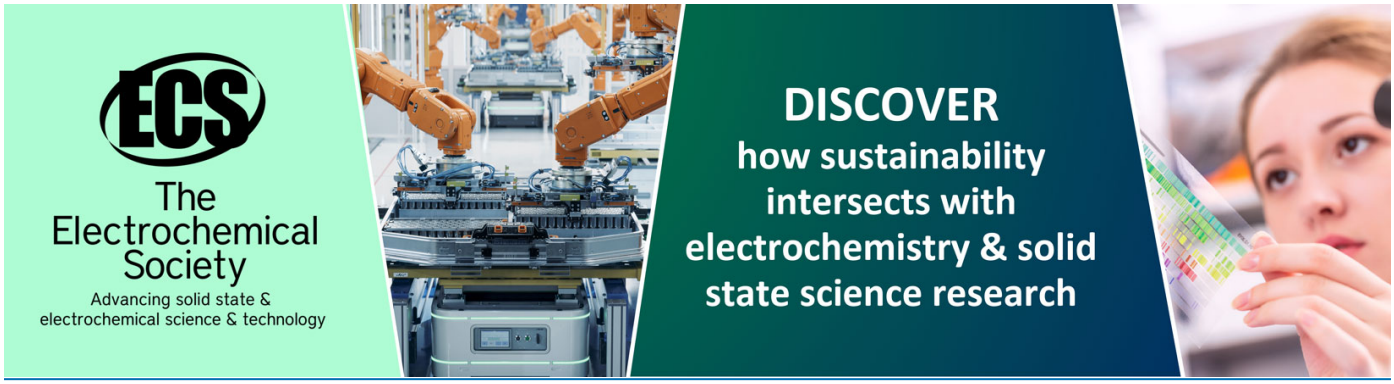
A humidity compensation method for a temperature and humidity sensor



A humidity compensation method for a temperature and humidity sensor

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Abstract. This paper introduces the method of humidity compensation in the temperature and humidity sensor to improve the measurement accuracy of humidity. The nonlinearity of humidity and humidity affected by temperature are compensated in circuit and data processing respectively. On the circuit, the sampling principle and the structure of the operational amplifier in the design are introduced. The data processing is mainly polynomial fitting of the chip test data by MATLAB software, so as to improve the humidity measurement accuracy. After the final fitting, the humidity error can reach ±1.5RH in the range of 10 ºC to 50 ºC.

1. Introduction

People's lives are closely related to humidity, and with the development of The Times, it is difficult to find a field that has little to do with humidity. Therefore, how to accurately obtain the humidity in the environment is very important [1]. Now the humidity sensor is mainly divided into two kinds: resistive and capacitive. The principle of capacitive humidity sensor is that the dielectric constant of humidity sensitive material changes with the change of humidity, which is further shown as the capacitance value changes. Because the capacitive humidity sensor is easy to integrate, high sensitivity, so its principle is widely used in the integrated humidity sensor. Because humidity is closely related to temperature, it is generally a sensor integrated with temperature and humidity.

This paper mainly introduces how to compensate the humidity of the temperature and humidity sensor to improve its humidity accuracy. The structure of this paper is arranged as follows: The second section mainly introduces the basic principle of circuit design in this paper, the third section is the nonlinear compensation method of humidity under constant temperature, the fourth section introduces the nonlinear compensation method of humidity under temperature change, and the last section is the summary of the whole paper.

2. Basic principles of circuit design

2.1 Sampling circuit principle:

The sampling part of the circuit uses the switching capacitor sampling circuit, Vin is the input voltage[2], S is the switch, and its principle is as follows:

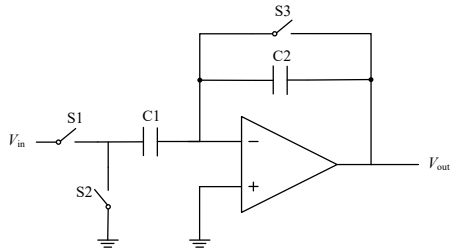

Figure 1 sampling circuit

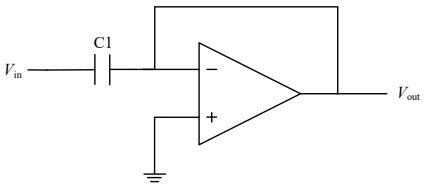

Figure 2 The sampling period

Sampling stage: switches S1 and S3 are closed, S2 is disconnected, and the charge quantity of capacitor C1 Qc1 is:

$$Q_{C1} = V_{in} * C1 \quad (1)$$

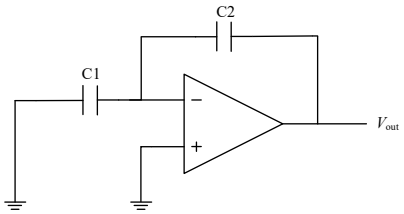

Figure 3 The sampling period

Integration stage: switch S2 is closed, S1 and S3 are disconnected. Since the voltage at both ends of capacitor C1 is 0V[3], the capacitor on capacitor C1 is transferred to capacitor C2, so the output voltage Vout is:

$$V_{out} = \frac{Q_{C2}}{C2} = \frac{V_{in} * C1}{C2} \quad (2)$$

When humidity is measured, the input voltage Vin is the reference voltage output by the bandgap reference circuit, which is used to charge the humidity sensitive capacitor. When humidity changes[4], the capacitance value of the humidity sensitive capacitor changes. According to Formula (3), the transferred charge changes [5], so as to realize the sampling and integration of humidity signal. The principle of temperature measurement is basically the same, except that the input voltage proportional to temperature charges the sampling capacitor[6].

2.2 Gain enhanced operational amplifier

In this design, a first-order Sigma-Delta ADC structure is adopted. The circuit used mainly affects the performance of the integrator, that is, the performance of the operational amplifier. The gain-enhanced operational amplifier [7] adopted in this design improves the output impedance through two auxiliary operational amplifiers, thus improving the gain.

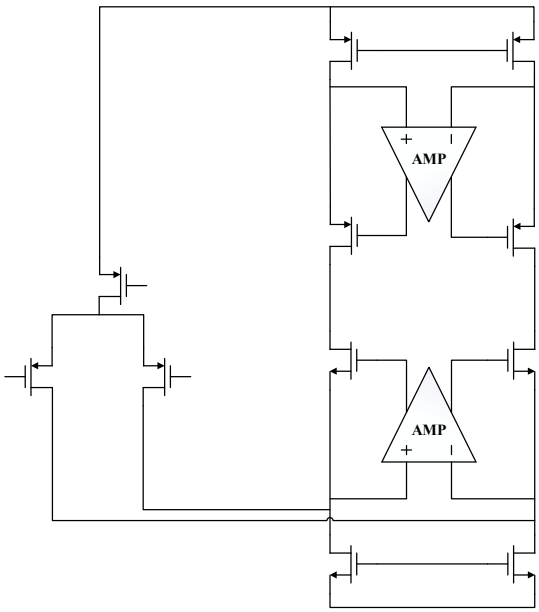

Figure 4. Gain enhanced operational amplifier

3. Constant temperature humidity compensation

After a lot of tests, it is found that there is a nonlinear relationship between humidity and hygrocapacitance at constant temperature, as shown in Figure 5[8]. It is difficult to compensate the nonlinearity from the analog circuit, but the accuracy of humidity can be significantly improved by processing the measured data from the perspective of data processing.

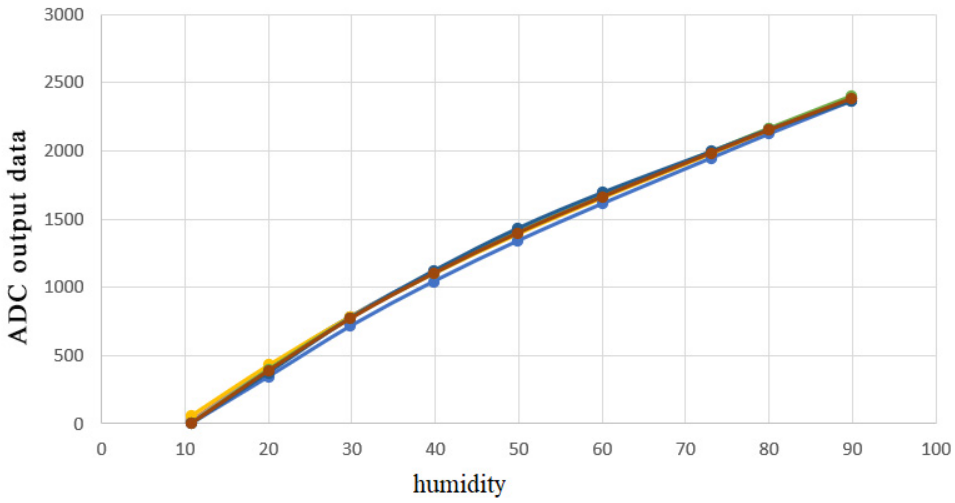

Figure 5. Graph of chip output data

Figure 6 and Figure 7 show the curve and humidity error of the chip after polynomial fitting of data by MATLAB software.

The steps of data fitting using MATLAB are as follows:

1. Use the readtable function to extract data from Excel files
2. Obtain the sub-term coefficients after data polynomial fitting by polyfit function
3. Obtain the fitted value through polyval function

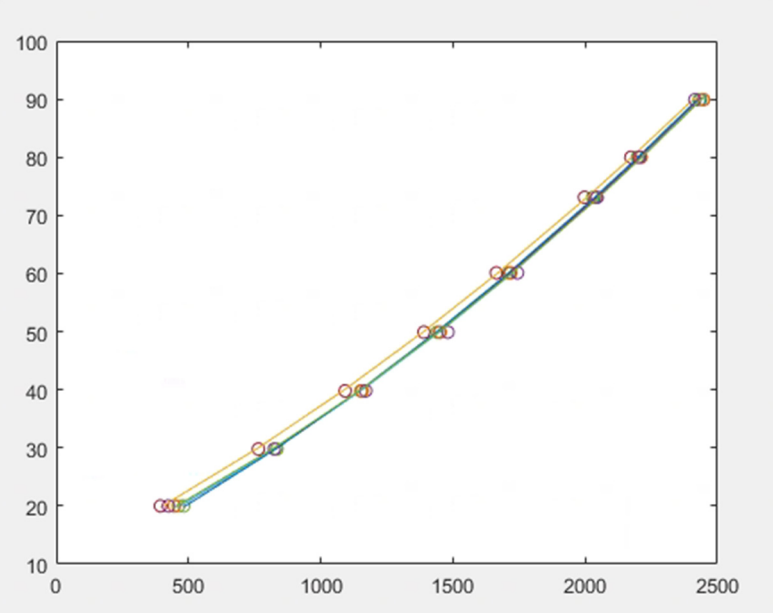

Figure 6 Fitting curve of test data of multiple chips

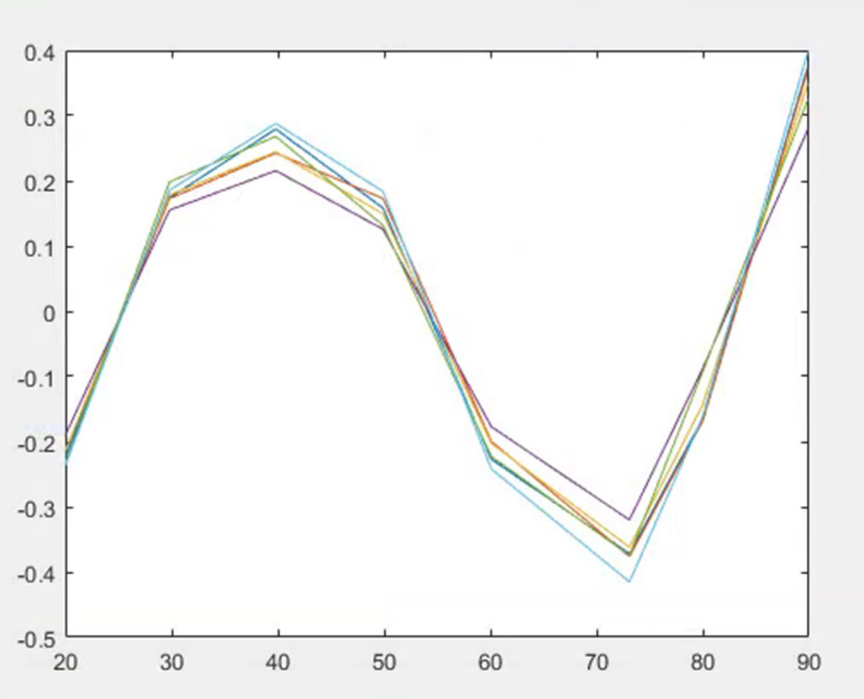

Figure 7 Humidity error curve after fitting

4. Compensation for temperature characteristics of humidity

The input of the humidity sensor will also be affected by different temperatures, especially under high humidity conditions. The specific test data is shown in Figure 8.

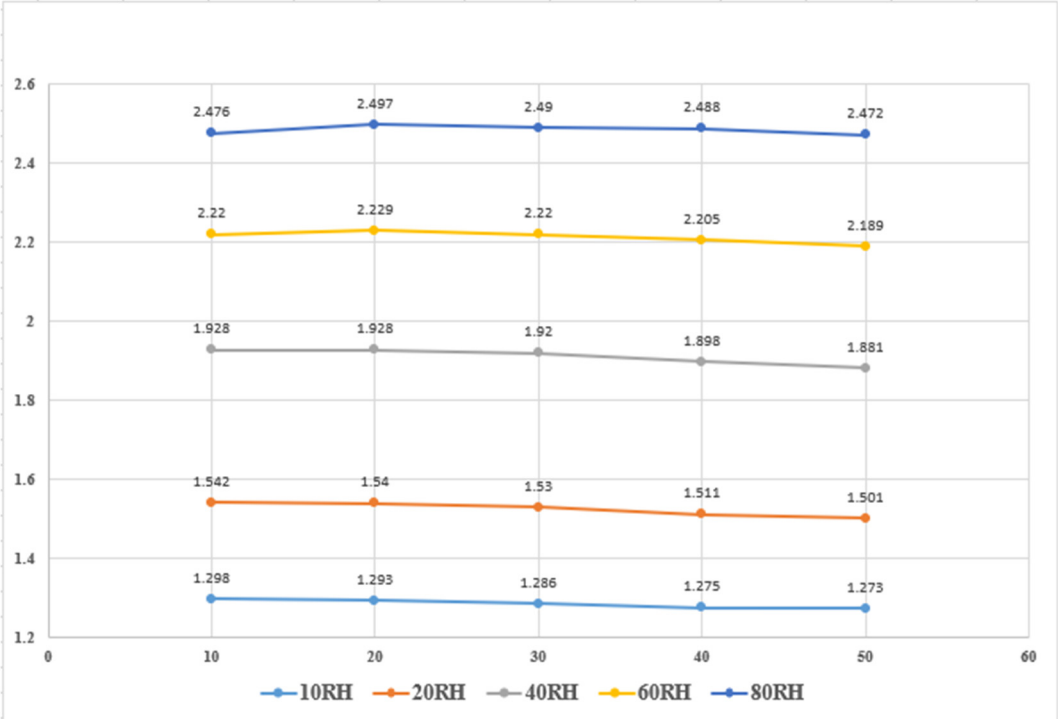

Figure 8 Humidity sensitive capacitance curve with temperature

It can be found from the curve that the humidity sensitive capacitance and temperature change can be approximately negative correlation. The compensation is mainly carried out from two aspects[9]. One is through circuit modification. When humidity sampling is carried out, the input PTAT voltage is compensated by appropriate coefficient, as shown in Figure 9[10]. Second, polynomial fitting was carried out for the output humidity data and temperature data. Finally, the humidity error after fitting was shown in Figure 10, which could be within ±1.5 within the range of 10ºC to 50ºC[11].

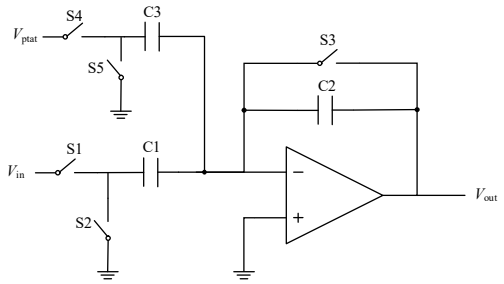

Figure 9. Principle of temperature characteristic compensation circuit for humidity

$$V_{out} = \frac{V_{ptat} * C3 + V_{in} * C1}{C2} \quad (3)$$

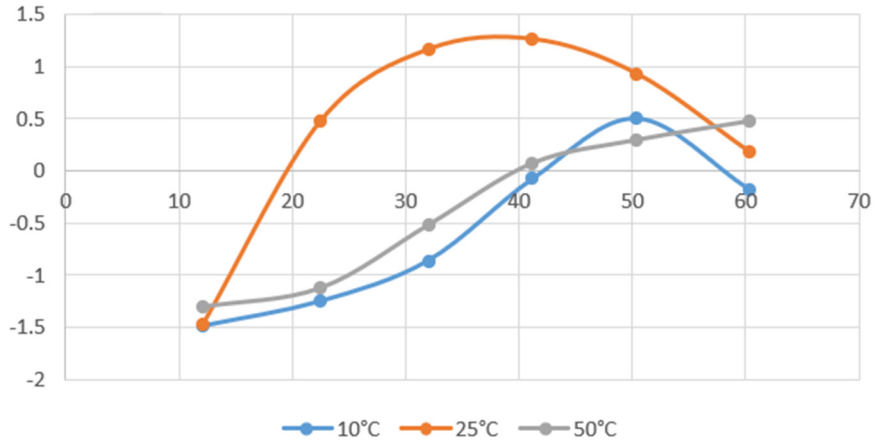

Figure 10. Humidity error curve after temperature compensation and fitting

5. Conclusion

This paper presents a reliable method to improve the accuracy of temperature and humidity sensor, and introduces the basic principle of switching capacitance sampling and the structure and principle of gain enhanced operational amplifier.At the same time, the nonlinear problem of humidity in the temperature and humidity sensor is analyzed, and the nonlinear problem of humidity itself and the influence of temperature on humidity are analyzed and the compensation method is proposed.The results show that this method can improve the accuracy of humidity sensor and has reliability.

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