Development of a Compact Wireless Sensor for Electric Field Measurements

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Abstract

Measuring the electrical field strength generated by any charged surface is of great interest but can only be carried out by using rather bulky measurement devices. Depending on the material, which is exposed to varying environmental conditions, changes in the surface charges lead to a changing electric field strength in its vicinity. In this paper we describe the development of a compact sensor, based on a variable plate capacitor electrostatic voltmeter principle, to quantify the field strength. The measurement result of the system is verified with a commercial field mill device, showing a close correlation. The presented solution, therefore, can be used as simple measurement unit for electric fields and in a wider sense for surface charge detection.

1 Introduction

Nowadays, the measurement of electric fields and their corresponding charged surfaces is of great interest, due to its implications on for example handling of sensitive electronic devices. Non-contact measurements of DC fields are complicated due to the accumulation of random space-charges near the sensors, which interfere with the measurement done in the field of interest. Therefore, many devices for field measurements are either limited to AC measurements or use oscillating components to create such pseudo-AC fields.

In this work we present a method to evaluate the electric field caused by the charge of any surface, by using a facile circuit, based on the electrostatic voltmeter concept and near field communication (NFC).

2 Measurement Principle

For measuring an electrostatic field, several principles are applicable. The most common one is the electrostatic field meter, which is not applicable in the case where compact geometric dimensions are required, [1]. Another common principle is the electrostatic voltmeter, [2] which is implemented in this work.

A common technique for measuring a DC electric field *E*, originating from a surface under test, is to convert it into a pseudo-AC field, by oscillating one plate of a plate capacitor, while the other one is fixed (Figure 1), [3]. The current *I* at the capacitor plate is proportional to the voltage *V* across the capacitor and the temporal change of the capacitance *C* expressed by,

$$I = V\, dC/dt. \tag{1}$$

Equation 1 can be re-written as

$$I = -V\, \varepsilon\, A\, [D1 \omega \cos(\omega t)]/[D0 + D1 \sin(\omega t)]^2, \tag{2}$$

where *A* describes the capacitor electrode area, *D0* is the nominal distance between the tested surface and the electrode, *D1* is the vibration amplitude of the vibrating electrode, ω is the vibrating frequency and ε is the electric permittivity of the medium between the electrodes, which is air in the present case. The vibrating electrode is placed, such that the voltage can be measured with reference to ground.

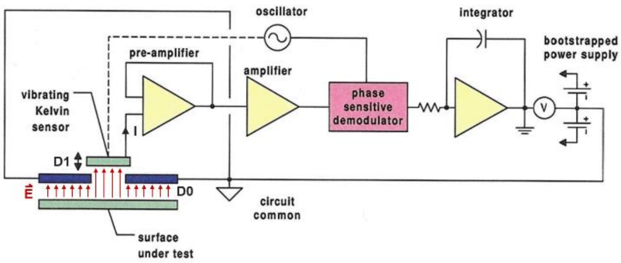

Figure 1 Schematics of the variable plate capacitor concept of an electrostatic voltmeter referenced to ground, (modified from [3]).

3 Implementation and Measurement Results

The principle, shown in Figure 1, can be realized in an efficient way by combining very few commercially available electronic components, due to their highly integrated functionalities. A simple microcontroller (µC), configures the lock-in amplifier, generates the main clock to drive the vibrating capacitor and performs the analog to digital conversion of the extracted signal amplitude, representing the electric field.

To provide the necessary power to drive the moving plate of the configuration and to ensure large values of the measured signals additional amplifier components are employed. Since the circuit has to be powered only during the measurement cycle, an NFC antenna with a corresponding harvesting circuit is implemented. An additional advantage of this technology is that beside the power supply, also the measured data can be transmitted for example to a cellular phone, where an APP processes the data and visualizes the

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result. Figure 2 depicts the arrangement of the electronic components in the system.

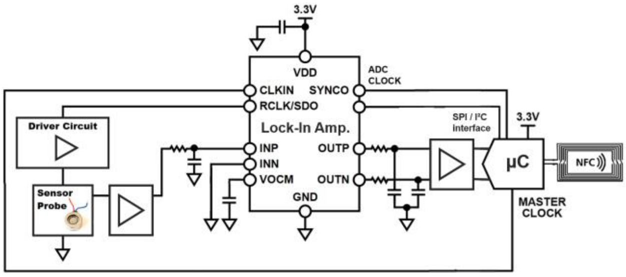

Figure 2 Block diagram of the implemented circuit.

Different measurements were carried out with the developed system and compared to a commercially available field mill device (KEYENCE SK-H050). Figure 3 shows a measurement result of one position on a charged surface, typically found in office environments and at ambient conditions. Note that the sensor has not been calibrated. The actual potential voltage that is indicated by the field mill device, can be determined by the sensor system if applying,

$$E = V / D1, \quad (3)$$

where V is the sensor output voltage and D1 the absolute mechanical amplitude of the vibrating capacitor plate.

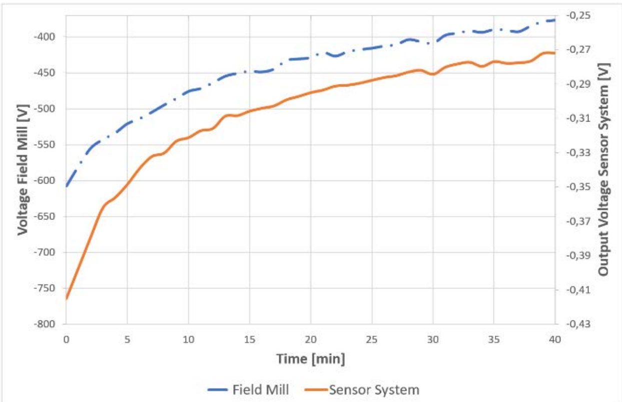

Figure 3 Measurement results and continuous characterizations comparison of a charged surface over time with both systems.

It turned out that the field strength measured initially differs quite a bit according to the position on the investigated material, which could even be verified by measurement with the reference field mill. The results show that during the measurement time, the field decreased, according to the discharging of the surface. This discharge occurred faster during the first couple of minutes, before approaching a linear discharge characteristic.

4 Conclusion

The developed method provides the capability to measure electric fields with a compact and wireless sensor system. It enables analyzing the charge state of the surface of a material, by applying an electrostatic voltmeter technology based on a vibrating capacitor. The results are verified with a reference field mill device. The results are in good agreement with the reference measurement over an extended period of time. The developed sensor system represents a suitable method for the indication of surface charges, and with the NFC based read out interface, various convenient user interface implementations are feasible.

5 Acknowledgement

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6 References

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