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Multi-Channel Weighing Acquisition Control System Design

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Abstract

This paper first analyzes the working principle of several sensors, application occasions to compare their advantages and disadvantages, and selects the resistance strain transducer for the acquisition of weighing signals. Subsequently from the signal conditioning channel research and design, analog-to-digital conversion unit design, data processing unit design, output channel design, power supply processing unit design from the detailed description of the hardware design of the two-channel data acquisition system. Finally, the software design of the system is given, and a two-channel weighing acquisition control system is realized.

Keywords

Resistive Strain Sensors; Analog Filtering; Digital Filtering.

1. Introduction

Sensor technology is an important technical foundation for the modern information society, with sensors being the primary components of various information acquisition systems [1]. With the development and widespread adoption of science and technology, particularly in computer and electronic technologies, the use of sensors for information collection, detection, and measurement is becoming increasingly prevalent across various fields. As one of the most common sensor technologies, weighing technology is widely used in coal, petroleum, chemical industries, electric power, light industry, metallurgy, mining, transportation, ports, construction, machinery manufacturing, agriculture, national defense and other fields. A large part of the transformation of material flow into capital flow in industrial and agricultural production is achieved through weighing information flow [2]. Nowadays, with the development of electronic technology, sensor technology and corresponding digital processing, high-precision, high-stability, miniaturized, modular, and intelligent digital weighing acquisition systems have become a significant trend. This system represents a crucial direction in the development of modern weighing measurement and control system engineering.

2. Sensor Selection

Sensors are capable of sensing measured signals and converting them into usable output signals according to a certain pattern. The output signal required for this paper is a voltage signal, which serves as the key component of the entire weighing acquisition system. The most commonly used types of load cells include photoelectric, electromagnetic force, capacitive and resistive strain sensors.

Photoelectric weighing sensor also includes grating type and code disc type. This type of sensor offers anti-electromagnetic interference, corrosion resistance and electrical insulation, along with good long-term stability and ease of networking [3]. It is primarily used in electromechanical combination scales designed for harsh industrial environments. However, its accuracy is relatively low, and most applications involve large tonnage. Additionally, the general size of these sensors is larger, making them unsuitable for applications requiring small ranges. Furthermore, the operating speed is relatively low, which does not meet the demands of high-speed weighing.

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Electromagnetic force balance sensor operates on the principle that the gravitational force of the object placed on the load table is counterbalanced by an electromagnetic force [4]. These sensors are highly accurate, with precision ranging from 1/2000 to 1/60,000; however, their weighing range is limited to a few tens of milligrams up to 10 kg. They are primarily utilized in small-range electronic balances, which do not satisfy the range requirements outlined in this paper.

Capacitance weighing sensor is a type of sensor that converts measured mechanical quantities, such as displacement and pressure, into changes in electrical capacitance [5]. Capacitance weighing sensors are not suitable for use in harsh environmental conditions, high humidity, dust, and heavily polluted air, as these factors can adversely affect test results.

Resistive strain sensor has a wide weighing range, from 300g to several thousand of kilograms, and offers high measurement accuracy, ranging from 1/1000 to 1/10,000. This performance meets both the specified range and sensitivity requirements outlined in the title [6]. Additionally, the sensor features a simple structure, high reliability, long lifespan, and excellent frequency response characteristics.

Through a comparative analysis of various types of sensors, considering the advantages of resistive strain sensor, its extensive wide range of application and the current state of technic, the design of this paper's weighting transmitter is based on the resistive strain sensor.

3. Design Proposals

3.1 Program Overview

A multi-channel weighing acquisition control system is required, featuring two input and output channels with weight ranges of 4kg and 80kg respectively. The sensitivities of the sensors for the input channels are 2mv/0.001kg and 1mv/0.01kg, while the resolutions of the corresponding transducers are 0.001kg and 0.01kg, respectively. The input sensors convert the measured weight signals into voltage signals with resolutions of 0.001kg and 0.01kg. The signal frequency for the input channels is less than 1 kHz, and these channels are subject to high-frequency noise. The operating temperature range for the test system is -40C° to 60C°. The output channel employs a proportional control valve: 0-10V input, corresponding to the valve's transition from closed to fully open. The required A/D and D/A converter chips for a sampling period of less than 5ms are the AD976 and TLV5620C, respectively.

3.2 System Structure

The interface structure of this design is shown in Figure 1. The main functional units of the system are as follows:

(1) Analog filtering unit: It used to filter out the noise in the analog signal; after filtering the analog signal into the A/D converter.

(2) A/D conversion unit: It converts the analog signal into a digital signal that can be processed by a single chip microcomputer. This system uses AD976 chip to achieve.

(3) Microprocessor unit: the MCU part serves as the core of the system. It is responsible for data acquisition, processing and the control of each functional module. This component utilizes the TMS320F28377D chip for its control functions.

(4) Analog output channel: It consists three components: D/A conversion, low-pass filter and isolation amplifier. D/A converter used TLV5620C, which is a four-channel 8-bit digital analog converter. Therefore, for a two-channel input, only one TLV5620C chip is required

(5) Power supply processing unit: It consists two sections: AC/DC and DC/DC. The AC/DC section utilizes flyback converter to convert 220VAC city electricity into 15VDC output. The DC/DC section then converts the 15VDC into two different reference voltages: 5VDC and 3.3VDC. The 5V output is supplied to the DSP microprocessor and the AD976 chip, while the 3.3V output is provided to the TLV5620C.

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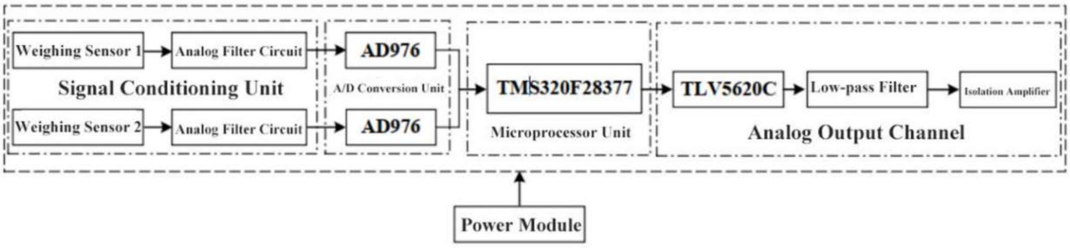

Figure 1. The interface structure

4. Hardware Design

The working principle of the resistance strain indicates that the output signal of sensor is influenced by the stability of the excitation power supply and external interference [7]. Clutter is accompanied by the voltage output of the sensor and the existence of differential signals within the sensor's output. Consequently, the sensor's voltage signal output is affected by both differential mode interference and common mode interference. This effect is especially significant when there is a considerable distance between the sensor and the transmitter; as the transmission distance increases, the impact of these interferences becomes more pronounced. In order to suppress differential mode and common mode interference during signal transmission while retaining the DC active components as much as possible, an analog low-pass filter is usually added to the analog transmission channel. Considering the use of integrated operational amplifiers in active power filters, the requirement for a dual power supply inevitably increases the complexity of the power supply design. Additionally, the active power filter configuration imposes stringent demands on the precision and temperature characteristics of the resistors and capacitors. Therefore, this system employs passive power filtering to realize. Since the output of the sensor is a differential signal [8], it effectively suppresses common mode interference. However, the circuit has relatively high symmetry requirements; and if the components are mismatched, it can introduce additional errors and result in a common mode output. Therefore, in circuit design, it is essential to distinguish between differential mode signal and common mode signal. This distinction allows us to implement appropriate measures. Common mode noise refers to external interference that affects both lines of the noise voltage, that is, the signal line and the ground, so the two signal lines exhibit the same characteristics in terms of interference frequency, amplitude, and other parameters. Commonly used techniques to suppress common mode interference include isolation technology and floating ground technology. Isolation technology can be further divided into isolation transformer, longitudinal choke, photocoupler. As shown in Figure 2, J3 connected to the sensor, L1 and L2 all equal at 470uH. Due to the two differential conductors, which generate magnetic flux from the round-trip current in L1 and L2. The magnetic flux is equal in magnitude but opposite in direction, resulting in cancellation. Consequently, there is no inductance affecting the differential mode noise. Additionally, the conductors and the ground work together to provide an inductive suppression against common mode noise. C3 and C4, like C5 and C6, use capacitors with excellent high-frequency characteristics, with reference values ranging from 0.01uF to 0.1uF. Differential mode signal. Differential mode signal refers to noise voltage added between two wires in a circuit, which can be viewed as noise superimposed on the signal being tested, potentially generated by the leaded inductive coupling, in passive filtering usually as shown in the suppression of common mode interference prior to the shunt connection of a capacitor (C3) in the circuit. C3 needs to use ceramic capacitors or polyester capacitors with good high-frequency characteristics, the capacity reference value ranging from 0.01uF to 0.1uF. Additionally, the leads should be kept as short as possible. To prevent the reintroduction of differential mode interference while suppressing common mode interference, the filter clogging network is ultimately connected in parallel with a capacitor (C5). The recommended capacitance value ranges from 0.01uF to 0.1uF.

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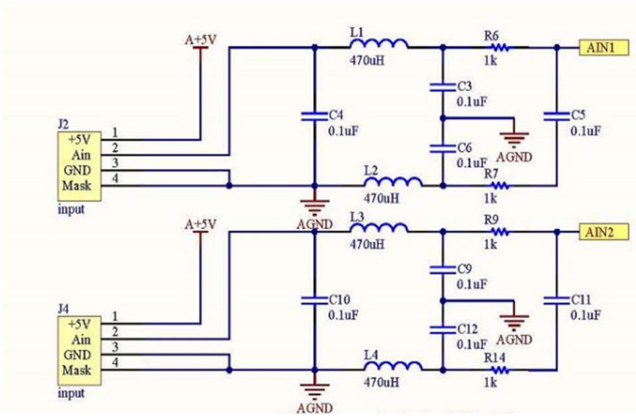

Figure 2. Analog filter circuit

5. Driver Design

5.1 ADC Program

The ADC driver of this paper is shown in Table 1 below:

Table 1. The ADC program

```
//ADC program

#define ADC_CKPS 0x1 // ADC module clock = HSPCLK/2*ADC_CKPS =
25.0MHz/(1*2) = 12.5MHz
#define ADC_SHCLK 0xf // S/H width in ADC module periods = 16 ADC clocks
#define BUFF_SIZE 4
Uint16 SampleTable[BUFF_SIZE];
main()
{
  Uint16 i;
  InitSysCtrl();
  EALLOW; //Editing of the protected registers is allowed
  SysCtrlRegs.HISPCP.all = 0x3; //HSPCLK = SYSCLKOUT/6 = 25.0 MHz
  EDIS; // Editing is prohibited.
  DINT; // Shut down
InitPieCtrl(); // Reset PIE. Control register =0
IER = 0x0000; // Clear all CPU interrupt identifiers
IFR = 0x0000;
InitPieVectTable(); // Initialize the Interrupt Vector Table
InitAdc(); // Turn on the ADC clock, calibration, power the ADC circuit
AdcRegs.ADCTRL1.bit.ACQ_PS = ADC_SHCLK;
AdcRegs.ADCTRL3.bit.ADCCLKPS = ADC_CKPS;
AdcRegs.ADCTRL1.bit.SEQ_CASC = 1; //Cascade Mode 1
AdcRegs.ADCMAXCONV.bit.MAX_CONV1 = 3; // Set the maximum number of channels to n + 1, starting from channel 0, and calculate in
sequence
AdcRegs.ADCCHSELSEQ1.bit.CONV00 = 0x0; // Channel (pin): ADCINA0
AdcRegs.ADCCHSELSEQ1.bit.CONV01 = 0x1; //ADCINA1
AdcRegs.ADCCHSELSEQ1.bit.CONV02 = 0x8; //ADCINB0
AdcRegs.ADCCHSELSEQ1.bit.CONV03 = 0x9; //ADCINB1
AdcRegs.ADCTRL1.bit.CONT_RUN = 1; // Continuous running mode
AdcRegs.ADCTRL2.all = 0x2000; //1 << 13; Start SEQ1. No need of SEQ2 for cascading mode
for(i = 0; i < BUFF_SIZE; i++)
{
  SampleTable[i] = 0;
}
for(;;)
{
  while (AdcRegs.ADCST.bit.INT_SEQ1 == 0) {} // Waiting for the conversion. No waiting for cascading.
  INT_SEQ2
  AdcRegs.ADCST.bit.INT_SEQ1_CLR = 1; // Clear interrupt identifiers
  SampleTable[0] = AdcRegs.ADCRESULT0>>4;
  SampleTable[1] = AdcRegs.ADCRESULT1>>4;
  SampleTable[2] = AdcRegs.ADCRESULT2>>4;
  SampleTable[3] = AdcRegs.ADCRESULT3>>4;
}
```

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5.2 Digital Filtering Program Design

Due to the weak output signal of the weighing sensor and the poor environmental conditions surrounding the weighing equipment, it is often subject to high levels of noise and significant electromagnetic interference. Although the hardware design of the system has achieved analog filtering, it primarily mitigates high-frequency noise interference (common mode and differential mode) and power frequency interference. However, it is unable to eliminate low-frequency pulse interference. In order to better suppress impulse interference during system operation, digital filtering is commonly employed (Table 2).

Table 2. Arithmetic average filtering method

```
    // Arithmetic average filtering method

    #define N 11
char filter(void) {
  int sum = 0, i = 0;
  for(i = 0; i < N; i++) {
  sum += get_ad();
  delay();
}
  return (char)(sum / N);
}
```

6. Conclusion

This paper compares and analyzes several commonly used sensors, and determines the processing of resistance strain sensor signals such a research subject. The main problems and research methodologies addressed in this design are outlined, along with the technical specifications that must be met. Additionally, the data processing unit adopts digital filtering to eliminate the impulse interference during system operation. The program code for the system is also provided.

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