A Printed Capacitance Sensor for Soil Moisture Measurement

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1. Summary

TDR (Time Domain Reflectometry) has been shown to give a good measurement of soil moisture by measurement of permittivity. However, TDR is expensive and not power efficient. This work describes an alternative approach to designing a soil moisture sensor that is also using the dielectric constant, but tackles some of the drawbacks of TDR. It is designed to infer the water content in soil by obtaining it's permittivity via the measurement of the capacitance of a PCB capacitor. The simple design of the sensor allows mass-manufacturing at a low cost, enabling a large number of the sensors to be deployed networked. This makes it ideal for those requiring soil moisture monitoring over a large area such as farmers, to do so without a large financial cost.

2. Motivation and results

The design of the soil moisture sensor is motivated by the currently available moisture sensor systems on the market, which tend to involve TDR or resistive measuring to infer the soil moisture content. The use of TDR is accurate but expensive with high power consumption [1] and the resistance-based sensors tend to lose precision if the soil makeup changes [2] eg the addition of fertilizer. The capacitance-based soil moisture sensor aims to keep the insensitivity to conductance variation of TDR sensors by obtaining the soil permittivity (via capacitance measurements) but designed in such a way as to reduce the cost and complexity of the sensor and associated measuring system itself.

The printing of parallel tracks on a PCB was chosen as the design for the capacitor (figure 1), allowing for a sensor design where the majority of the components are located on the PCB (reducing manufacturing complexities). The principle uses the fringing capacitance of the interdigitated electrode structure to allow measurements into the surrounding soil. Capacitance measurement is achieved by charging/discharging the capacitor repeatedly between two fixed voltages, using a comparator built into the MCU (figure 2). The sensor capacitance can be calculated using the time taken for a fixed number of charge-discharge cycles resulting in a simple technique that works well across the range of capacitances predicted (figure 3). This can be used to calculate the dielectric of the material surrounding it via calibration, which then leads to the measurement of the soil moisture.

Initial testing of the system using test capacitances show an excellent linearity with capacitance with the simple charge/discharge process These results show 10 discharge/charge cycles between 2.3V and 0.1V. Figure 3 shows the results, clearly demonstrating the capacitance is directly proportional to the time recorded by the microcontroller. It demonstrates that this is a viable way of measuring the capacitance of the sensor.

Initial tests in surrounding media also show results in keeping with the test results shown, and the extended paper will detail the associated low power logging system developed (not discussed here), together with soil trial results. In conclusion, this interdigitated electrode approach appears to be a viable, low-cost solution, allowing simple measuring electronics to be incorporated onto the PCB.

Word Count: 497

References:

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[2] F. Zazueta and J. Xin, "Soil Moisture Sensors", Pollution Prevention Regional Information Center, 1994. Available online: http://infohouse.p2ric.org/ref/08/07697.pdf (accessed on: 10- Dec- 2017).

Figure 1: Example capacitance-based sensor

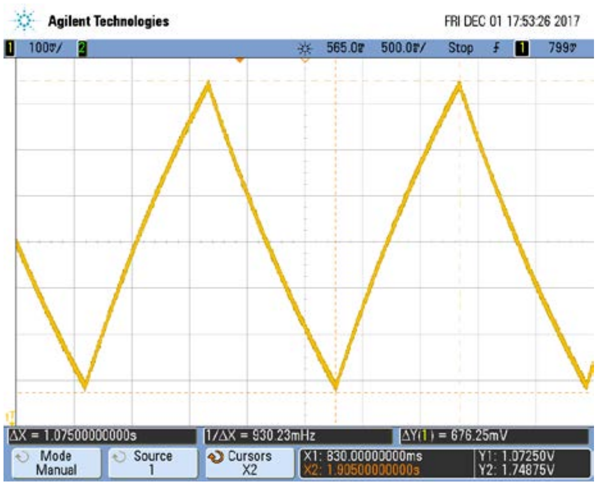

Figure 2: Example measuring waveform

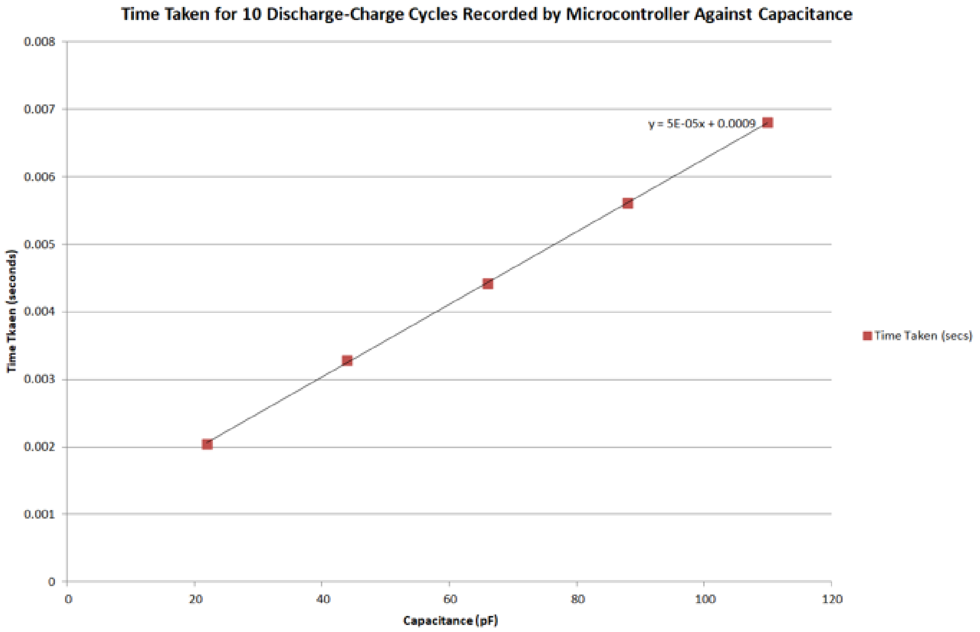

Figure 3: Comparison of capacitance against time recorded by microcontroller