

Bill of Materials: Pressure & Flow Anchor (PFA)

Role: Source/Well Monitor & Safety Actuator | **Deployment:** 1 per Well Station | **Reporting To:** VFA (Field Aggregator)

The Pressure & Flow Anchor (PFA) is the "Sentry of the Source." While other network components monitor the consumption of water at the crop level, the PFA focuses exclusively on the extraction point—the pump and the aquifer. It provides the high-fidelity data required to bridge the gap between farm-gate operations and regional aquifer health, serving as the primary hardware interface for the "Digital Water Ledger."

1. Sensing Array (Source & Pump Diagnostics)

The PFA utilizes an industrial-grade sensor suite to monitor both the mechanical health of the pumping infrastructure and the hydrological state of the underlying water table.

- **Energy Monitor (Non-Invasive):** 400A Split-Core CT (Current Transformer) Clamps.
 - *Mechanism & Phase Logic:* Measures real-time current draw and phase balance of the pump motor. Unlike inline meters, these clamp around the existing 480V leads, requiring zero downtime for installation.
 - *Predictive Analytics:* By analyzing the "Energy Signature" (harmonics and torque ripple), the Zo engine (at the DHU/RSS level) can detect early-stage cavitation, bearing wear, or impeller inefficiency. This enables "Predictive Maintenance," allowing the farmer to repair a pump in the off-season rather than facing a catastrophic motor burn-out during a 100°F July heatwave.
- **Well Depth Sounder (Hydrostatic):** Vented 316-Stainless Steel Pressure Transducer (0-100m range).
 - *Hydrological Logic:* Monitors static water levels (recovery) and dynamic water levels (draw-down). This provides empirical, minute-by-minute proof of the farm's actual impact on the aquifer.
 - *Defensibility:* This data is essential for legally defensible Water Court testimony. In an era of increasing regulation, having a time-stamped record of well-level recovery proves sustainable management and protects the seniority of the user's water rights against regional depletion claims.
- **Line Pressure Sensor:** 0-200 PSI Industrial Stainless Steel Transducer (1/4" NPT).
 - *Operational Safety:* Acts as the "Digital Heartbeat" of the hydraulic mainline. The PFA monitors for sudden pressure drops (indicating a burst pipe or blown gasket) or dangerous spikes (indicating a blocked valve or "water hammer").

- *Reflex Integration:* If pressure deviates from the safe "Worksheet" window, the PFA executes an autonomous shutdown command in milliseconds, preventing massive soil erosion or pump damage.

2. Internal Alpha-Sled & Computing

The PFA utilizes a ruggedized version of the shared FarmSense architecture, specifically hardened for the high-EMI (Electromagnetic Interference) environments found in pump houses.

- **Core MCU:** NXP i.MX RT series (Cortex-M7 Shared Architecture).
 - *Role:* Handles high-speed synchronous sampling of the CT clamps and executes local "Reflex" logic. It compresses complex source data into encrypted, low-bandwidth packets for the VFA.
- **Expanded Power Stack:** Dual-Pack LiFePO4 (40,000mAh total).
 - *Thermal Resilience:* Includes a 5W Kapton heater and 8mm PE Closed-Cell Foam insulation.
 - *The "Blackout Buffer":* While the PFA is typically powered by a step-down transformer from the pump's AC line, the double-capacity battery provides a **7-day fail-safe**. This allows the unit to continue monitoring well-recovery levels and static pressure even during a total grid power failure or a "Public Safety Power Shutoff."
- **Memory (The Sentry Log):** 4GB Industrial eMMC for local storage. This ensures that even if the mesh network is down, the PFA maintains a local "Ledger" of every gallon pumped and every foot of draw-down.

3. Structural Housing & Actuation

- **Enclosure:** NEMA 4X Ruggedized Polycarbonate.
 - *EMI Hardening:* Features internal Mu-metal or conductive spray shielding. This is critical for preventing the high-frequency "noise" generated by Variable Frequency Drives (VFDs) from corrupting the sensitive analog-to-digital conversions of the well-depth sounder.
- **Control Interface (The Reflex Actuator):** Integrated Industrial Relay Output (Dry Contact).
 - *Mechanism:* Tied directly into the pump's "E-Stop" or "Remote Start/Stop" circuit via the motor starter's control coil.
 - *Reflex Logic:* Receives encrypted "Soft-Stop" commands from the network. For example: "Stop pump if the PMT detects a pivot stall" or "Stop pump if the VFA detects moisture saturation at 66 inches." This prevents "wasteful pumping" where water would otherwise just perk into the aquifer without hitting the root zone.

4. Communication & Lifecycle

- **Protocol:** 2.4GHz High-Gain Link to VFA Alpha Node.
 - *Redundancy:* Programmed with "Critical Packet Priority." During network congestion, the PFA suppresses diagnostic data (like motor phase balance) to ensure that "Line Pressure" and "Emergency Stop" packets have a clear path to the field coordinator.
- **Environment:** Fully potted electronics option for high-humidity pump pits, ensuring a 20-year lifecycle regardless of local condensation or "sweating" pipes.

Funding & Compliance Note: As the primary tool for aquifer monitoring and "Digital Ledger" auditing, the PFA is the highest-priority asset for state-level conservation funding. It is 100% eligible for **State Water Plan (CWCB)** and **NRCS Conservation Innovation** grants, as it provides the transparent, tamper-proof data required for next-generation groundwater management.