The STOP control in the frozen wiring table is a GPIO input; its effect depends on firmware execution. It must not be described as an independent hardware disconnect. A physical series cutoff or driver disable circuit would be needed to make that stronger safety claim.

## VII. VERIFICATION AND EXPERIMENTAL PROTOCOL

The document audit is limited to design consistency. The blueprint reports 18 assigned pins with zero duplicates, distinct I2C addresses 0x68, 0x40 and 0x3C, and a budget total of INR 1,894 (INR 1,249 electronics + INR 465 mechanical + INR 180 supply) [1]. These checks cannot verify continuity, electrical margin, sensor function or diagnostic accuracy. No firmware listing, measured waveforms, test log or assembled hardware was provided with the blueprint.

A staged validation should begin with rail measurements before inserting the controller; individual I2C, 1-Wire, optical pulse and ultrasonic checks; sensor calibration against appropriate reference instruments; motor and servo current measurement; and timeout, brownout and STOP tests. Controlled abnormal conditions should be mild and reversible, including a small rotor imbalance, a fixture imposed load change and a sensor dropout. Temperature and load effects must be monitored so testing stays within the selected device and driver limits [1].

A fair decision study requires repeated healthy and controlled abnormal runs at prespecified speed, load, mounting and ambient settings. Split runs by session or acquisition day, keeping correlated windows from one run in a single partition. Choose baseline bands, fusion rules and floors on training and validation partitions only; freeze all settings before a held out test. Record the number of NORMAL, ABNORMAL and INCONCLUSIVE decisions separately for healthy and abnormal conditions. Report false alarm and miss rates with denominators, rejection rate, coverage, conditional accuracy among accepted scans, and confidence intervals. Compare with a calibrated single channel baseline under the same test runs. No such dataset or results currently exist.

| Check                | Evidence and current status                                                            |
|----------------------|----------------------------------------------------------------------------------------|
| Design audit         | 18 GPIO and distinct I2C addresses reported in blueprint; physical wiring not checked. |
| Power and STOP       | 5 V and 3.3 V rail, current peaks and stop response require bench measurements.        |
| Decision performance | No run counts, confusion matrix, rejection rate or accuracy measured.                  |
| Reliability          | Repeatability, sensor dropout, thermal drift and restart behavior planned, untested.   |

TABLE II. Available evidence and verification still required.

## VIII. DISCUSSION AND LIMITATIONS

The design makes a scientifically testable proposition: independent corroboration and abstention may reduce unjustified positive verdicts from isolated sensor excursions, at the possible cost of more inconclusive scans. The tradeoff is not known until thresholds and operating conditions are fixed and a comparator is tested. One instrument measures current and voltage, and environmental or supply changes may influence several signals together; those channels should not be treated as statistically independent simply because they are separate values. The HC-SR04 presence signal is not itself proof of motor health.

The project is currently a design, so the paper cannot claim fault detection accuracy, a working prototype, web response time or robustness. The baseline is volatile, only one reference DUT is in scope, and the design does not classify root causes or predict failure time. The proposed unauthenticated local API can issue actions, so an isolated trusted network is a constraint, not a security certification. The estimate for component costs and power demand is uncertain until purchase and bench measurement. The specified software STOP is not independent of firmware.

## IX. FUTURE WORK

The immediate next stage is assembly, calibration, firmware implementation and preregistered validation of the three state rule. If component measurements reveal insufficient regulator or motor supply headroom, revise the power path before diagnostic testing. A hardware cutoff and authenticated local controls should be designed before broader demonstrations. Persistent device profiles, additional sensing and optional machine learning are later extensions only if measured evidence shows benefit over the rule baseline [1].

## X. CONCLUSION

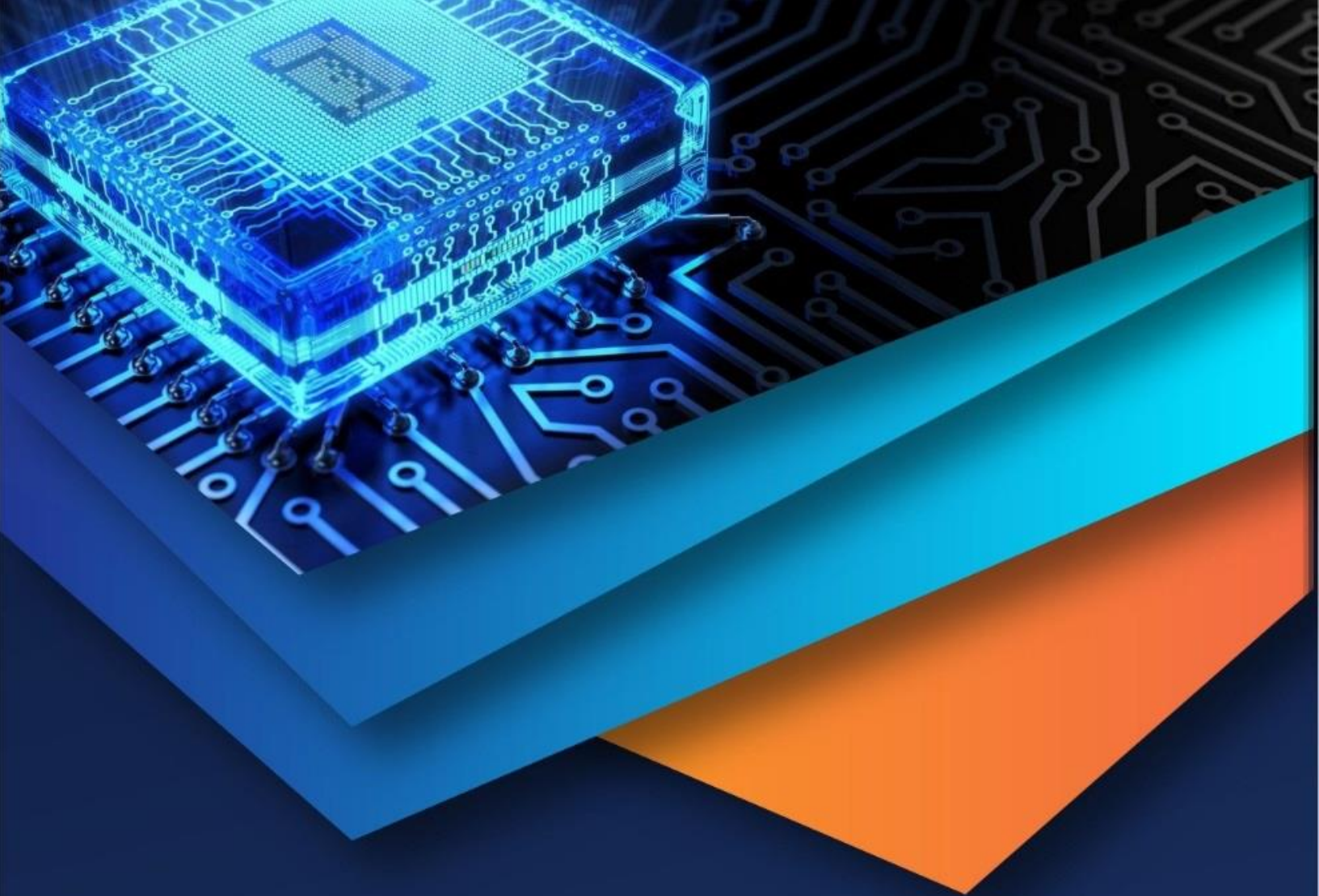
NEXUS PRIME V1 specifies a low voltage rotating machine condition assessment architecture using device baselines, multiple physical signals and an INCONCLUSIVE state for weak or conflicting evidence. Its present contribution is a precise, testable design and evaluation plan. Design consistency checks are available, while the physical build, safety response, accuracy and reliability remain unverified. Publication as an experimental fault diagnosis result requires the planned hardware and held out validation data.

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