Design of Four Channel Data Acquisition System Based On Ldc1614

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Abstract. The four channel data acquisition software based on STM32F103 is used for metal detection and runs on the embedded processor STM32F103 series chip. The software can read ldc1614 metal detection value by STM32F103. The results are displayed on the display device.

Keywords: LDC1614t, Capacitance Sensing, STM32F103

1. Hardware Structure

1.1 System Design Block Diagram
The system design block diagram is shown in Figure 1. Stm32f103zet6 is used as the main control in the figure. The processor has 3 Hardware SPI interfaces, 8 timers, 3 serial ports and 144 pins. It is a 32-bit microprocessor based on cortex m3, with powerful functions and rich resources [1-5]. Ldc1614 transmits the collected data to STM32 through IIC serial bus. STM32 judges the position of iron wire according to the digital quantity collected by two channel sensors a and B in ldc1614. Control the running of the car. The 1.44 inch TFT true color screen is used as the display device to display the collected digital quantity and time information of sensors a and B.

![Figure 1. System block diagram](image)

1.2 Hardware Circuit Diagram
The hardware connection between stm32f103zet6 and ldc1614 is shown in Figure 2. Through SDA, SCLK two data lines interconnection to achieve high-speed data transmission. The sequence of reading and writing ldc1614 by stm32f103zet6 is shown in Fig. 3 and Fig. 4. Communication follows the standard IIC communication protocol. When the data is read first, the slave address is sent.

![Figure 2. Hardware circuit diagram](image)
1.3 Design of ldc1614 Sensor
The schematic diagram of ldc1614 is shown in Figure 5. In the figure, 1 pin of ldc1614 is SCL, which is the clock signal line in IIC bus. The 2-pin is SDA, which is the data line in IIC bus. They are respectively connected to the PE4 and pe5 pins of STM32. As common IO ports, PE4 and pe5 are used to transmit data with ldc1614 in the way of analog IIC. In order to ensure the reliability of transmission, 10K Ω pull-up resistance is connected to the pins. Ldc1614 adopts 3.3V power supply. In the figure, 9 pin in0a and 10 pin in0b of ldc1614 are IN0 input channels; 11 pin in1a and 12 pin in1b are in1 input channels; these two channels are respectively connected with self-made inductance coil and capacitor to form LC resonant circuit, and metal is detected through eddy current principle [6, 7].

![Figure 5. Connection diagram of STM32 and ldc1614](image)

The self-made coil is shown in Figure 3, which can be wound manually or drawn in Altium design and then processed. In Figure 3, the coil is drawn in a PCB with a diameter of 4cm. The coil in the figure is equivalent to an inductance, and a suitable capacitance is configured for the inductor. When there are metal objects on the outside, LC resonance will occur. The resonant frequency of LC is calculated by formula (1).

\[ F_{sen} = \frac{1}{\frac{F_{ex}}{F_{cnt}} \times RT} \]  

(1)

Where fsen is the LC resonant frequency, Fex is the external clock reference frequency, which is generated by ldc1614 internal crystal oscillator with the value of 4MHz, fcnt is the internal counter value of ldc1614, and RT is the response time set by the internal register of ldc1614. By calculating the reciprocal of both sides of formula (1) and making appropriate changes, formula (2) can be obtained.

\[ RT*(1/Fsen)=3*Fcnt*(1/Fex) \]  

(2)

In formula (2), 1 / fsen is the LC resonant period and 1 / Fex is the reference clock period. The frequency of the reference lc61t is recorded using the frequency of the reference lc614.

According to the principle of eddy current, in order to detect small metal, enough eddy current must be generated, and the inductance L must be increased. Through many experiments, an inductance coil with a diameter of 4cm is drawn. The thickness of the wire is 0.1mm, the inductance is 0.250mh, and the matching capacitance is 2.5nf. The detection distance of metal is 3cm. In order to increase the detection distance, the inductance and capacitance can be appropriately increased.
2. Working Principle of Inductive Sensor

The induction detection principle is the electromagnetic induction principle in physics. If an alternating current is added to the PCB coil or self-made coil (as shown in Figure 5), the alternating electromagnetic field will be generated around the coil. At this time, if a metal object (as shown on the right side of Figure 5) enters the magnetic field, eddy current (induced current) will be generated on the metal object. The eddy current is opposite to the coil current direction, and the induced electricity generated by eddy current is generated. The magnetic field is opposite to that of the coil. Eddy current is a function of distance, size and composition of metal objects [8-10].

The reverse magnetic field produced by eddy current is coupled with the coil, just as it produces another secondary coil. In this way, the coil of ldc1614 is used as primary coil, and eddy current is used as secondary coil to form transformer. As shown in Figure 6, the parameters of the secondary coil can be detected at one end of the primary coil due to transformer mutual inductance.

The equivalent parallel circuit of Fig. 6 is shown in Fig. 7. The oscillation circuit in Figure 7 consists of a closed-loop frequency selection circuit with gain. The criterion of starting vibration is (1) the gain is greater than 1. (2) The closed-loop phase shift is $2\pi$. In oscillatory condition, R-L-C determines frequency selection and phase shift. The frequency selection is shown in formula (1). In the circuit, RP (d) determines the driving current of the sensor, and the calculation method is shown in formula (3).
Here, C is the induced capacitance (ctank + CPAR) and l is the inductance L (d).

\[ Q = R_P \sqrt{\frac{C}{L}} \]  \hspace{1cm} (4)

Here, C and L are defined as formula (3), and RP is RP (d). In practical application, there is a certain curve relationship between RP and test distance, as shown in Fig. 8. In the figure, the test coil is 14mm PCB coil, and the test target is 2mm thick stainless steel sheet.

After RP and C are determined, the calculation formula of inductance L is shown in formula (5).

\[ L(d) = L_{inf} - M(d) = \frac{1}{(2\pi f_{SENSOR})^2 \times C} \]  \hspace{1cm} (5)

Where \( L_{inf} \) is the inductance of coil without inductor, \( M(d) \) is mutual inductance. Other definitions are the same as those in formula (3) and (4).

3. Software Design

Firstly, the serial port and IIC interface are initialized, and the data format, baud rate and parity check are set. Select whether the data format is 7-bit or 8-bit. Set the number of transfers, start the transfer, and check whether it is completed. If not, continue to transmit the next data and modify the count value until the end of the transfer.

After the initialization of SPI interface, the LCD screen can be initialized. Some codes are as follows.
The main codes are as follows:

```c
void LDC1612_Init(void)
{
    uint16_t deviceID = 0;
    IIC_Init();
    delay_ms(500);  //
    LDC_ADDR = 0;
    LDC_SD = 0;     LCD_write_16bit(LDC13xx16xx_CMD_CONFIG,0x2801);
    LCD_write_16bit(LDC13xx16xx_CMD_REF_COUNT_CH0,0xFFFF);
    LCD_write_16bit(LDC13xx16xx_CMD_REF_COUNT_CH1,0xFFFF);
    LCD_write_16bit(LDC13xx16xx_CMD_REF_COUNT_CH2,0xFFFF);
    LCD_write_16bit(LDC13xx16xx_CMD_REF_COUNT_CH3,0xFFFF);
    LCD_write_16bit(LDC13xx16xx_CMD_SETTLE_COUNT_CH0,0x0100);
    LCD_write_16bit(LDC13xx16xx_CMD_SETTLE_COUNT_CH1,0x0100);
    LCD_write_16bit(LDC13xx16xx_CMD_SETTLE_COUNT_CH2,0x0100);
    LCD_write_16bit(LDC13xx16xx_CMD_SETTLE_COUNT_CH3,0x0100);
    LCD_write_16bit(LDC13xx16xx_CMD_CLOCK_DIVIDERS_CH0,0X0001);
    LCD_write_16bit(LDC13xx16xx_CMD_CLOCK_DIVIDERS_CH1,0X0001);
    LCD_write_16bit(LDC13xx16xx_CMD_CLOCK_DIVIDERS_CH2,0X0001);
    LCD_write_16bit(LDC13xx16xx_CMD_CLOCK_DIVIDERS_CH3,0X0001);
    LCD_write_16bit(LDC13xx16xx_CMD_ERROR_CONFIG,0X0000);
}
```

4. Summary

Because the induced magnetic field will decay rapidly when the distance exceeds the coil diameter, it is suggested that the target distance should not exceed the coil diameter to ensure the accuracy. When moving within a certain range, the variation of every um also presents regular changes. According to this, the measurement accuracy of moving objects can be close to UM level. Figure 10 describes the change of the digital quantity and inductance value read when the test object moves from 0 mm to 100 mm. The black line represents the code value, the red line represents the inductance, and the tested object is 14mm × 25mm aluminum sheet.

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