DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
COLLEGE OF ENGINEERING & APPLIED SCIENCES

RESEARCH OPPORTUNITIES FOR UNDERGRADUATE students

APPLICATION DEADLINE: April 3, 2026

PROJECT TITLE: Secure On-Chip AI & Analog Feature Extraction for Precision Agriculture

Physical Requirement :
Light lab work at an electronics bench (optional soldering), 2–3-hour sessions, light lifting (less than 20 lb), and occasional short outdoor sensor setups.

Project's Technical Skills Requirement :
Student should be comfortable with Arduino-style MCU programming (STM32/ESP32) and circuit design/simulation. Lab & Data: Hands-on experience with Oscilloscopes, Power Monitors, and Python/MATLAB for automated performance plotting. Bonus: Familiarity with LoRa radio and basic wireless packet security (encryption/replay defense) is a significant plus.

Project's Available Positions : 1

Ankit Mittal
College of Engineering and Applied Sciences
833 Rhodes Hall
Cincinnati, OH 45221
ankit.mittal@uc.edu

Project Description

Why this matters:
On a modern agricultural farm, every reading and every byte costs battery life. Sensing takes power, Processing takes power, and Wireless transmission takes the most.
If we want months of autonomous life from a tiny, buried node, we cannot simply "send everything." We have to send less, send smarter, and make sure fake or replayed packets don’t waste energy or corrupt the data. This project explores moving "AI" from power-hungry software into efficient, low-level analog and mixed-signal circuitry.

What the Project is About:
You will design and build a small, ultra-low-power farm sensor node. The goal is to move data processing as close to the sensor as possible by using on-chip AI techniques to shrink data before it ever reaches the radio.
Core Research & Design Focus:
1. Low-Power Sensing: Measure soil conditions (moisture/EC, temperature, humidity) and explore simple analog triggers for pest detection.

2. Circuit-Level Intelligence: Investigate and implement analog blocks like Zero-Crossing Detectors for frequency analysis, Voltage Multipliers for signal scaling, and Analog Correlators for real-time pattern recognition.
3. Data Shrinking & Security: Compress data at the hardware level to save energy and implement software defenses against wireless spoofing or replay attacks.
4. Long-Range Communication: Transmission via low-power radio to a central base station.

Key Deliverables:
Students will be responsible for the following technical milestones:
1. Literature Review & Theoretical Foundation:
a) A concise review of existing low-power sensing literature.
b) Comparative analysis of Zero-Crossing vs. ADC-based sampling.
c) Research into Analog Correlators for feature extraction in agricultural environments.

2. Circuit Design & Simulation:
a) Detailed circuit diagrams for the Analog Front-End (AFE).
b) Simulation results demonstrating how voltage multipliers and correlation blocks "shrink" raw sensor data into essential features.

3. The Working Prototype:
a) A hardware node that measures, shrinks, sends, and (re)builds data at the base station.
b) Basic wireless security in software to ensure eavesdropped data is unrecoverable without a key.

4. Performance & Security Analysis (One-Button Script):
a) A plotting script showing Energy per message (before vs. after shrinking).
b) Reconstruction quality and Time to reconstruct data chunks.
c) Security tests: Acceptance rates for valid vs. spoofed/replayed packets.

5. Project Documentation:
a) A short technical write-up (15 pages) covering the design, testing, and results.
b) A complete package including firmware, scripts, circuit diagrams, and a parts list (BOM).

Note (Living Document)
Consider this a living plan: the instructor may adjust scope, milestones, or deliverables to keep the work feasible, safe, and aligned with learning goals. Any changes will be shared in writing with reasonable notice.