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Development of an AD5933-based Impedance Meter Prototype for Impedimetric Sensor Applications

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Abstract

This paper summarizes the progress done on the development of an impedance meter prototype. The prototype is to be a substitute for commercial equipment in reading impedimetric sensor for future portable applications. The prototype allows the impedimetric sensor to be excited with a frequency from 0.1-20 kHz. Autolab's "Dummy Cell 2" has been used as the Device under Test (DUT). The DUT's phase response to AD5933 Evaluation Board and Hioki IM3590 Chemical Impedance analyzer in the range of 0.1-20 kHz has been recorded and analyzed. It was found that the R-squared values of the regression lines were above 0.9 which indicates that AD5933 measurement is comparable to commercial equipment and suitable for impedimetric sensor application.

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1. Introduction

This project is an extension of a Science Fund project on Nitrate contamination detection in paddy granary areas. Currently, commercial impedance analyzer is used to analyze the impedimetric sensor measurement. However, a portable impedance reader dedicated for the impedimetric sensor measurement would make the sensor more desirable and easier to adopt on the field. Therefore, development of an impedance reader is duly undertaken. The reader would consist of an Analog Device AD5933 impedance converter Integrated Circuit (IC) and its corresponding circuit, calibration circuit, Analog Front End circuit, frequency multiplexer circuit and a microcontroller. In this paper, AD5933 Evaluation Board (EVAL-AD5933EBZ Rev. C) is used to determine the performance of AD5933 phase measurement by comparing it to commercial equipment and the result is discussed.

2. Material and Methods

Autolab "Dummy Cell 2" has been used as the DUT. The Dummy Cell has three electrical Resistor-Capacitor (RC) models. In order for the AD5933 IC to do proper estimation, it needs to be calibrated with reference impedance. The value of reference impedance is chosen based on the electrical RC model and the excitation frequency tested [1]. By its basic configuration, AD5933 can measure impedance from 1 kΩ to 10 MΩ in the frequency range of 1 to 100 kHz. To measure at lower frequencies and lower impedances, Analog Front End and frequency multiplexer circuits should be added to the AD5933 circuit. The AD5933 Evaluation Board has a built-in Analog Front End (AFE) to enable the impedance IC to measure low impedance [2]. To measure impedance at low frequencies, the default system clock of 16 MHz must be scaled. This means that for different frequency range, different system clock must be used, which necessitates the use of a frequency multiplexer circuit. In this experiment, Tektronix AFG3102 Function Generator has been used to provide the system clock as a substitute for the frequency multiplexer circuit.

The AD5933 IC includes a serial I^2C port as communication interface that allows the adjusting of sweep parameters, output excitation voltage (2 Vpp, 1 Vpp, 0.4 Vpp or 0.2 Vpp), PGA gain (x1 or x5) and calibration impedance value. Besides that, Direct Digital Synthesizer (DDS) settling time cycles and Calibration Gain Factor calculation method (Mid-point frequency calibration or Multipoint frequency calibration) can be adjusted as well. The transmission of the impedance data results is also done through the I^2C port. The AD5933 evaluation board has a USB microcontroller that converts the I^2C signals from the AD5933 to USB. It also comes with a computer program that can communicate with the AD5933 through USB. It can be powered up via the USB port but to ensure a stable power supply, Agilent E3631A Power Supply has been used.

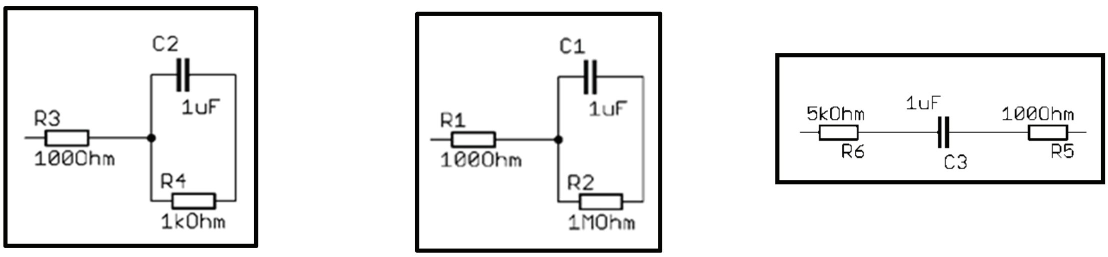

Fig. 1. Three electrical RC models of the dummy cell (a)WE(b); (b)WE(c); (c)WE(d)

HIOKI's IM3590 chemical impedance analyzer has been used to benchmark the performance of the AD5933 phase measurement. It has measurement frequency range of 1 mHz to 200 kHz and phase measurement accuracy of ±0.03° [3]. It can also perform high-speed sweep measurements in as little as 2 ms.

In this study, phase measurements have been conducted based on the following parameters on the DUT electrical circuits using both AD5933 and HIOKI:

- Excitation frequency range of 100-1000 Hz and clock frequency of 250 kHz (100-250 Hz excitation) & 1 MHz (250-1000 Hz excitation)
- Excitation frequency range of 1-3 kHz and clock frequency of 2 MHz
- Excitation frequency range of 3-20 kHz and clock frequency of 16 MHz

Result and Discussion

At first, system clock of 16 MHz was used to measure the phase across excitation frequency of 1-20 kHz frequency. The result shows that below ~3 kHz, AD5933 measurements degraded (Fig 2).

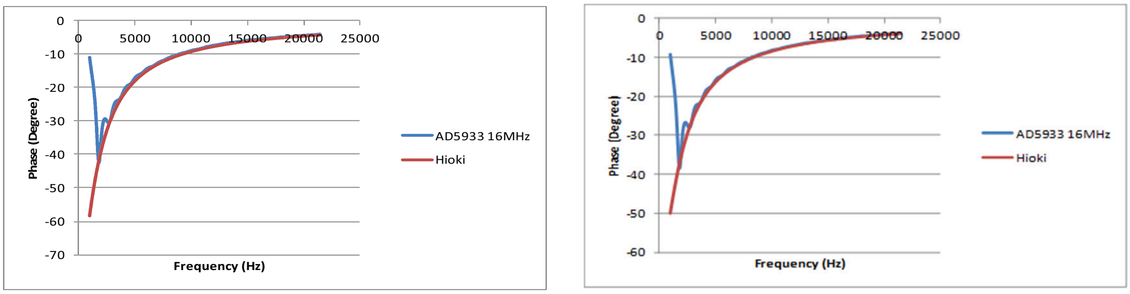

Fig. 2. AD5933 16 MHz clock vs Hioki measurement of the dummy cell (a)WE(b); (b)WE(c)

After configuring the AD5933 clock frequency according to evaluation board user guide [2], the R-squared values of the regression lines for phase measurements below 3 kHz were all above 0.9.

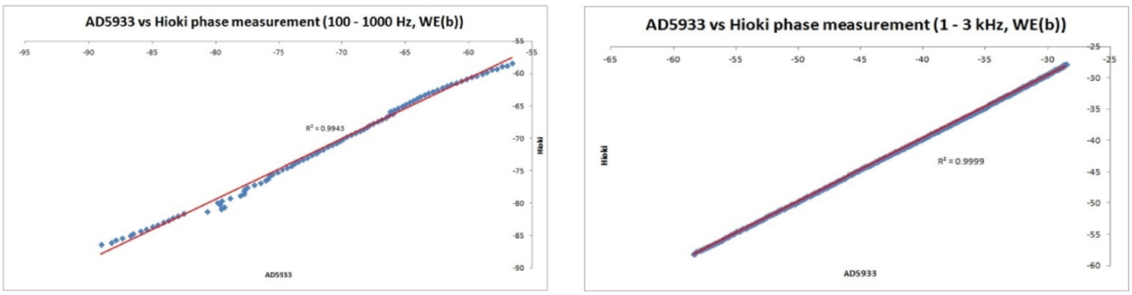

Fig. 3. AD5933 vs Hioki measurement of WE(b) after correction (a)100-1000 Hz; (b)1-3 kHz

3. Conclusion

AD5933 IC phase measurement is comparable to commercial equipment for the Autolab "Dummy Cell 2" based on the R-squared values of the regression lines. Therefore, AD5933 IC can potentially be used in the proposed impedimetric sensor system.

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