Smart Wireless Ag Sensors for Measurement of Soil Water Contents

DESIGN DOCUMENT

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Table of Contents

List of figures/tables/symbols/definitions

1 Introduction

1.1 PROBLEM AND PROJECT STATEMENT

The research department is working towards improving the crop yields within the agriculture field. In order to increase yields it is important to research and understand the differences between various crops and the nutrients contained in the soil and the plants.

This can be done with the development of electrochemical sensors. Our goals is to improve these sensors, it will allow for enhanced data collection and interpretation. The team can then find out what would be the best type of crops to plant in certain areas or how much fertilizer will be needed throughout the season. Ultimately this research can be used to help farmers grow better crops increasing their yields allowing for more food and less waste.

1.2 OPERATIONAL ENVIROMENT

Our sensors will need to be constructed to be able withstand all weather conditions. They will be used outside in the fields put there for use throughout the farming season. We will ensure that our design is waterproof, and that it can handle the outside environment. In doing this our electrical components will remain operational and safe from everyday conditions.

1.3 INTENDED USERS AND USES

The intended users for our sensors in the near future are for those who do research looking into the crop yields. This includes researchers here at Iowa State. Eventually, we would like to incorporate this with farmers and give them the technology to conduct soil sample testing on their own, rather than having to ship it out to a third-party company.

1.4 ASSUMPTIONS AND LIMITATIONS

Our main assumption is that we will be designing these sensors strictly for research purposes. Eventually, we plan to push this out to farmers to give them the ability to conduct their own soil samples. Starting with 10 sensors but increasing to test communication further. Each sensor will have one sensor per control box that is interchangeable between plant and soil.

Some limitations we have is that our sensor box needs to be approximately 6 cm^3. Also, we need to be able to produce as many sensors as possible given a $2000 budget. Schedule limitations stem from limited availability with meeting in order to acquiring information to move forward between various timelines to work around to limited documentation from earlier revisions before we were brought in. We also need to reduce battery consumption using rechargeable batteries with solar panels.

1.5 EXPECTED END PRODUCT AND DELIVERABLES

Soil and Plant Sensors

Two new sensor designs that incorporate a circular design that will make the fabrication process more efficient.

User Interface -

User interface that can be accessed from a mobile device for easy transfer and view of data on sensors.

Mesh Network Capabilities

The software and hardware of the sensor box must support a mesh style network so that multiple sensors can connect to a collection point without additional infrastructure.

Control Box

The size of the control box is to be reduced to a quarter of its current size. In doing so the electronic components also have to be reduced in order to fit in the new control box. Smaller circuit boards, and battery for each box.

2. Specifications and Analysis

Functional Requirements:

75% smaller control box - we have started to look into 3D printing different models for the new control box.

Energy Efficient - We will continue the use of solar panels and rechargeable batteries for power while decrease the size of the battery.

Waterproof – The sensor connection to our control box is already waterproofed with a coating of a specific polymer. We need to make sure that the box itself does not allow for water to enter and damage any of the components.

Portable - the sensors, boxes, and solar panels are small and easy to move with decreasing the size it will improve this portability.

Non-Functional Requirements:

User-friendly software interface - We have explored the application currently used for the sensors and looked into improvements on how to improve the UI. We are already working on creating a plot of the data readings to be able to see trends throughout a period of time.

Cheap, scalable hardware - We are looking into prices and comparing different parts for a comparison to get something that is both affordable and efficient.

Mesh Networking -

Standards:

IEEE Standards

2.1 PROPOSED DESIGN

The proposed design for the in-soil sensors changes the copper contact pads into a more circular design. This design eliminates "the step up" from the PCB substrate to the copper pad. Errors can occur on this "step up" when silver is deposited on our PCB. The proposed solution is displayed in Figure X.

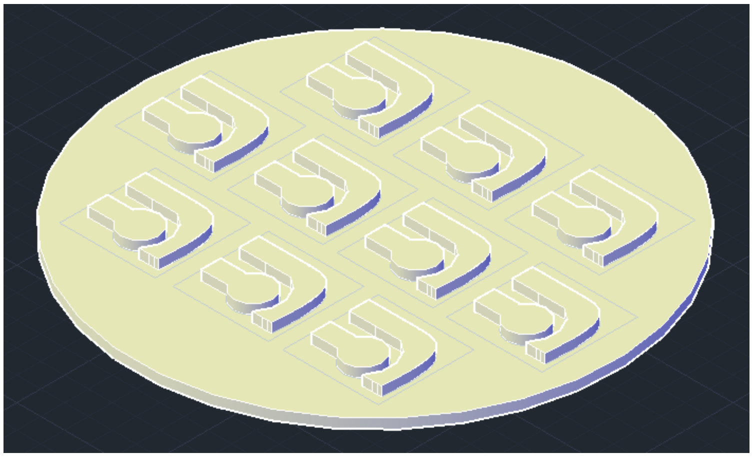

Figure X. Proposed design for in-soil sensor.

From Figure X, you can see that our proposed design in also wafer shaped rather than typical rectanglualr shape. The circular shape allows the PCB to fit better in our silver deposition machine. We plan on either applying a glue or shadow mask between the working and reference electrode to eliminate the "step up" problem.

Our team is currently looking into how to design the circuit previously created for the sensor. We are looking to decrease the size of the box which in part we need to then create a smaller circuit with the same capability of the old circuit design.

2.2 DESIGN ANALYSIS

For the in-soil sensors, we have currently redesigned our PCB to a more circular design. Our intuition tells us that this should be a suitable solution to our current sensors problems. We are awaiting the fabrication of our sensors so we can test our new design. The strengths to our proposed solution are the removal of the "step up" problem and the easier deposition of silver on our PCB. However, due to the circular design we cannot print as many sensors on our PCB at one time. After we do more testing with our sensors we will be able to determine other possible trade-offs for our proposed design.

Currently we are in the process of re-designing our circuit. We have the previous circuit layout but since we are trying to cut the size by ¼ and will need to also decrease the size of the circuit.

3 Testing and Implementation

Testing for the in-soil sensor has yet to be completed. We have recently created a new design and are waiting on the fabrication of our sensors. Once fabrication is complete we will begin testing on the in-soil sensor.

Testing our circuit is a very large portion of our project. At this time, we are still in the process of re-designing our circuit and have not conducted any reasonable testing for it. Once we design a functional circuit we will be simulating it with circuit simulation software, then testing it in the field.

3.1 INTERFACE SPECIFICATIONS

The hardware interface will be a small waterproof box containing the circuitry. There will be two ports, one for the sensor, and a second for connecting a solar panel.

The software interface will include a way to download the data wirelessly and display it on the device using graphs for easy in-field inspections.

3.2 HARDWARE AND SOFTWARE

Due to the lack of technical documentation, we have just recently received the circuit schematics and are currently improving the old design. While testing our designed circuit we plan on using the circuit simulation software P-Spice. The software is very helpful with simulating how our circuit would respond with different input voltages. This is important because given the different nitrate or phosphate levels it has a different input voltage to our circuit. We will also be testing in real time in the soil or in a plant.

3.3 PROCESS

Here are some of our testing plans we have yet to begin major testing of our project.

For testing the sensors that we are designing throughout the fabrication process we will be testing the conductivity of the sensor to make sure that we are applying the chemicals correctly and that the PCBs are machined without fault. We will then take our completed sensor and test it against an existing sensor and control box pulling test data from both to look at accuracy and the results.

Testing for a waterproof control box will be conducted with various conditions and at different angles around the box checking to make sure the box is sealed tight not allowing water to pass.

Testing for an improved user interface will be done throughout the process with either real time data collection or with simulated situations depending on what part of the process we are in.

3.4 RESULTS

We are currently in the process of re-designing our circuit and have not done any significant testing for this part. Once we have a useful circuit to test we will be simulating it in P-Spice and physically in the soil and plants.

4 Closing Material

4.1 CONCLUSION

We have done some research into different networking protocols and determined what kind of hardware we would need to support them. Currently we are using an Arduino with a Bluetooth chip for communication which does not support mesh networking very well. Going forward we will research different standards that work with mesh networks.

For the hardware we are still trying to learn about the sensors and the circuitry. We are using partial circuit diagrams to redesign the circuit. We have also started designing a new sensor with a circular structure that will improve its accuracy and fabrication process.

4.2 REFERENCES

4.3 APPENDICES

Commented [SR1]: This will likely be different than in project plan, since these will be technical references versus related work / market survey references

Commented [SR2]: Any additional information that would be helpful to the evaluation of your design document.
If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.