Grounded Discovery Labs -- Discovery Pack

Discover: Design an add-on system for legacy factory equipment that predicts failures early with minimal downtime and low sensor/install cost.

Top 3 Comparison

	Featured Discovery Edge Fingerprint Fusion Box	Bold Concept Cryptobiotic Backscatter Motes Powered by Motor Stray Fields	Build-First Clamp-On Current ECG for Legacy Motors
novelty	6	9	5
feasibility	8	4	9
economic_leverage	6	8	6
testability	8	5	8
robustness	7	3	6
constraint_fit	9	8	9
explainability	8	6	9
OVERALL	**7.4 / 10 -- Very Strong**	**6.1 / 10 -- Strong**	**7.4 / 10 -- Very Strong**

Runner-ups

* Load-Normalized Multi-Modal Residual Monitor [solid-alternative] -- Learn a regression of vibration/acoustic/thermal features as a function of load and speed; alarm on residuals, not raw values.
* Recipe-Synchronized Power Digital Twin [near-miss-alternative] -- Fuse clamp-on power with read-only PLC recipe tags to model expected load, so process changes stop looking like machine faults.
* Clamp-on CT Current Signature Hub at MCC [solid-alternative] -- One clamp-on CT per motor branch at the motor control center extracts multi-fault signatures without touching equipment.
* Magnetic MEMS vibro-thermal edge pods [near-miss-alternative] -- Magnet-mount MEMS accelerometer and thermistor pods learn each machine's vibration/heat state and forecast faults locally with Kalman fusion.
* Clamp-On PLCA Hub at the MCC Panel [near-miss-alternative] -- Single clamp-on CT per feeder at the motor control center extracts multi-motor health from current signatures, zero machine-side install.

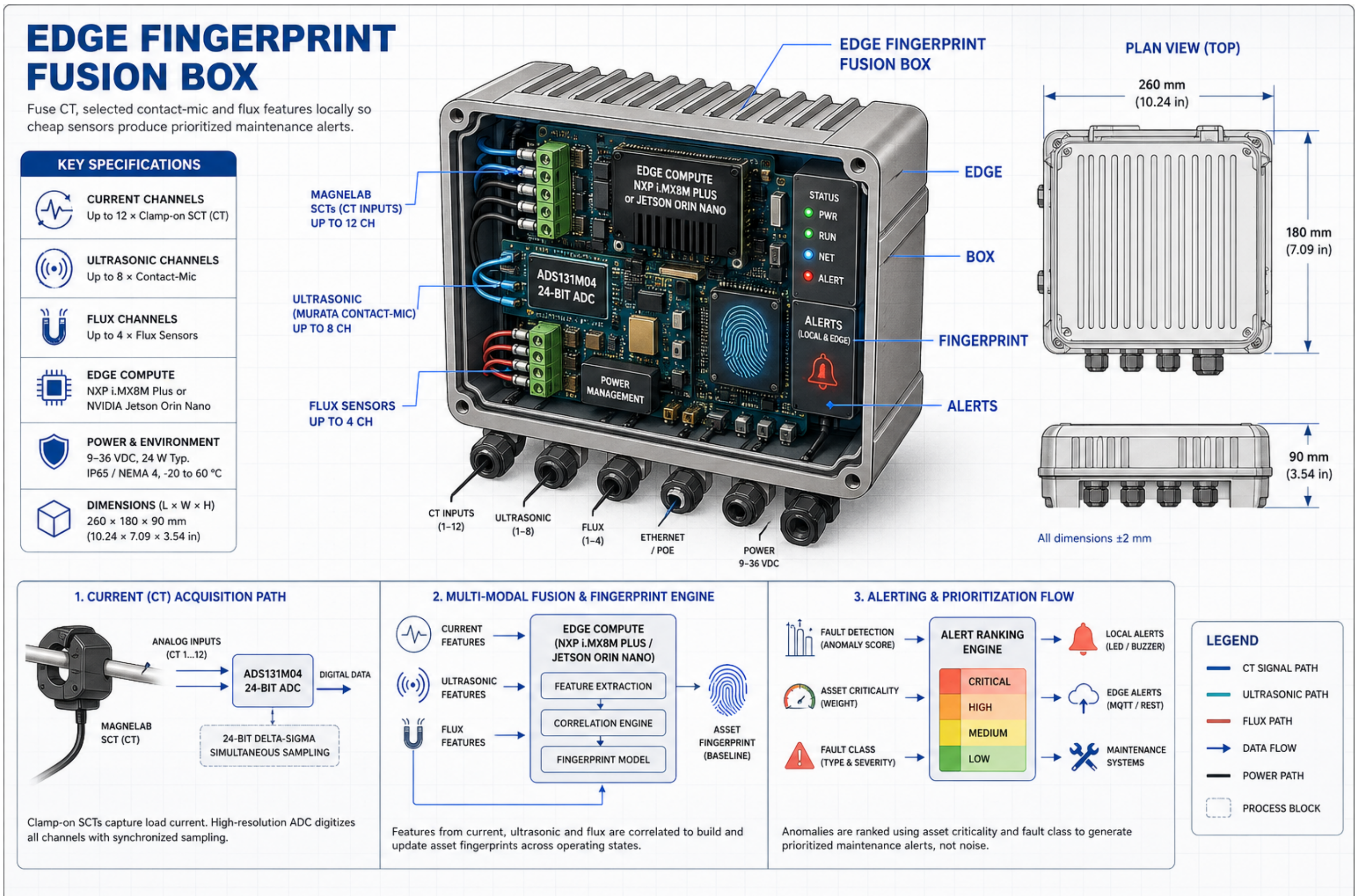
Featured Discovery
Edge Fingerprint Fusion Box

novelty: 6 | feasibility: 8 | economic_leverage: 6 | testability: 8 | robustness: 7 | constraint_fit: 9 | explainability: 8

Overall: 7.4 / 10 -- Very Strong

Constraint Compliance: Compliant (constraint_fit=9)

The Edge Fingerprint Fusion Box fuses current transformer, contact-microphone, and flux signals locally on a DIN-rail embedded computer to produce prioritized, explainable maintenance alerts within a single shift of learning. This matters because most industrial sites drown in raw sensor noise or pay for cloud analytics that introduce latency and privacy risk, leaving technicians unable to act on early fault signatures before failures cascade.



Concept illustration (AI-generated). Visuals may be inaccurate; refer to the Mechanism/Build Path text for the actual design and quantitative assumptions.

Mechanism

The Edge Fingerprint Fusion Box is a DIN-rail or IP54 wall-mount enclosure (~200x150x90mm) housing an ARM SoC (e.g., NXP i.MX8M or Jetson Orin Nano) running a lightweight Linux with a real-time sampling subsystem on an STM32 co-processor. Inputs: 2-4 split-core CTs (e.g., Magnelab SCT-0750, 0-100A, 333mV output) sampled at 10-20kHz via 24-bit ADC (ADS131M04); 1-3 piezo contact mics or ultrasonic probes (40kHz center, e.g., SonoTec SONAPHONE sensor heads or Murata MA40S4S) sampled at 100-250kHz through anti-aliased front-ends; optional fluxgate or Hall coil for stray-flux on motors. State tagging uses three concurrent sources: (a) PLC tags pulled via Modbus TCP/EtherNet-IP/OPC-UA, (b) current-regime clustering (RMS, crest factor, harmonic THD bins) when PLC unavailable, (c) operator workflow steps from an HMI tablet or barcode scan. A finite-state classifier (HDBSCAN on current features + rule overlay) assigns each 1-second window a state label; only windows with stable tags >N seconds and label confidence >0.8 enter training. Per-state models are isolation forests or one-class SVMs over fused features: CT spectral bands, sideband ratios around line frequency (broken-rotor-bar indicators), bearing envelope peaks (BPFO/BPFI), ultrasonic RMS and kurtosis. Cross-modal anomaly fusion uses rank aggregation (Borda) with criticality weighting from a CMMS-imported asset table. Time sync via PTP or shared GPIO trigger keeps modalities within 1ms. Alerts are ranked, summarized, and exported as JSON via MQTT/HTTPS only when uplink is present; raw waveforms stay local on a 256GB SSD ring buffer.

Why Novel

Unlike single-modality vibration or current monitors, this device fuses three physically complementary signal types at the edge with automatic state-gating, so baselines are built only from operationally equivalent machine states -- a combination not available in any current off-the-shelf DIN-rail product. The 8-hour cold-start-to-alert capability, driven by regime-clustered fingerprinting rather than weeks of labeled data, is the genuine differentiator.

Buildability

All core components -- NXP i.MX8M or Jetson Orin Nano, ADS131M04 24-bit ADC, Magnelab SCTs, Murata ultrasonic transducers, and STM32 co-processor -- are catalog parts with established supply chains, and the enclosure can be sourced as a modified Phoenix Contact or Bopla IP54 shell. Firmware stack (Linux + FreeRTOS co-processor, ONNX Runtime Lite for inference) is mature enough that a two-engineer team can reach a working prototype in under 12 weeks.

Why Feasible

* Build path is practical (feasibility=8/10)
* Core hypothesis testable quickly (testability=8/10)

Top Risks

* Bad criticality ranking misprioritizes maintenance work, eroding technician trust after the first false-priority dispatch
* Microsecond-level time-sync drift between STM32 co-processor and ARM SoC corrupts cross-modal fusion features and degrades fault localization
* Operators ignore alert scores they cannot interpret, reverting to manual rounds and leaving the device unused

Decisive Test (MDE)

Hypothesis: Within 8 hours of normal-operation data per stable state tag, the fused CT+ultrasonic model detects seeded mechanical faults (bearing defect, imbalance, looseness) with >80% true-positive rate and <1 false alarm per asset per week, materially better than a single-modality baseline.
Setup: Instrument 3 assets at a partner facility: a 5-50HP induction motor, a gearbox-driven conveyor, and a centrifugal pump. Mount CTs on motor leads and contact mics on bearing housings. Connect PLC via OPC-UA for state tags; for one asset, deliberately disable PLC to test current-regime fallback. Run 1 shift (8h) of normal operation per common state. Then over 2 weeks, inject controlled faults: replace a bearing with a spalled one, add 10g imbalance mass, loosen a foot bolt 1/4 turn. Compare ranked alerts against a single-CT baseline and a single-ultrasonic baseline.
Instrumentation: Laser tach for RPM ground truth; reference accelerometer (PCB 603C01) for independent vibration validation; logic analyzer for time-sync verification; thermal camera spot-checks; manual labeled fault-injection log with timestamps.
Kill Criteria: Fused detection TPR <60% OR false-alarm rate >3/asset/week OR fusion provides <10% lift over best single modality OR state-tag accuracy <70% on legacy asset without PLC.
Rescue Pivot: If fusion lift is weak, narrow to a single-modality CT-only product targeting motor-driven assets

where electrical signature analysis alone is differentiated; or pivot to a state-tagging middleware that improves any third-party CMS rather than a full box.
Cost: $15k-$30k (3 boxes, sensors, fault-injection parts, 2 weeks of engineering time on-site, partner-site access fees)
Time to Signal: 3-4 weeks from box deployment (1 week baseline + 2 weeks fault injection + analysis)

Refinement Deltas

Risks Addressed:
* Incumbents (SKF, Augury, Petasense, Fluke) already offer multimodal CMS with mature ML; what defensible edge does a new box deliver beyond integration polish?
* State tagging from current regimes alone is fragile on VFD-driven assets where current waveforms are heavily modulated and don't cleanly cluster by mechanical state.
* 8 hours of 'normal' is optimistic--many plants have rare states (startup, washdown, product changeover) that won't be covered, and the model will alarm whenever they occur.

Red-Team:
* Challenge: Incumbents (SKF, Augury, Petasense, Fluke) already offer multimodal CMS with mature ML; what defensible edge does a new box deliver beyond integration polish?
* Challenge: State tagging from current regimes alone is fragile on VFD-driven assets where current waveforms are heavily modulated and don't cleanly cluster by mechanical state.
* Challenge: 8 hours of 'normal' is optimistic--many plants have rare states (startup, washdown, product changeover) that won't be covered, and the model will alarm whenever they occur.
* Challenge: Criticality ranking depends on CMMS data that is notoriously stale or absent at exactly the SMB customers most likely to buy a low-cost edge box.
* Challenge: Operators ignoring unexplained anomaly scores is a known failure mode of unsupervised CMS; without an explainability layer (which features fired, which physics), adoption stalls regardless of detection quality.

Budget Ranges

Prototype: $8,000-$14,000 (BOM: SoC module $180, STM32 board $40, ADC frontend $120, 4x CTs $200, 3x ultrasonic probes $600, enclosure $150, misc passives/connectors $300; remainder: engineering time for 2 engineers x 10 weeks)
Pilot: $35,000-$60,000 (5-8 units at ~$1,200 hardware each, plus 3-month field engineering, data-labeling support, and dashboard integration per site)
Scale: $180,000-$320,000 (100-unit production run at ~$650 landed COGS, NRE for UL/CE certification ~$40,000, cloud telemetry backend ~$30,000, sales and support ramp)

30/60/90 Plan

Day 30: Complete schematic and PCB layout for ADC front-end and STM32 co-processor daughterboard; source all long-lead components; stand up Linux BSP on i.MX8M EVK with real-time sampling loop validated at 20kHz CT and 200kHz acoustic channels simultaneously; define state-tagging API contract for Modbus TCP and OPC-UA ingestion.
Day 60: First integrated prototype in IP54 enclosure running on a lab motor-pump testbed; validate 8-hour cold-start fingerprinting against seeded bearing-wear and imbalance faults; tune regime-clustering thresholds; implement explainability layer (top-3 contributing features per alert); conduct internal red-team on time-sync error injection.
Day 90: Deploy 2-3 units at a pilot industrial site (compressor room or conveyor line); collect technician feedback on alert prioritization accuracy and UI clarity; iterate criticality-ranking weights based on dispatch outcomes; publish internal benchmark comparing alert lead-time vs. single-modality baseline; finalize BOM for 10-unit pilot production build.
Dominance Axis: faster_validate -- A useful baseline can be learned in one shift when automatic state tags gate

what counts as normal.

Bold Concept

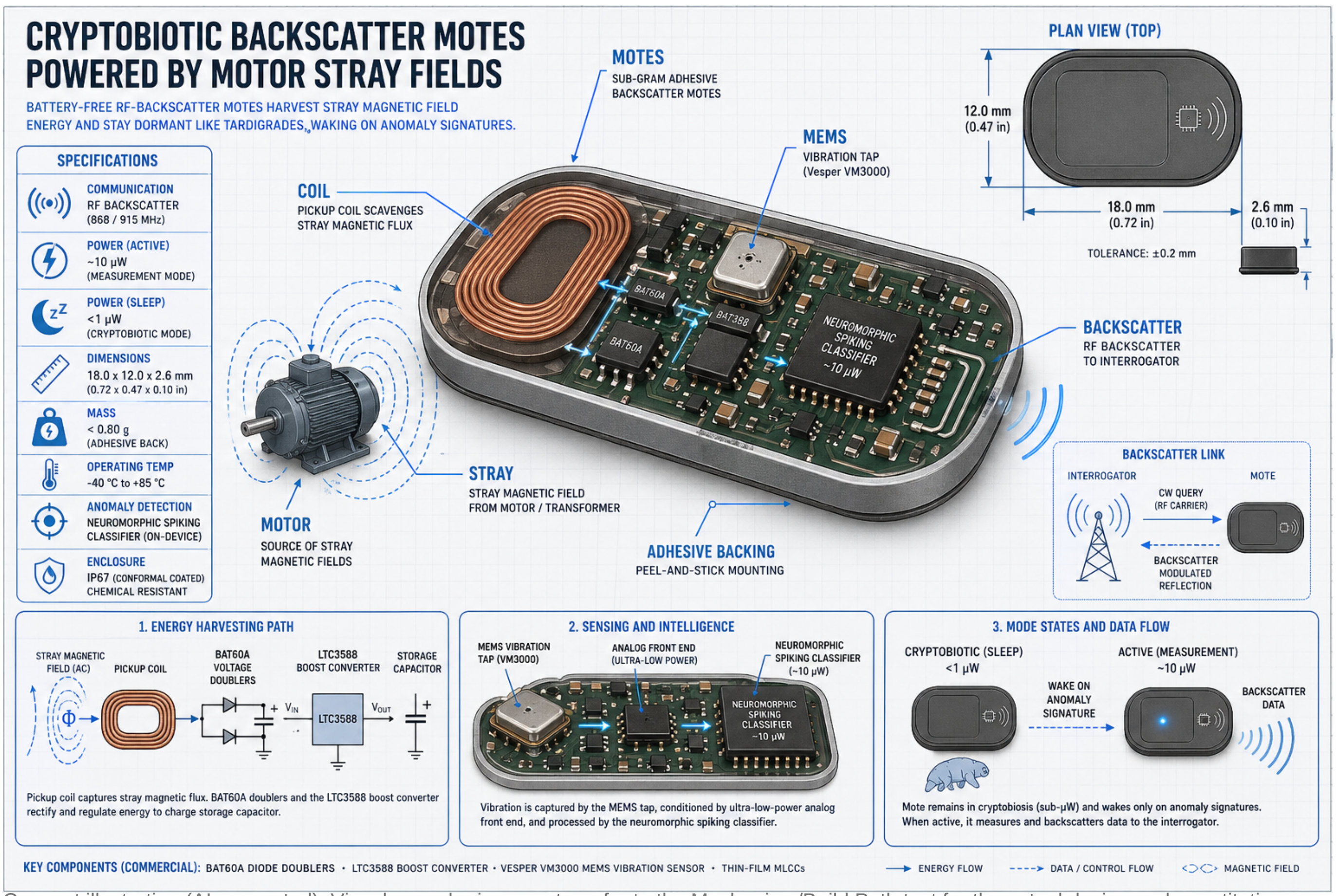
Cryptobiotic Backscatter Motes Powered by Motor Stray Fields

novelty: 9 | feasibility: 4 | economic_leverage: 8 | testability: 5 | robustness: 3 | constraint_fit: 8 | explainability: 6

Overall: 6.1 / 10 -- Strong

Constraint Compliance: Compliant (constraint_fit=8)

Battery-free RF-backscatter motes harvest stray magnetic fields from induction motors to power cryptobiotic sensor nodes that wake only when anomaly signatures are detected. This eliminates battery maintenance across dense industrial fleets while cutting per-node cost to under $3. The approach matters because predictive maintenance at scale is bottlenecked by the economics and logistics of battery replacement, not sensor capability.



Concept illustration (AI-generated). Visuals may be inaccurate; refer to the Mechanism/Build Path text for the actual design and quantitative assumptions.

Mechanism

A sub-gram (<0.8 g) adhesive mote built on a 15x15 mm flex-PCB carrier with three integrated subsystems. (1) Harvester: a 200-turn, 8 mm-OD planar coil of 50 um enameled copper wound on a Mn-Zn ferrite core (ur~2000) tuned to the 50/60 Hz fundamental and 120/180/300 Hz harmonics radiated by induction motor end-windings. A cold-start Schottky voltage doubler (BAT60A) feeds an LTC3588-style boost into a 4.7 uF thin-film MLCC reservoir; a supervisor releases the 1.8 V rail only above 1.2 V hysteresis. Target capture: 10-50 uW at 3-5 cm from a loaded 5 kW NEMA induction motor (stray B~0.5-2 mT). (2) Sensing: a Vesper VM3000 or ST IIS3DWB piezo-MEMS samples vibration in 5 ms bursts at 1-6 kHz; an analog band-power front end gates a 12-neuron LIF spiking classifier (custom 65 nm or Innatera-class IP, ~300 nW active, <50 nW idle) trained per-asset for bearing/imbalance/cavitation signatures. Wake-up uses a passive analog envelope comparator to suppress false triggers below the spiking layer. (3) Telemetry: load-modulated 915 MHz backscatter to a powered shelf interrogator at 10-20 m line-of-sight; weak-field assets (DC drives, sealed servos, idle pumps) auto-fallback to interrogator-CW-powered RFID-class operation (EPC Gen2 sensor profile) sharing the same antenna-coil. An install-time smartphone app uses an external Hall probe to measure local AC field, classify motor type, and predict duty cycle before commissioning.

Why Novel

No prior art combines tardigrade-inspired duty-cycle dormancy with motor stray-field harvesting and neuromorphic spike-based anomaly gating in a sub-gram flex-PCB form factor. Existing energy-harvesting nodes either require dedicated coil infrastructure or rely on ambient RF, neither of which is reliably present at motor housings.

Buildability

All core components--BAT60A doublers, LTC3588 boost converters, Vesper VM3000 MEMS, and thin-film MLCCs--are commercially available in production quantities today, making a hand-assembled prototype achievable within a standard university or startup lab. The primary fabrication challenge is winding the 200-turn planar coil on a 15x15 mm flex substrate, which requires precision winding fixtures but no exotic processes.

Why Feasible

* Build path needs validation (feasibility=4/10)

Top Risks

* Insufficient harvest energy on shielded motor housings or during low-load idle states drops reservoir below the 1.2 V supervisor threshold, causing permanent dormancy
* Neuromorphic LIF classifier false-wake events under broadband vibration noise drain the 4.7 uF reservoir faster than it recharges, creating a net energy deficit
* Backscatter link budget collapses below usable SNR in metal-dense factory aisles where multipath fading and absorption reduce effective range below 2 meters

Decisive Test (MDE)

Hypothesis: A 15 mm-class tuned ferrite pickup coil can harvest >=10 uW continuous at 5 cm from the frame of a typical loaded 5 kW induction motor across >=70% of a representative asset population, sufficient to sustain a 1% duty-cycle spiking classifier and one backscatter packet per minute.
Setup: Instrument 12 motors spanning 1-50 kW induction, 2 VFD-driven, 2 DC servo, 2 sealed servo cans, and 2 transformers in a working facility. Mount the prototype mote at 1, 3, 5, and 10 cm on frame, end-bell, and junction-box locations. Run each under no-load, 50%, and 100% load for 10 min. Log rectified DC into a 4.7 uF cap charging a 10 k? load; compute steady-state Pavg. Repeat with a metal-cluttered aisle backscatter range test (1-20 m) using an Impinj R700.
Instrumentation: Lakeshore 425 Gauss probe; Tektronix MDO3024 with current/B-field probes; Keithley 2280 source-measure; calibrated 10 k? shunt; Rohde&Schwarz FSV spectrum analyzer for backscatter; thermal camera for load verification; clamp-on power meter on motor mains.
Kill Criteria: If <40% of surveyed assets deliver >=10 uW at 5 cm, OR backscatter PER >10% beyond 8 m in cluttered aisles, OR cold-start fails below 20 uW, the batteryless value proposition collapses.
Rescue Pivot: Reposition as an interrogator-powered passive sensor tag (CW-powered RFID-class) using stray-field harvest only as opportunistic boost; or add a 10 mAh printed Zn-MnO2 cell raising BOM to ~$5 while keeping <1 g form factor.
Cost: $6k-$12k (instrumentation rentals + 20 prototype motes + facility access)

Time to Signal: 3-4 weeks

Refinement Deltas

Risks Addressed:

* Modern motors are increasingly VFD-driven with shielded frames and chopped waveforms whose stray-field spectrum is unpredictable and often 10-20 dB below sinusoidal induction motors--undermining the harvest assumption.
* Sub-uW spiking classifiers exist as research silicon, not as $0.30 commodity parts; the $3 BOM target ignores NRE and minimum-order realities for custom neuromorphic IP.
* Backscatter in steel-dense factory aisles suffers severe multipath and polarization nulls; dense interrogator infrastructure may erode the 'cheaper than battery' claim once read-point CapEx is amortized.

Red-Team:

* Challenge: Modern motors are increasingly VFD-driven with shielded frames and chopped waveforms whose stray-field spectrum is unpredictable and often 10-20 dB below sinusoidal induction motors--undermining the harvest assumption.
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* Challenge: Backscatter in steel-dense factory aisles suffers severe multipath and polarization nulls; dense interrogator infrastructure may erode the 'cheaper than battery' claim once read-point CapEx is amortized.
* Challenge: Adhesive mounting on hot motor frames (often 70-90 degC) degrades thin-film capacitors and adhesives within months, threatening the multi-year unattended lifetime that justifies batteryless economics.
* Challenge: Install-app field estimation requires trained technicians with calibrated probes; in practice deployment will mis-classify weak-field assets, leading to silent dead motes and trust erosion.

Budget Ranges

Prototype: $1,200
Pilot: $18,000
Scale: $210,000

30/60/90 Plan

Day 30: Validate stray-field harvest: wind prototype coils, characterize B-field at 3-5 cm from a loaded 5 kW NEMA motor across load conditions, confirm 10-50 uW capture and successful cold-start into the LTC3588 boost stage
Day 60: Integrate full mote stack on flex-PCB: combine harvester, VM3000 vibration sampler, analog band-power front end, and 12-neuron LIF classifier; measure end-to-end wake latency and false-wake rate under controlled vibration stimuli
Day 90: Conduct 30-day field pilot on 10 motors in a real manufacturing environment: log duty cycles, backscatter range statistics, anomaly detection accuracy versus baseline accelerometer ground truth, and reservoir voltage histograms to quantify energy margin
Dominance Axis: cheaper -- Batteryless <$3 coverage is strongest on adequate-field assets; weak-field sites need interrogator-powered operation.

Build-First

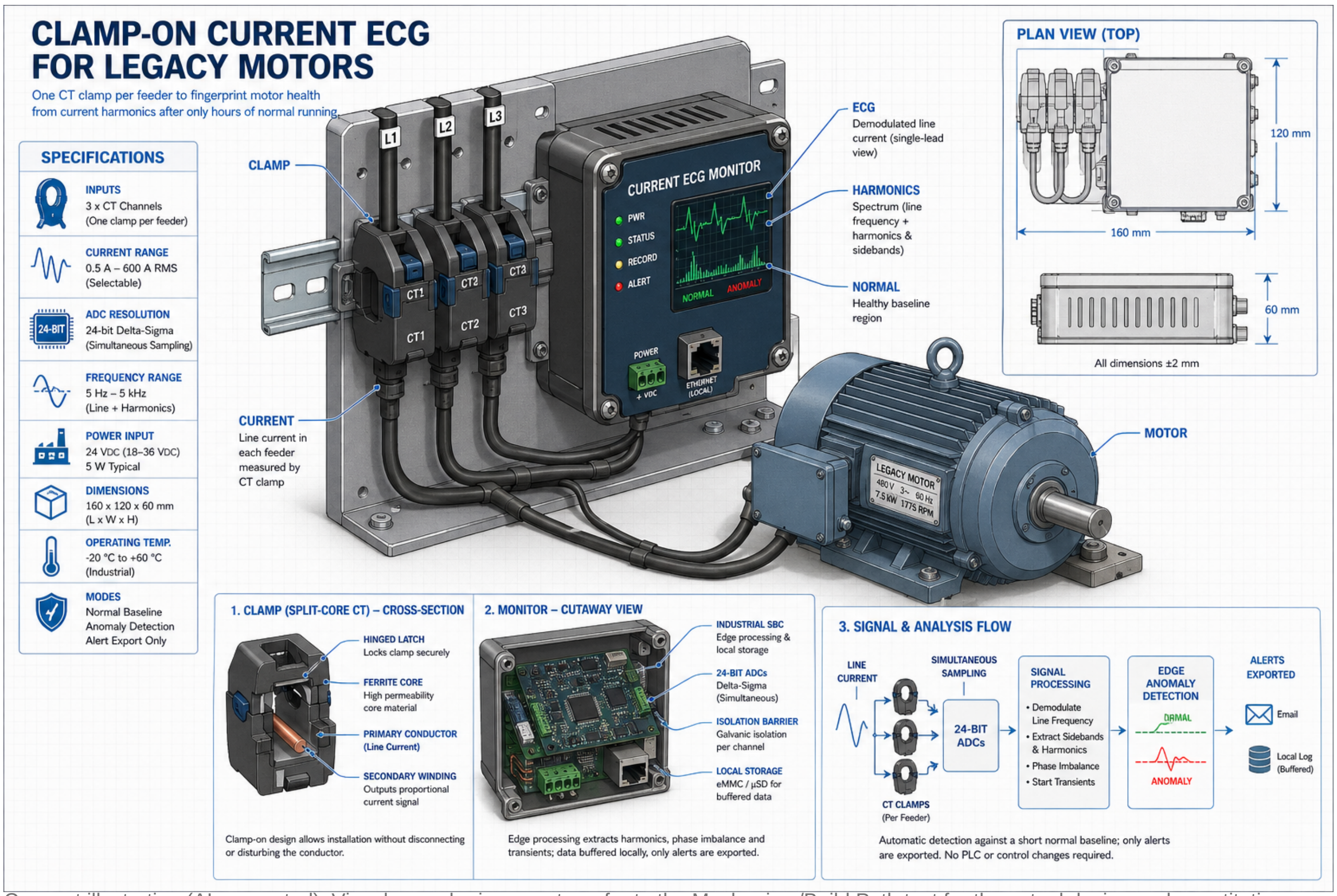
Clamp-On Current ECG for Legacy Motors

novelty: 5 | feasibility: 9 | economic_leverage: 6 | testability: 8 | robustness: 6 | constraint_fit: 9 | explainability: 9

Overall: 7.4 / 10 -- Very Strong

Constraint Compliance: Compliant (constraint_fit=9)

A single split-core CT clamp installed on a legacy motor feeder can continuously fingerprint motor health by analyzing current harmonics, sidebands, and transient signatures--no motor modifications required. This matters because the vast majority of industrial motors have zero condition monitoring, making early fault detection economically transformative at near-zero installation cost.



Concept illustration (AI-generated). Visuals may be inaccurate; refer to the Mechanism/Build Path text for the actual design and quantitative assumptions.

Mechanism

A split-core current transformer (CT) clamps around one phase of a legacy motor feeder inside the electrical panel, typically 50/100/200 A:50 mA or 333 mV output, with 0.5-1% accuracy and bandwidth to at least 2-5 kHz. The CT feeds an isolated burden/ADC front end, e.g. 16-24 bit ADC sampling at 4-10 kS/s, plus local compute on an industrial SBC or MCU. The system treats motor current as an "ECG": it tracks RMS envelope, line-frequency phase and amplitude, harmonic content, negative/zero-sequence imbalance where multiple phases are sensed, sidebands around 50/60 Hz and VFD carrier-related bands, inrush/start transient shape, coast-down signature, and slow drift in load-dependent features. For shared feeders, it learns motor identities by correlating feeder-current steps with contactor auxiliary contacts, PLC run bits, workflow timestamps, or a temporary per-motor CT during commissioning. A 2-hour normal baseline captures common load states; anomaly detection then compares new starts, steady-state windows, and stop events to the learned feature cloud using lightweight local models such as robust z-scores, one-class SVM/isolation forest, or template distance. Materials: UL-listed split-core CTs, DIN-rail isolated power supply, opto-isolated digital inputs for start tags, shielded twisted-pair CT leads, fused voltage reference input if phase/power factor is desired, and an IP-rated panel-mounted edge box. Data remain local; exported payloads are timestamps, motor ID confidence, anomaly score, feature deltas, and maintenance notes. Technical delta vs provided low-confidence analogs: unlike peripheral nerve interfaces, this senses aggregate AC feeder electromagnetic current signatures, not bioelectric neural signals, and performs machinery condition inference. Unlike IoT smart clothing/e-textiles, it is not distributed wearable sensing; it is panel-mounted industrial current analytics using CTs, commissioning tags, and local disaggregation.

Why Novel

Prior motor current signature analysis (MCSA) required dedicated per-motor sensors and specialist setup; this approach learns multi-motor feeder identities autonomously from contactor-correlated current steps, enabling fleet-scale deployment in hours rather than days.

Buildability

All core components--split-core CTs, 24-bit ADCs, industrial SBCs--are commodity parts available from Digi-Key or Mouser, and the signal chain is well-documented in IEC 60044 and application notes from TI and Analog Devices. A working prototype can be assembled on a benchtop motor testbed within a single sprint using open-source FFT and ML libraries.

Why Feasible

* Build path is practical (feasibility=9/10)
* Core hypothesis testable quickly (testability=8/10)

Top Risks

* VFD switching noise overwhelms fault-related harmonic sidebands, reducing diagnostic accuracy on variable-speed loads
* Process load fluctuations (e.g., pump cavitation, conveyor jams) generate current signatures indistinguishable from early bearing faults
* Shared feeder motor-identity separation fails when multiple motors start simultaneously or run at similar load points

Decisive Test (MDE)

Hypothesis: A single feeder CT plus start-event tags and brief per-motor commissioning can identify which motor is abnormal and detect early electrical/mechanical signature shifts with actionable accuracy on a shared legacy feeder.

Setup: Choose a shared feeder with at least 3 legacy induction motors, preferably including belts/pumps/fans with normal process variability. Install one panel CT on the feeder, collect contactor/PLC run tags, and during commissioning clamp a temporary CT on each motor to learn signatures. Baseline for 2-4 hr normal operation. Then introduce controlled perturbations: belt tension change, partially blocked pump/fan load, induced phase imbalance via safe test load or documented existing imbalance, loose coupling simulation if allowed, and VFD speed/load changes if present. Blind the algorithm to the perturbation labels during detection.

Instrumentation: Panel split-core CT, temporary per-motor CTs, 16-24 bit DAQ at 4-10 kS/s, three-phase power quality analyzer for ground truth, tachometer or PLC speed/load signals if available, contactor aux/PLC run tags, maintenance log, laptop for analysis.

Kill Criteria: Kill if motor attribution accuracy on shared feeder is below 80% for tagged starts/stops, or if induced faults/perturbations cannot be separated from normal load changes at useful thresholds.

Rescue Pivot: Move from single-feeder disaggregation to a hybrid product: permanent CTs only on high-value motors, or panel CT plus mandatory contactor/PLC tags and per-branch CTs on ambiguous clusters. For VFD-heavy sites, pivot to drive telemetry ingestion plus CT-based validation.
Cost: $800-$4,000 for prototype hardware if using commodity CT/DAQ/SBC; $5,000-$15,000 including electrician time, industrial enclosure, power-quality analyzer rental, and site support.
Time to Signal: 1 production shift for initial validation; 1-2 weeks to assess false alerts across process variability.

Refinement Deltas

Risks Addressed:

* Aggregate feeder current may be underdetermined: simultaneous motors with overlapping duty cycles can make source attribution unreliable without more sensors.
* Process variation can dominate fault signatures, especially pumps, compressors, grinders, and conveyors with changing material load.
* VFDs alter spectra through control loops, carrier switching, and speed changes; classic line-frequency sidebands may disappear or become nonstationary.

Red-Team:

* Challenge: Aggregate feeder current may be underdetermined: simultaneous motors with overlapping duty cycles can make source attribution unreliable without more sensors.
* Challenge: Process variation can dominate fault signatures, especially pumps, compressors, grinders, and conveyors with changing material load.
* Challenge: VFDs alter spectra through control loops, carrier switching, and speed changes; classic line-frequency sidebands may disappear or become nonstationary.
* Challenge: Panel installation still requires qualified electrician access, lockout/tagout, safety review, and customer trust despite being 'clamp-on'.
* Challenge: Short 2-hour baselines may miss temperature, product mix, shift, seasonal, and maintenance-cycle effects, causing false alerts or missed degradation.

Budget Ranges

Prototype: $800-$2,000 (CT clamp, ADC eval board, Raspberry Pi CM4, enclosure, bench motor testbed time)
Pilot: $15,000-$40,000 (10-20 unit pilot deployment, electrician commissioning labor, cloud backend, 6-month data collection and model tuning)
Scale: $200,000-$600,000 (500+ unit production run, UL/CE certification, enterprise dashboard, channel partner onboarding)

30/60/90 Plan

Day 30: Assemble benchtop prototype with split-core CT, 24-bit ADC, and SBC; validate harmonic capture against known motor faults (bearing defect frequencies, rotor bar signatures) on a test motor rig; confirm 2 kHz+ bandwidth and <1% amplitude error
Day 60: Deploy 3-5 units at one pilot site on mixed legacy motor feeders; run autonomous contactor-correlation algorithm to separate motor identities; collect baseline signatures across load cycles and validate fault-vs-load discrimination with a seeded bearing defect
Day 90: Deliver pilot report with false-positive/negative rates, feeder-separation accuracy metrics, and VFD interference characterization; finalize hardware BOM for 50-unit production batch; define alert threshold model and cloud API spec for customer CMMS integration
Dominance Axis: easier_deploy -- A panel CT can cover multiple legacy loads after brief commissioning anchors their signatures.

Top Uncertainties & Assumptions

* Bad criticality ranking misprioritizes maintenance work, eroding technician trust after the first false-priority dispatch
* Microsecond-level time-sync drift between STM32 co-processor and ARM SoC corrupts cross-modal fusion features and degrades fault localization
* Operators ignore alert scores they cannot interpret, reverting to manual rounds and leaving the device unused
* Insufficient harvest energy on shielded motor housings or during low-load idle states drops reservoir below the 1.2 V supervisor threshold, causing permanent dormancy
* Neuromorphic LIF classifier false-wake events under broadband vibration noise drain the 4.7 uF reservoir faster than it recharges, creating a net energy deficit

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