

Integrated Nitrate Sensor for Real-time Soil Monitoring

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Summary:

Integrated systems for soil monitoring are of growing interest, especially to detect in real-time the presence of pollutants like nitrate and thus decrease the exploitation cost in field.

This paper presents a wireless multi-sensor system developed during the European FAMOSOS project along with laboratory test results. The system measures the concentration of nitrate in the soil water, the pH, temperature, and soil moisture status using automated data acquisition and wireless LoRa data transmission through the soil.

Keywords: Analog Front-End, Integrated systems, soil monitoring, nitrate, low-power, real-time, wireless sensor network

Background, Motivation and Objective

Guided by the European zero-pollution vision for 2050 and its key 2030 targets “improving soil quality by reducing nutrient losses and chemical pesticides’ use by 50%” [1], our work focuses on the detection of nitrate in soil.

Clean water is vital to human health and to natural ecosystems. Nitrogen pollution remains one of the most challenging and costly environmental problems [2]. Nitrate, soluble in water, can easily leach through the soil into the receiving waterways, contaminating groundwater, rivers and lakes.

Monitoring soil environments is thus essential. The FAMOSOS project (Farm Monitoring via Real-time Soil Sensing) [3] from European EJP-SOIL initiative, addresses this challenge by developing a low-cost, real-time electronic system designed to help farmers optimize fertilizer use, reduce greenhouse gas emissions, and minimize water pollution. This paper focus on the Analog Front-End (AFE) specifically developed for an electrochemical nitrate sensor.

System Architecture

A schematic view of the FAMOSOS system architecture and more specifically the electronic architecture interface with others components is represented in Fig.1. The red rectangle

highlights the electronic board with IoT power management circuit, along with all other components that can be connected to the board.

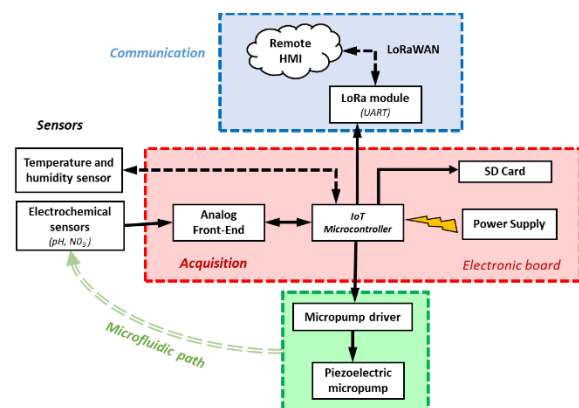


Fig. 1. FAMOSOS simplified design

The multi-sensors system is dedicated to pH and nitrate (NO_3^-) concentration measurements along with soil temperature and moisture in view of our specific application for soil monitoring in the field. It combines a sensor network together with a microfluidic path (composed of porous ceramic cup associated with a micropump and an electrochemical sensor), an analog front-end board for the data acquisition and an antenna for wireless LoRa data transmission through soil.

Analog Front-End for Nitrate Sensor

The previous architecture [4] embedded an Analog Front-End that integrates an STM32 microcontroller unit (MCU) and a portable potentiostat AD5941 from Analog Devices. It was designed to support both analog and digital sensors while also controlling the micropump.

Raw data from the sensors are collected by the AFE and converted into physical values by the microcontroller unit.

Optimizations were performed in this work to operate the bipotentiostat Square Wave voltammetry technique (specific for nitrate sensor) and to improve the robustness and the reproducibility of the electronics. The board also embeds the micropump driver and the LoRa module.

A representation of the FAMOSOS system electronic architecture is shown in Fig.2.

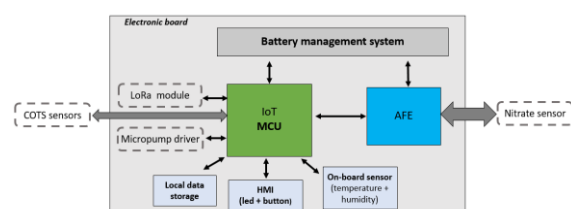


Fig. 2. FAMOSOS Motherboard architecture

The wireless interface for data transmission through the soil, consists of a setup of base stations and wireless end devices, which will be buried underground.

To minimize power consumption, sensors and peripherals remain in standby mode and wake up only when data transmission is required.

Laboratory results

NO_3^- solutions with concentrations of 10, 50 and 100 ppm, were filled into the sensor casing manually with syringe (fig.3).

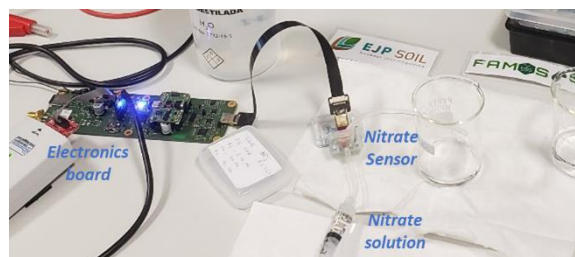


Fig. 3. Laboratory set-up for testing nitrate sensor

The sensor detected changes in nitrate levels over time as shown in Fig 4, providing real-time monitoring of nitrate movement and availability in the soil.

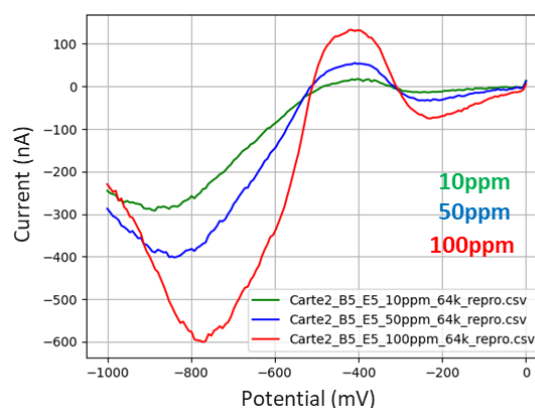


Fig. 4. Nitrate concentration in ppm

The reproducibility and robustness of the electronics were demonstrated through successful laboratory tests.

The next actions will be the deployment in field and Subsequent trials with the overall system and different nitrate concentration.

FAMOSOS will make a significantly contribution to enhancing soil understanding to improve management practices such as optimizing N fertilization strategies.

References

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