A Threshold Voltage Variation Calibration Algorithm for An ISFET-Based Low-Cost pH Sensor System

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***Abstract*— To utilize an ISFET in a low-cost pH sensor system, this paper presents an algorithm to calibrate V_{TH} variation of ISFET by one-time measurement of I_{DS}-pH curves of the reference ISFET and per-instance measurement of one I_{DS}-pH point of the instance ISFET. In our algorithm, the I_{DS}-pH curves of the reference ISFET are measured at various conditions once, and then a single I_{DS}-pH point of the instance ISFET is measured per instance for 6-pH PBS. From these two data, the calibrated I_{DS}-pH curve of the instance ISFET is acquired by fitting the reference I_{DS}-pH curve closest to the measured single I_{DS}-pH point of the instance ISFET into three-degree polynomial formula. In our experiment with PBS solution to verify our algorithm, our algorithm reduced mean absolute errors of the measured pH by 21 times from 4.31 to 0.2 compared with non-calibrated ones.**

Keywords—SiNW ISFET; ADC; DAC; Mean absolute error; Threshold voltage variation

I. INTRODUCTION

An ion-sensitive field-effect transistor (ISFET) which is a new type of electrochemical sensor was introduced by Bergveld [1]. By combining the principles of an MOS transistor and a glass electrode, these ISFETs can be used for measurements of ion activities in electrochemical [1]. In recent years, it has attracted great attention because of their biocompatibility, size compatibility, ultra-sensitivity, selectivity, label-free, and real-time detection capabilities [2].

Although ISFETs have many advantages as an electrochemical sensor, their extreme small sensing area and the existence of trapped charge result in irregular variation of the device's threshold voltage (V_{TH}) [3], [4]. The V_{TH} variation of ISFETs causes a variation in the sensing current, which leads to inaccuracy of the pH measurement [4]. Therefore, the calibration algorithm to compensate V_{TH} variation is required for mass-production of ISFET-based sensors.

In this paper, we propose a calibration algorithm of the V_{TH} variation. Our calibration algorithm requires two types of measurements: one-time measurement for drain-source current versus pH (I_{DS}-pH) curves of the reference ISFET and per-instance measurement of one I_{DS}-pH point of the instance ISFET. In our algorithm, the I_{DS}-pH curves of the reference ISFET are measured at various conditions once, and then a single I_{DS}-pH point of the instance ISFET is measured per instance for 6-pH phosphate buffered saline (PBS). By using these two data (reference and instance one), we can calibrate the V_{TH} variation of each instance ISFET. The calibration algorithm is implemented and evaluated on a portable low-cost pH sensor system (Fig. 1)

The rest of this paper is organized as follows. The target low-cost pH sensor system is described as the environment of the proposed algorithm in Section II (Background). The

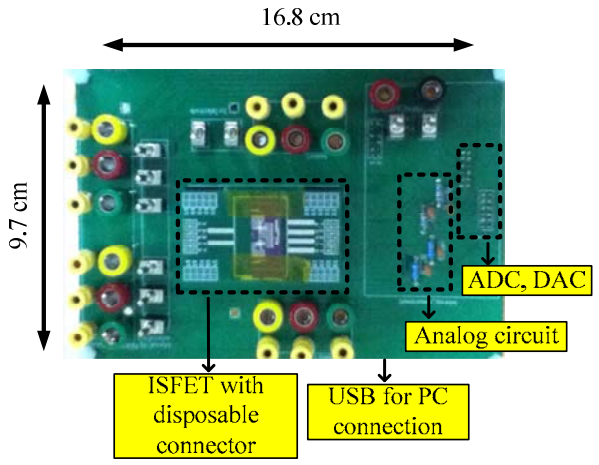

Fig. 1. The photograph of the pH sensor system in which our algorithm is implanted. (size: 16.8cm × 9.7cm)

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