A Capacitance-Based Soil Moisture Sensor using PCB-Printed Interdigitated Electrodes

UNIVERSITY OF Southampton

Alexander Stonard, Nick Harris

Department of Electronics and Computer Science, University of Southampton, Hampshire, SO17 1BJ, UK

Tel: +44 23-8059-3274   Email: nrh@ecs.soton.ac.uk

Motivation

1. People have to be fed!
2. Population rising to 9.7 billion by 2050 [1]
3. Major supply of food is agriculture
4. Water is a huge user of water in agriculture
5. Need to minimise wastage
6. Need for a very low cost ‘place and forget’ sensor for IoT enabled agriculture

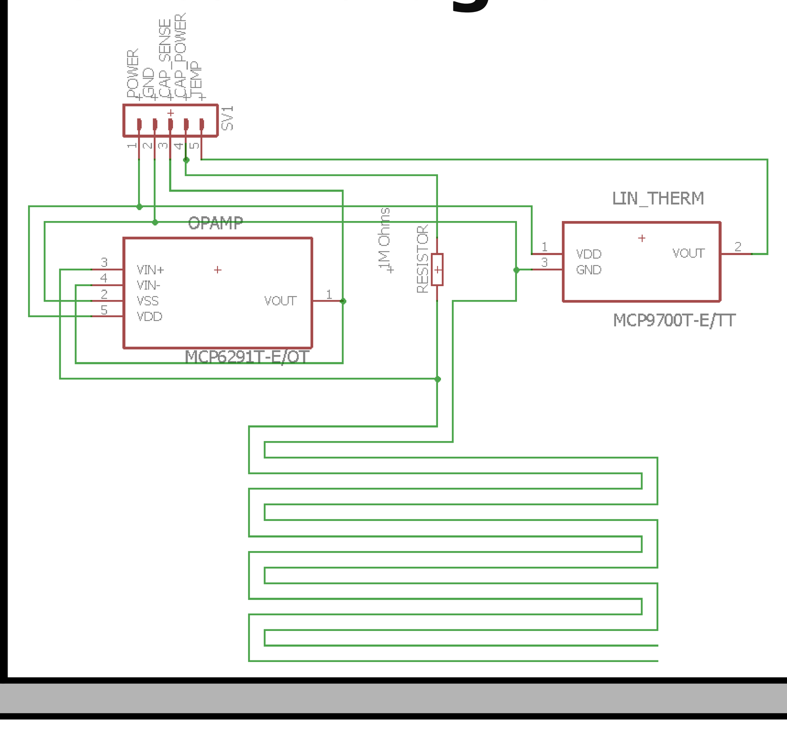
1. United Nations, Department of Economic and Social Affairs. Available online: http://www.un.org/en/development/desa/news/population/2015-report.html (accessed 20/06/2018).

Sensor Design

Simple manufacture via the printing of tracks on a PCB Costs are reduced as entire sensor system including electronics can be on a single PCB.

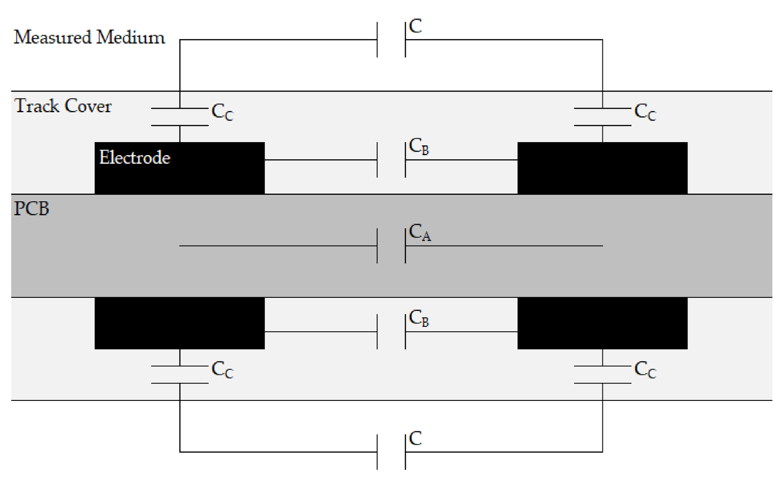
The prototype sensor (poster background) includes a buffer to the microcontroller taking measurements – stray lead capacitance affects are minimized. A 1MΩ resistor is in series with the capacitor which is charged and discharged under the control of the microcontroller. A temperature sensor is also present as an additional data point. No ADC needed. Fully digital measurement.

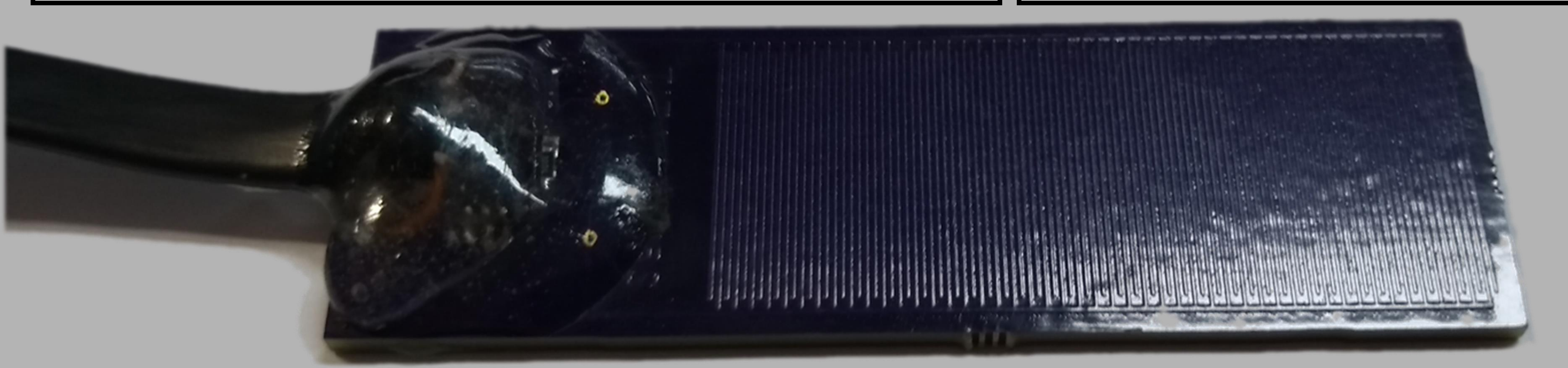
Circuit diagram



What is it?

Novel, low-cost soil moisture sensor. Designed for measurements in the ‘available water capacity’ range. Changes in the capacitance of the sensor are used to identify when the surrounding dielectric has changed – primarily due to changes in local water content.

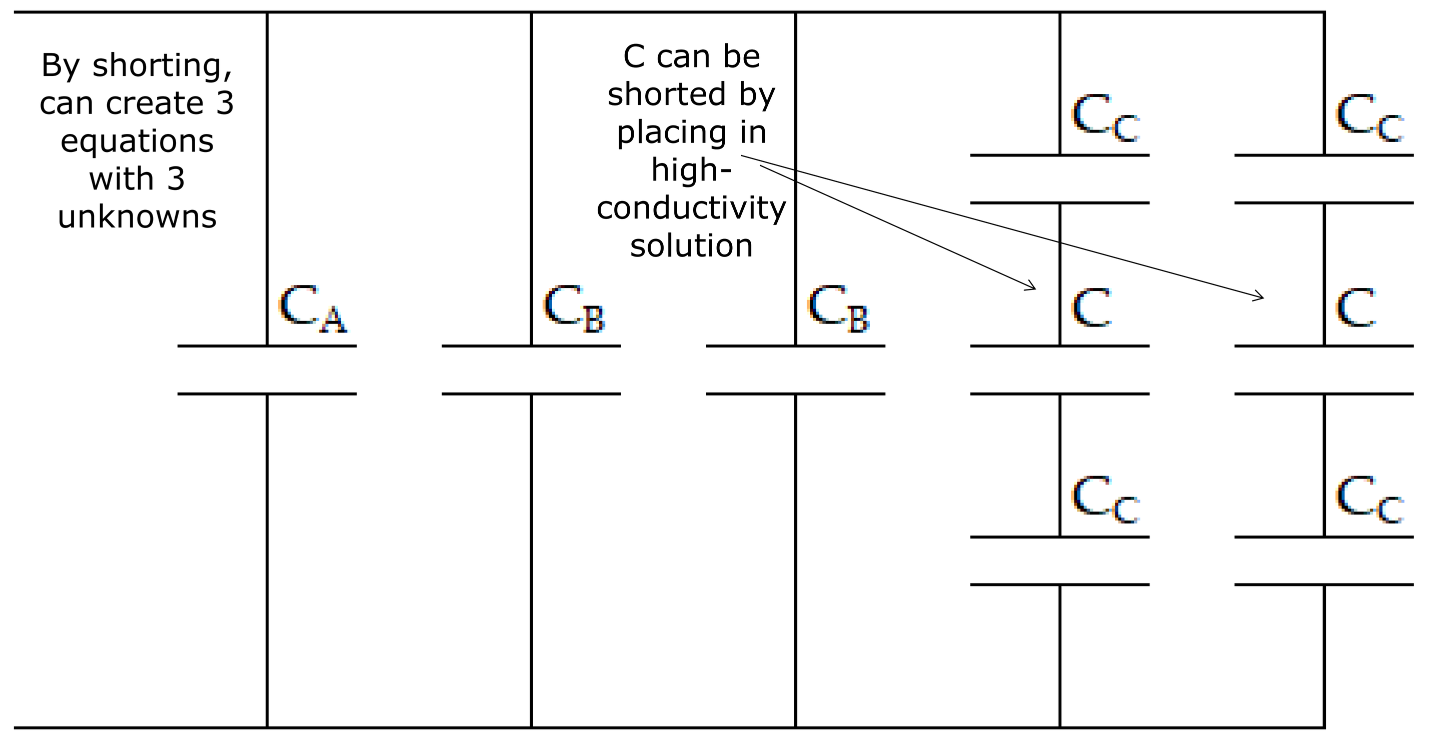




Sensor Model

C_{air} = ~80 C_{water}

C_C = 662.7pF, $C_A + C_B + C_B$ = 87.3pF, C_{air} = 8.6pF



Moisture Relationship

Water has a permittivity of around 80, while soil only has a permittivity of around 5 [2]. Change in water content thus has a big impact on the surrounding permittivity, making measuring dielectric changes a sensitive measure of soil moisture.

The surrounding medium (soil) makes up a partial dielectric of the capacitor (via fringe capacitance). As the permittivity of the soil changes, so does the fringe capacitance of the sensor. This change is measured.

2. Robinson, D. A.; Campbell C. S.; Hopmans , J.W.; Hornbuckle, B. K.; Jones, S. B.; Knight, R.; Ogden, F.; Selker, J.; Wendroth, O. Soil Moisture Measurement for Ecological and Hydrological Watershed-Scale Observatories: A Review. Vadose Zone Journal 2007, volume 7, pages 358-389, doi 10.2136/vzj2007.0143.

Experimental

Units: Volumetric Water Content

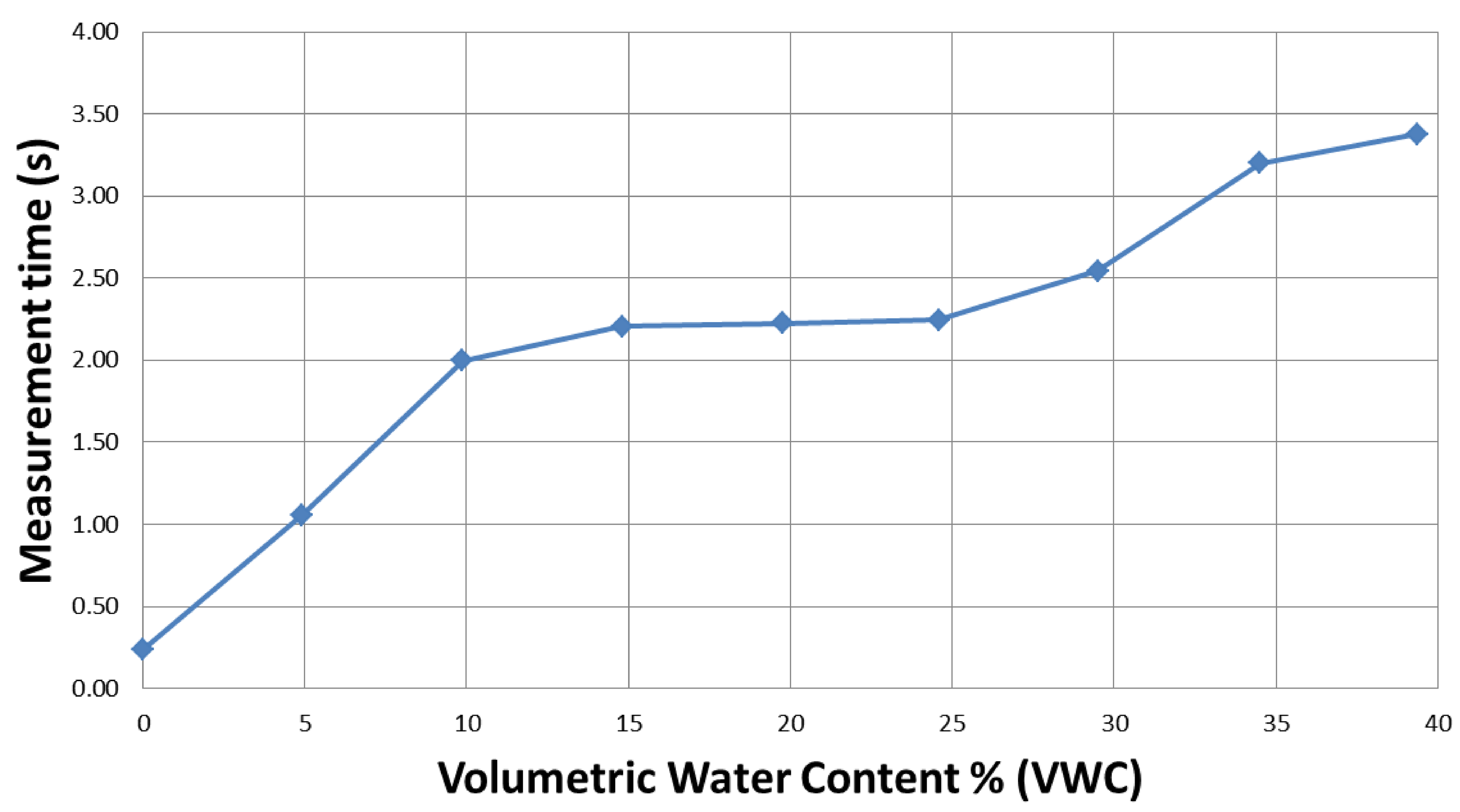
Permanent Wilting Point: 10-20%

Field Capacity: 30-35% VWC

Soil Type: Clay loam

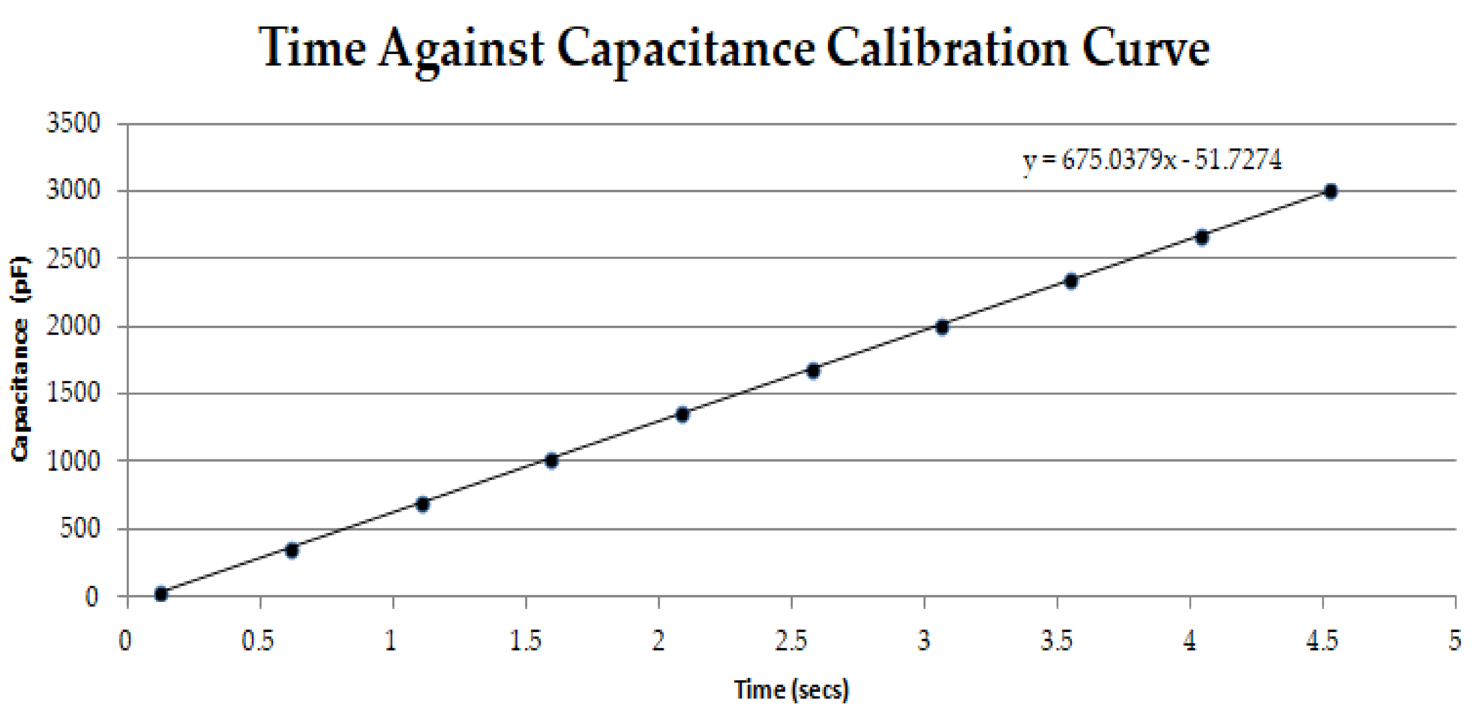
There is a clear relationship between sensor readout and soil moisture contents. Sensor is less sensitive between wilting point and just before field capacity. In future iterations of the sensor design, refinements will be investigated (such as hydrophobic coatings) combined with modelling to improve the range of operation.

VMC against time for 1000 Cycles



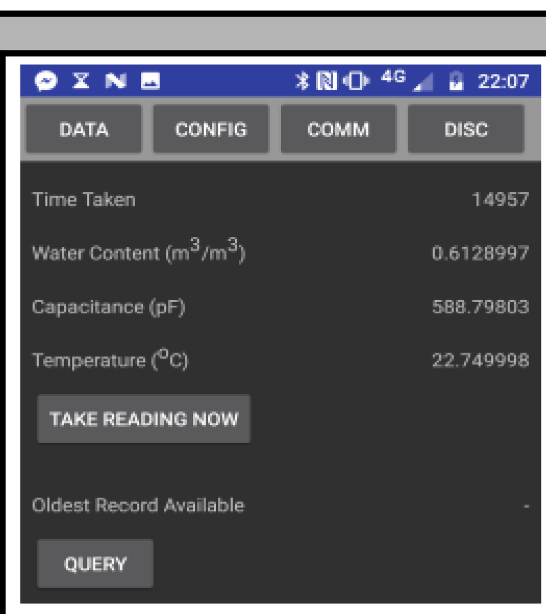
Measuring Capacitance

- Two voltage thresholds, upper (2V) and lower (1V)
- Charge capacitor when reached lower threshold (1V)
- Discharge capacitor when reached upper threshold (2V)
- Time 1000 discharge-charge cycles, relate this to capacitance
- Can be implemented on a low-cost microcontroller (two thresholds must be monitored with comparators)



An Example System

An Android app was produced that communicates with a Nordic Semiconductor NRF52832 microcontroller over Bluetooth. The microcontroller can periodically take readings and report them to the Android app on request, enabling an example Internet-of-Things sensor system.



Summary

This sensor design has a clear response to changes in the water content of the soil, showing a potential for being used as a low-cost but effective soil moisture sensor. Further investigation is required to increase sensitivity around the ‘flat line’ of the curve and to understand the sensor response to changes in soil types and soil salinity. This will involve refinement of the sensor manufacture based upon the model displayed here.

Acknowledgements

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