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

1 Introduction 2

1.1 Problem and Project Statement 2

1.2 operational Enviroment 2

1.3 Intended Users and uses 2

1.4 Assumptions and Limitations 2

1.5 Expected End Product and Deliverables 3

2. Specifications and Analysis 3

2.1 Proposed Design 3

2.2 Design Analysis 5

3 Testing and Implementation 5

3.1 Interface Specifications 5

3.2.1 Hardware and Software Testing 6

3.2 Process 6

3.3 Results 6

4 Closing Material 7

4.1 Conclusion 7

List of figures/tables/symbols/definitions

- Figure 1: Proposed design for in-soil sensor
- Figure 2: Proposed circuit PCB design

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 plant and soil sensors will have an operating environment of a corn or soybean field or greenhouse. With that in mind, they need to be waterproof to withstand rain as well as be able to withstand relatively extreme temperature swings depending on a farming location. Additionally, the sensors will be out in the field for anywhere from a few hours to a few days, weeks or months, so sustainability is a key component that we intend to address with a rechargeable battery.

1.3 INTENDED USERS AND USES

The intended users for our sensors in the near future are those researching crop yields and corn/soybean farmers. This will begin with researchers in the College of Agriculture at Iowa State University and then be outsourced to other agricultural companies.

The plan is to then have our product used by farmers in order to give them the technology necessary to conduct soil sample testing on their own, rather than having to ship soil out for testing to a third-party company.

We need to make sure that our sensors meet the standards of both intended users, we plan on achieving this by upkeeping and improving the accuracy of the sensors and data collection while improving the durability and longevity of the control boxes. Also, we are allowing for easy instillation into the fields.

1.4 ASSUMPTIONS AND LIMITATIONS

Assumptions:

1. Each control box will have one sensor.
2. Sensors will be interchangeable in order to test plants and soil water.
3. Plant and soil water sensors can be modified to measure Nitrogen, phosphorous, and potassium.

Limitations:

1. The end product needs to be ¼ of original size
2. The system must operate under moderate temperature changes (-20 Fahrenheit to 120 Fahrenheit)
3. Project budget cannot exceed $2,000.00

1.5 EXPECTED END PRODUCT AND DELIVERABLES

Soil and Plant Sensor PCB

A new sensor PCB design/product that improves the fabrication process and accuracy of the sensor.

Software

A simple to use mobile app that will collect the data, display it, and upload it to a remote server for storage. Server sided software to accommodate uploading and viewing of sensor data and other information.

Control Box

An optimized sized data acquisition device that accurately collects and analyses the data received from the sensors.

2. Specifications and Analysis

Functional requirements:

- Sensor box ¼ of original size
- The control box will need to run off a coin cell battery for 15-20 mins.
- Can withstand temperatures ranging from –20 Fahrenheit to 120 Fahrenheit
- Portable
- Takes accurate measurements of phosphate/nitrogen/potassium concentration
- Waterproof

Nonfunctional requirements:

- Easy to navigate software interface
- Efficient networking
- Cheap for consumers

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 1.

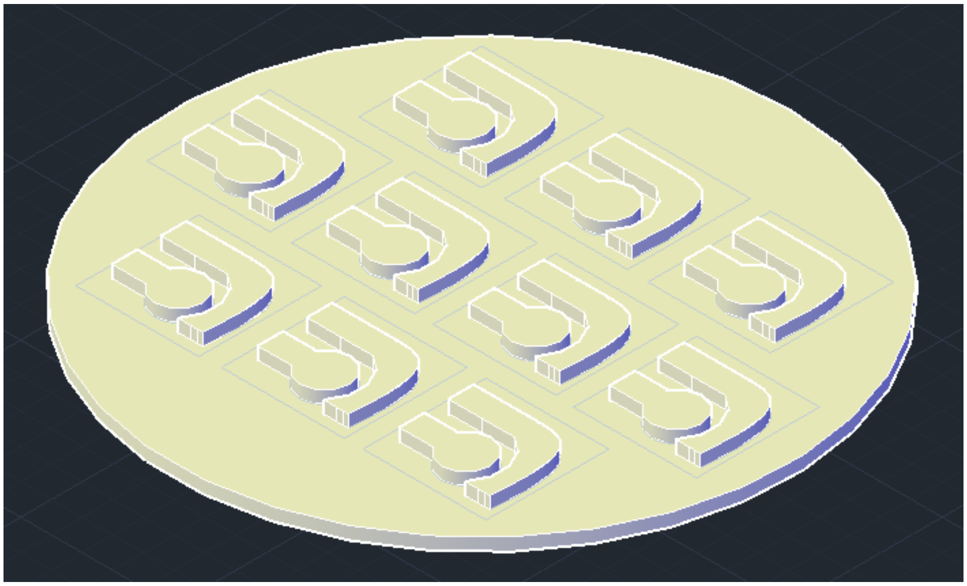

Figure 1. Proposed design for in-soil sensor.

From Figure 1, you can see that our proposed design in also wafer shaped rather than typical rectangular 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.

For our circuit design we are proposing making the PCB voltage differential circuit two-sided by moving half of the op-amps, capacitors, and resistors to the other side. In addition, we want to add the voltage booster, which is currently a separate PCB, to the voltage differential circuit in order to only have one PCB total in our control box.

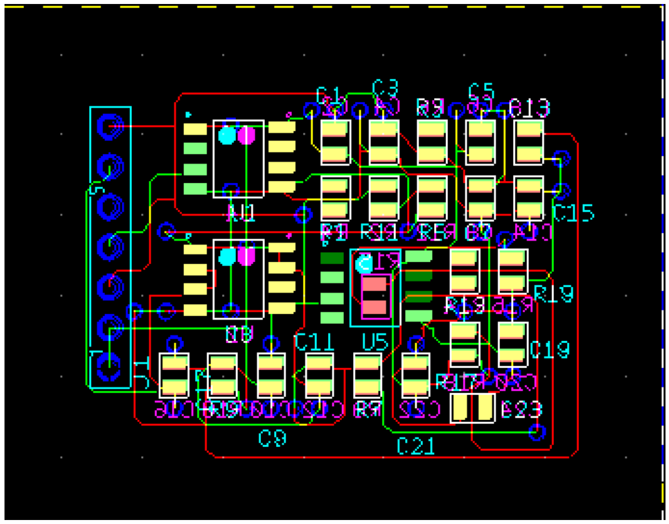

Figure 2. Proposed circuit PCB design

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 design and have been working to cut the size of the circuit by 75%. One way to reduce the size is to make the circuit PCB double sided. By adding components for the circuit to both sides we are able to cut the size of the circuit to half the size. We then proceeded to add a power booster to the PCB rather than using an additional power booster that greatly increased the size of our control boxes. After adding the power booster to our PCB design, we have effectively decreased the size of our control box by 75%.

3 Testing and Implementation

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.

3.2.1 HARDWARE AND SOFTWARE TESTING

Testing for the in-soil sensor has yet to be completed. We have recently created a new design and are waiting on approval before 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 our functional circuit is completed we will begin simulating it with circuit simulation software, then testing it in the circuits lab.

3.2 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.

3.3 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

For the first semester, our primary focus has been to get most of the design phase completed. At the conclusion of the semester, we have mostly planned out what we are going to implement next semester. For the hardware, we have preliminary designs for a new sensor and a new control box. Both of the designs meet our functional and non-functional requirements and are within our limitations. Next semester, we just need to finalize the designs and then we will be able to start the fabrication process.

For the software, we have started working on the design for both the app and the server. Since the software components are somewhat dependent on the hardware we do not have everything fully designed. That said we have a good idea of what is needed and have a tentative course of action to take starting next semester.