# Printed miniature nutrient sensors

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## Problem Statement

For the best yield per acre, farmers need accurate data regarding the current nutrient levels in the crop in order to determine the appropriate amount of nitrate fertilizer required for that acre. Soil analysis is slow and and does not perfectly reflect the nitrate levels in the crop. Unknown or inaccurate measurements of nitrate levels in crops either leads to excess fertilizer application which is costly and environmentally irresponsible, or inadequate fertilizer application which leads to lower crop yields and less profits.

**Solution:**

Accurately measure the nitrate level in the crop rather than the soil alone. Provide an app that aggregates crop nutrient level data on a convenient platform that updates regularly. Manufacture a micro-nutrient sensor that withstands the ingress of water for a minimum of 90 days inside the plant. Provide software and hardware that allows for short wake-up periods where data can be collected and sent via cellular signal to a database, and deep-sleep between measurements to preserve battery life for 90 days.

## Design Requirements

- Functional Requirements:
  1. Improve accuracy of sensors.
  2. Increase the battery life of the circuit box.
- Non- Functional Requirements:
  1. Reliable data transmission from the cellular module to the database.
  2. Sensors should be waterproof.
- The sensors will be tested out in corn fields in Iowa. Sensors will be inserted in the leaves, stalks and roots of these plants to get nutrient level readings.
- Constraints:
  1. Power consumption of sensors.
  2. Data accessibility.
  3. Size of the individual sensors.

## Intended users and uses

- Users
  1. Farmers
  2. Researchers in biotechnology
  3. Scientists
- Uses
  1. Access to measured data about the plant conditions.
  2. Grant users the flexibility to view relevant data at any location as long as the users have internet access.
  3. Eliminate nitrate pollution to rivers and watersheds.
  4. Increase efficiency of crop production.

## Testing

- Test 1 Filtering out data anomalies
  1. Plug in the sensor to the stalk of the plant.
  2. Check to see if the cellular module reads and stores data from the plant.
  3. Check the bounds of the data and plot data on Excel.

The goal of this test is to see that inaccurate values (values that are not logically possible) are filtered out.

- Test 2 Increasing the number of transmissions during peak season
  1. Plug in the sensor to the stalk of the plant.
  2. Check to see if the cellular module reads and stores data from the plant.
  3. Calculate daily averages for two days.
  4. If the difference between these averages is more than 5%, take readings more frequently.

The goal of this test is to provide our users, the most recent information about nutrient levels in soil, during peak harvest period.

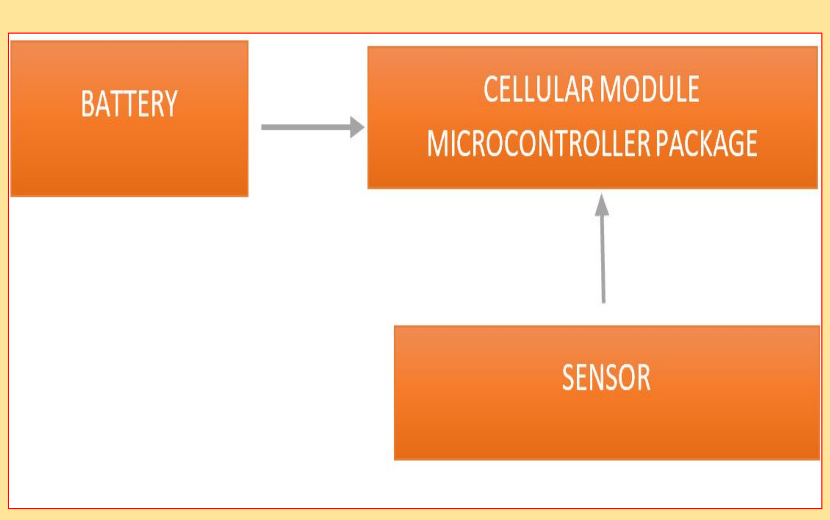
- The data for our testing was acquired in field. Having stored the data in Excel files, we were able to conduct the tests above in lab.

## Technical Details

- Programming Language:
  1. Cellular Module - C/C++, Webhook (HTTP Callback)
  2. Database Server - JSON, HTTP
  3. App - JSON, Java, XML
- Development Tools:
  1. Cellular Module - Arduino, Visual Studio
  2. Database Server - Hologram Router, Losant
  3. App - Android Studio
- Libraries:
  1. Cellular Module - ReadEvalPrint (Hologram Dash API), Arduino.h, wire.h
  2. App - Google maps API, Android Studio library
- All of the software development are conducted in Windows environment.

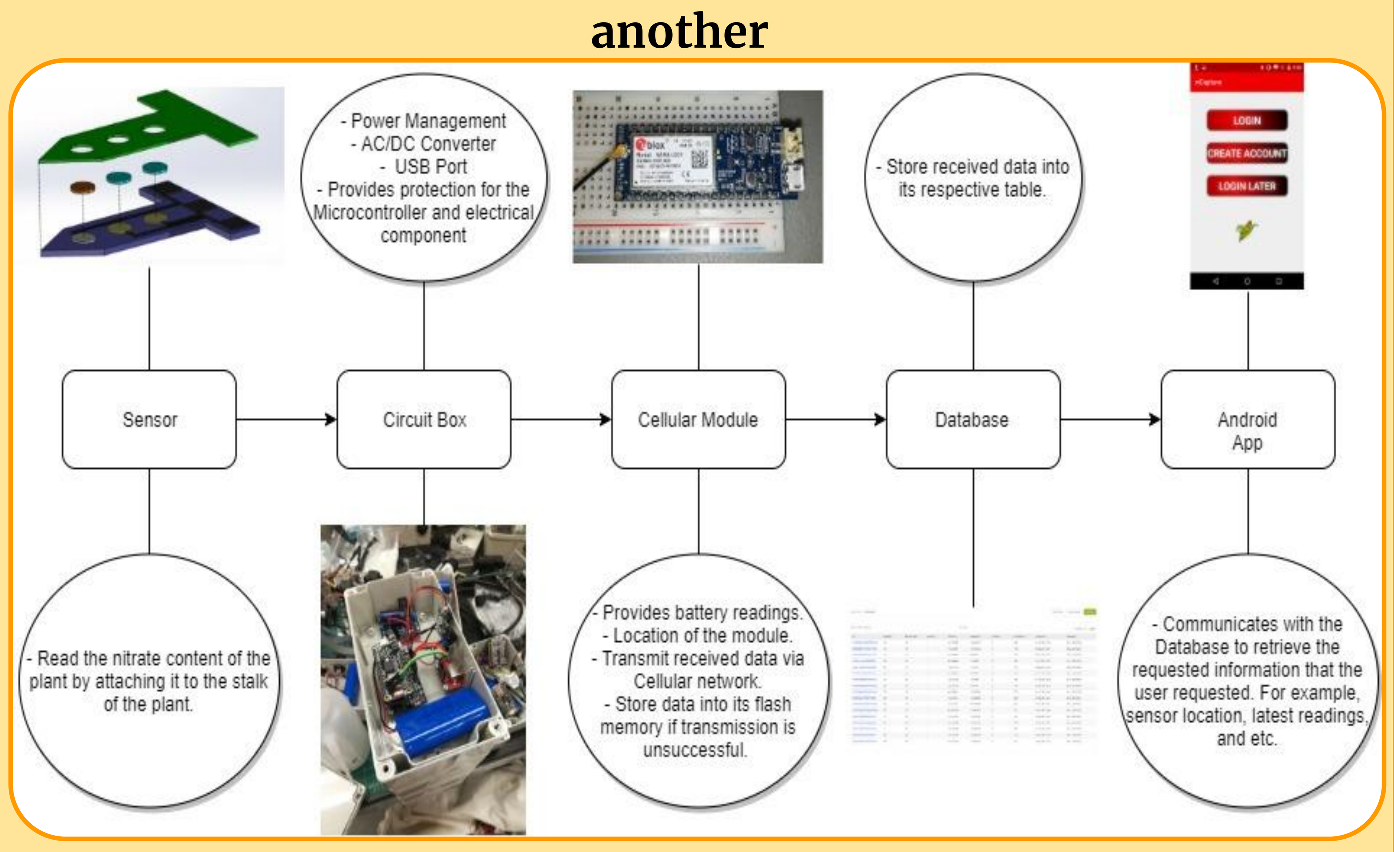
## Standards

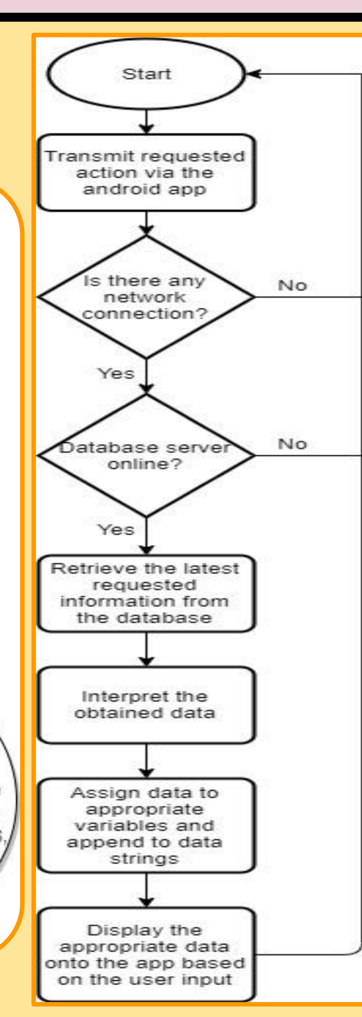
## Design Approach



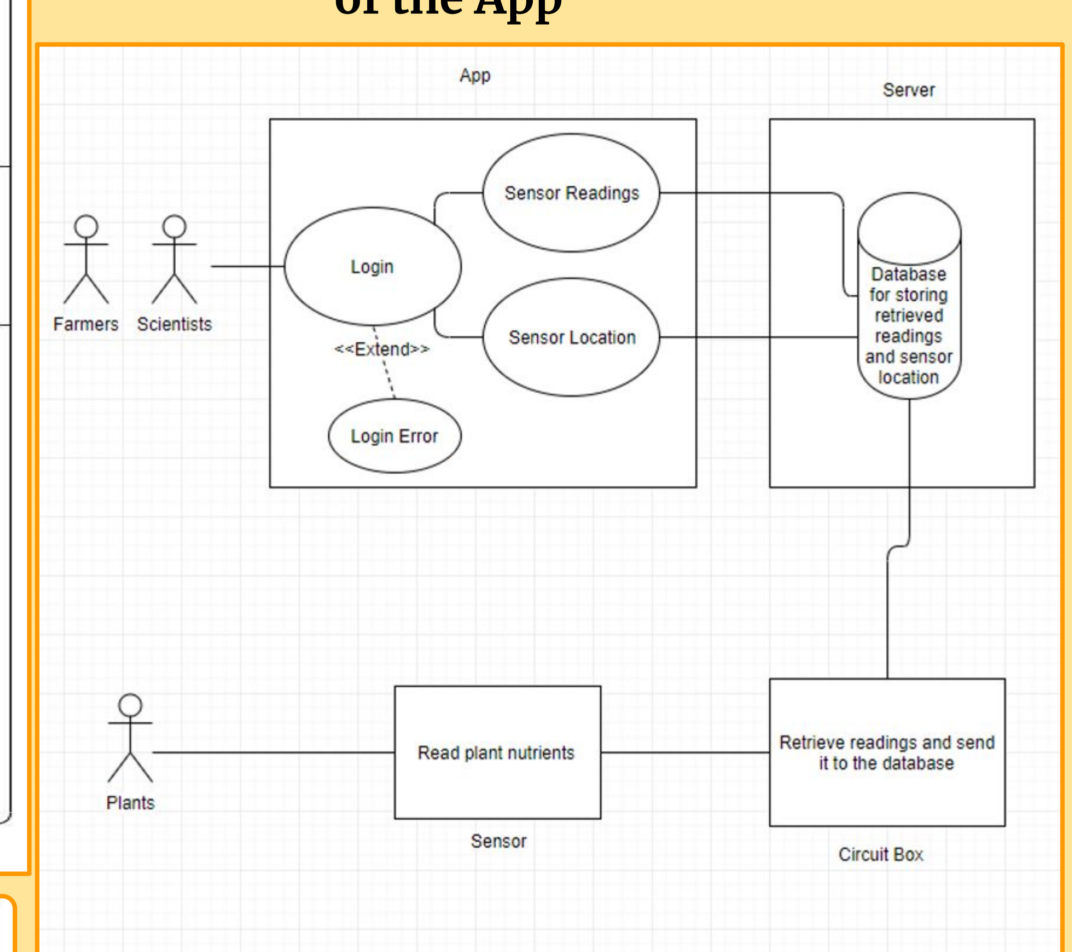

Circuit Diagram

**Main Functional Module and its Interaction with one another**



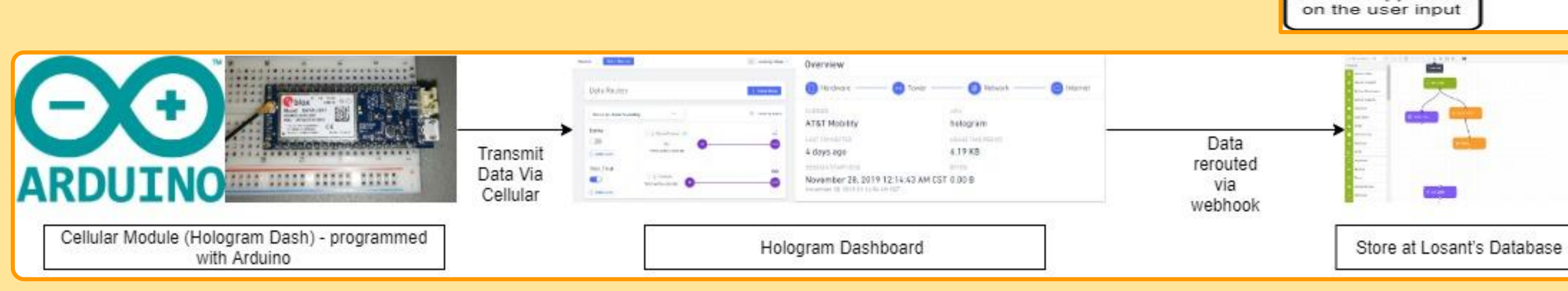




**Data Retrieving Process of the App**



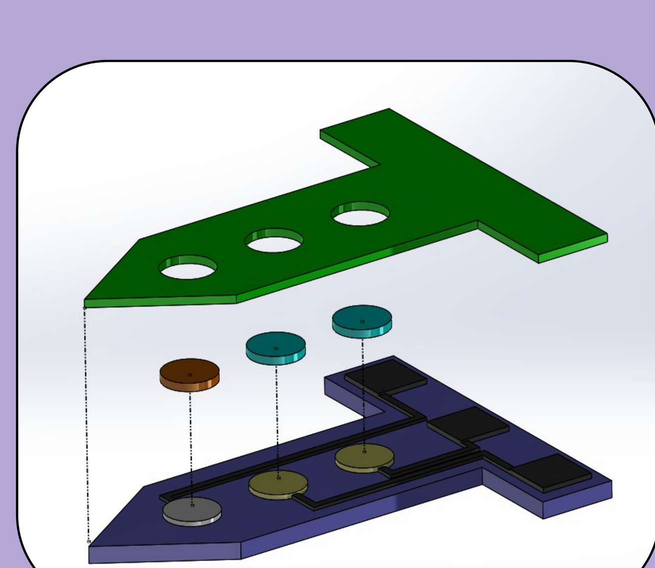

**Use Case Diagram**

**Data Transmission Workflow**



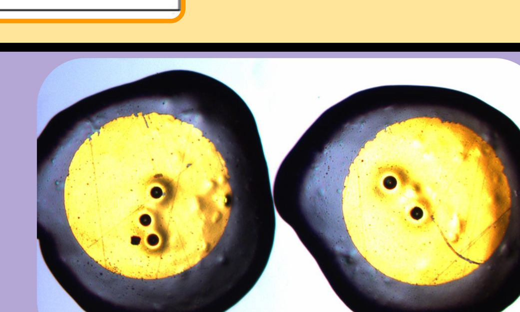

## Manufacturing

**Nordson Fluid Dispenser**
This machine is used for accurately dispensing microscopic layers of polymer resins on the sensor substrate.

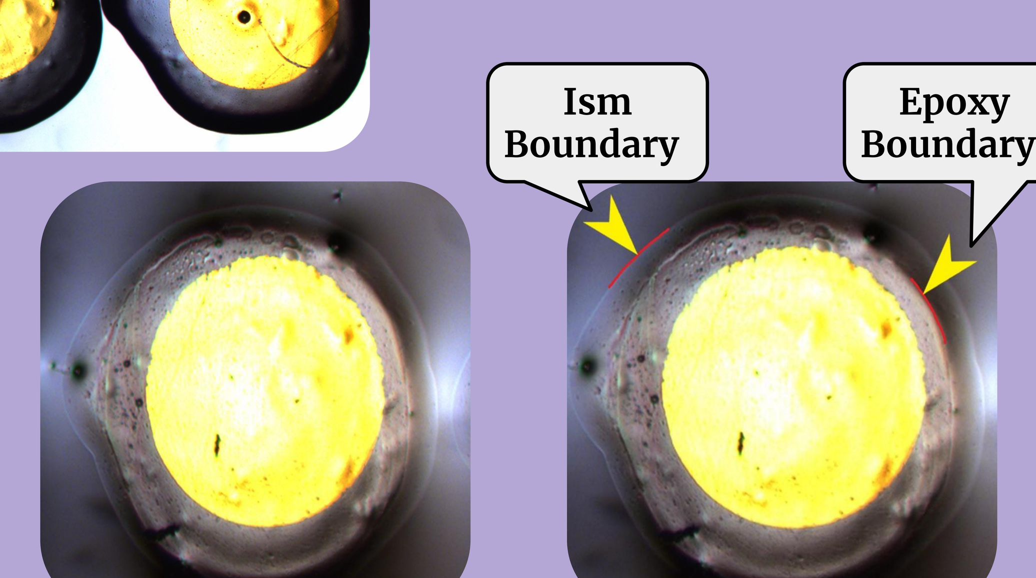


**Structure of the sensor:**

The sensor is a silicon wafer (shown in dark blue on the left picture) with working and reference electrodes. The working electrode and reference electrode are coated in gold. The Nordon dispensing robot is used to coat the sensor in ISM (shown in light blue), to separate the nitrate ions. The reference electrode is coated in KCl (shown in orange) for the redox reaction. The deposited material is then sealed with two-part epoxy (shown in green) to prevent water damage.



**Ism deposited on a dot**




**Ism deposits sealed with the epoxy**