Research on Liquid Concentration Measuring Instrument

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Abstract. In order to measure the concentration of different liquids, a new type of sensor is used to detect the small capacitance change. When a thin copper sheet is inserted into the solution, when the liquid concentration changes, the capacitance of the copper plate to ground will change. Fdc2214 is used to sense the change and convert it into digital quantity, which can be measured by various microprocessors through IIC output.

Keywords: Brine Concentration Measurement, Capacitance Sensing, Electronic Scale, Ultrasonic Ranging

Introduction
Liquid concentration detection is widely used in water resources protection. It can be measured by ultrasonic.

In ultrasonic measurement, a lot of calculation is needed, with high algorithm complexity and low measurement accuracy [1-4].

The capacitance sensing technology proposed in this paper is a non-contact measurement technology. Sensor is used to detect capacitance change, ultrasonic wave is used to measure the height and volume of liquid.

Electronic scale is used to measure the weight of liquid, and ultrasonic wave is used to measure the height and volume of liquid. Multiple data fusion for analysis and processing can improve the measurement accuracy and effectively remove the interference.

1. System Design
Firstly, the system is designed, and the block diagram is shown in Figure 1. Stm32h743iit6, a new type of embedded microprocessor, is used for the main control in the figure. It has rich IO interfaces, multiple IIC interfaces and a / D acquisition interfaces, which can meet the design requirements.
2. Hardware Circuit Design

2.1. The Basic Principle of Capacitance Sensing

The capacitance can be calculated by the following formula:

\[
C = 8.85 \times 10^{-12} \times \left( \frac{\varepsilon \cdot A}{d} \right)
\]  

In formula (1), D is the distance, A is area.

It can be seen from formula (1) that the dielectric constant \( \varepsilon \) will change with the change of liquid concentration, resulting in the change of capacitance C.
In the above formula, \( f_r \) in formula (4) is basically unchanged, bring it into formula (5) to get the changed 28 bit binary number \( DATA_0 \).

2.2. Capacitance Detection Principle

Figure 3 is the schematic diagram of liquid concentration detection. We use three channels of fdc2214 to detect the change capacitance of air, the change capacitance of liquid and the capacitance change caused by the change of liquid level.

2.3. Electronic Scale

The hardware circuit of electronic scale is shown in Fig. 4, in which bridge type pressure sensor is used. When the weight of the object changes, it will cause the change of resistance value and convert it into voltage value. It is processed by 24 bit a / D acquisition chip, and the results are sent to the microprocessor. The measurement accuracy can reach 1g.
In formula (6), \( D \) is the converted digital quantity of hx711. \( W \) is the calculated weight of the object.

### 2.4. Design of Ultrasonic Ranging Circuit

The ultrasonic distance measurement module of serial port is shown in Figure 5. The ultrasonic distance measuring circuit can detect the liquid level height, convert it into 16 bit digital quantity, and send it to the microprocessor through the serial port.

\[
D = H\_DATA \times 256 + L\_DATA
\]

3. Software Design

#### 3.1. Software Flow

The software is written in C language, compiled in keil MDK development environment, and then downloaded to the microprocessor stm32h743iit6. Firstly, the serial port, SPI, IIC, a / D acquisition interface and timer of stm32h743iit6 are initialized. After initialization, IIC interface is used to read capacitance sensing values; pressure bridge data is read from a / D acquisition interface and converted into corresponding weight value; ultrasonic ranging value is read from serial port to calculate water level height. Because of the interference, the above data should be collected many times, and the mean filtering algorithm is used to remove the interference [5-7].

#### 3.2. Software

```c
void TIM6_Init(u16 arr, u16 psc)
{
    RCC_APB1PeriphClockCmd(RCC_APB1Periph_TIM6, ENABLE);
    NVIC_PriorityGroupConfig(NVIC_PriorityGroup_2);
    TIM6->DIER = 0x0001; bPriority = 0;
    RCC_APB1PeriphClockCmd(RCC_APB1Periph_TIM6, ENABLE);
    NVIC_InitStructure.NVIC_IRQChannelCmd = ENABLE;
}
```

```c
extern long proximityDataMAX, proximityDataMAX2;
extern long frequencyDataMAX, frequencyDataMAX2;
extern unsigned long ch0, ch1, ch2, ch3;
extern int proximityDataMIN, proximityDataMIN2;
extern int frequencyDataMIN, frequencyDataMIN2;
extern char proximityData[2];
extern char frequencyData[3];
```
extern char proximtyData2[2];
extern char frequencyData2[3];
#include "timer.h"
#include "led.h"
#include "utils.h"
#include "stm32f10x.h"
#include "delay.h"
#include "LDC1000.h"
#include "lcd.h"
#include "gui.h"
#include "LDC1314.h"
#include "oled.h"
#include "DataScope_DP.h"

u16  TIM1CH1_CAPTURE_STA=0;
u16 TIM1CH1_CAPTURE_VAL;
u16  TIM2CH1_CAPTURE_STA=0;
u16 TIM2CH1_CAPTURE_VAL;
u16  TIM2CH2_CAPTURE_STA=0;
u16 TIM2CH2_CAPTURE_VAL;
u16  TIM2CH3_CAPTURE_STA=0;
u16 TIM2CH3_CAPTURE_VAL;
u16  TIM2CH4_CAPTURE_STA=0;
u16 TIM2CH4_CAPTURE_VAL;

void TIM7_IRQHandler(void)
{
    unsigned char Send_Count;   unsigned char i;
    if(TIM7->SR&0x0001)
    {
        SPI2_LDC1000_ReadBytes(LDC1000_CMD_PROXLSB,&proximtyData2[0],2);
        SPI2_LDC1000_ReadBytes(LDC1000_CMD_FREQCTRLSB,&frequencyData2[0],3);
        proximtyDataMAX2 = ((unsigned char) proximtyData2[1]<<8) + proximtyData2[0];
        frequencyDataMAX2 = frequencyData2[2]*65536+frequencyData2[1]*256 + frequencyData2[0];
        LCD_ShowChar(100,80,BLUE,WHITE,(((frequencyDataMAX2)%10000)%1000)/100+0x30,12,1);
        LCD_ShowChar(106,80,BLUE,WHITE,(((frequencyDataMAX2)%10000)%1000)%100/10+0x30,12,1);
        LCD_ShowChar(112,80,BLUE,WHITE,(((frequencyDataMAX2)%10000)%100)%100/10+0x30,12,1);
        LCD_ShowChar(118,80,BLUE,WHITE,(((frequencyDataMAX2)%10000)%100)%100%10+0x30,12,1);
        ch0=LDC_read_CHx(0);
        ch1=LDC_read_CHx(1);
        ch2=LDC_read_CHx(2);
        ch3=LDC_read_CHx(3);
    }

4. Test
After debugging, the test sample is made. In the figure, the bottom right corner is stm32h743iit6 module, with fdc2214 module and pressure bridge hx711 module in the middle; the upper right corner is 4.3 inch RGB true color screen; the upper left corner is the ultrasonic distance measurement module, which is placed directly above the glass container to measure the height of liquid level. The thin copper plate is 15cm * 10.5cm single-sided copper clad plate, one end of which is inserted into the
liquid, and the other end is exposed to the air. Glass containers are round vessels with a diameter of 16 cm and a height of 21 cm [8-10].

Part of the data is given below, as shown in Table 1.

**Table 1. Measurement results**

| Total weight(g) | Liquid level height (cm) | Capacitance sensing value | Brine concentration(%) |
|-----------------|--------------------------|---------------------------|------------------------|
| 103             | 53                       | 22289                     | 0.65                   |
| 207             | 58                       | 22278                     | 1.172                  |
| 309             | 63                       | 22271                     | 1.536                  |
| 411             | 69                       | 22264                     | 1.84                   |
| 513             | 73                       | 22257                     | 2.078                  |
| 615             | 78                       | 22251                     | 2.353                  |
| 716             | 83                       | 22245                     | 2.554                  |
| 817             | 88                       | 22239                     | 2.724                  |
| 918             | 93                       | 22233                     | 2.949                  |
| 1018            | 98                       | 22227                     | 3.074                  |
| 1119            | 103                      | 22220                     | 3.157                  |
| 1212            | 108                      | 22215                     | 3.252                  |

5. Conclusion

In this paper, the capacitance sensing technology is used to measure the liquid concentration, and the factors such as volume and weight are integrated to make the measurement result more accurate and reliable.

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