Development of Portable Bridge Strain Detector

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***Abstract*—The safety of the bridge impact the traffic capacity of road, and the bridge will be deformed to the disease when it is under repeated loads. In order to detect the real-time detection of operating conditions, we combine computer and automatic control technology, with which around the core parameter monitoring, and use ultra-low-power microcontroller MSP430F5418 as the main chip. Through the data acquisition unit, the data processing unit and data transmission unit, it can realize the strain signal monitoring. The research and development of a new strain of portable testing instruments could solve the current problems of equipment heavy. The hard installations, the complicated circuit, the low accuracy and high cost, which have proposed a new detection method for bridge safety.**

Keywords-portable; bridge; strain detection

I. INTRODUCTION

The bridge strain is an important parameter in the deformation monitoring of the bridge. Evaluation of the use function of bridge is according to three indexes like the structure defect state, the adequacy of bearing capacity and the enough capacity of traffic [1]; the strain of the bridge is the core reaction parameters of the state. By monitoring the changes in strain, we could keep abreast of the safety condition of the bridge, which has an important meaning to the bridge and users.

Strain monitoring equipment currently in use is usually fixed, with complex installation and not convenient in maintenance. It not only increases the cost, but also reduces the efficiency in use. Based on the wide investigation, our design developer a new tester portable of the bridge strain can not only meet the demand of long-term monitoring, but also satisfy the demand of rapid detection. The development of the system has the function of combining signal acquisition, amplification, preprocessing, analysis of wireless transmission in one, and a high degree of integration, small volume, convenient use, safety and reliability for the monitoring and the practicality of detection of the bridge are particularly important.

II. PRINCIPLE OF STRAIN MEASUREMENT

The bridge material under the action of external force to deform slightly because of "strain effect", the deformation effect by strain gauge which cause the change of resistance; by measuring the quantity of the resistance change, then according to the known relationship between the resistance changes with the deformation, it can reflect the size of the external force [2, 3, 4]. In a certain range, the relative variation of resistance of strain gauge($\Delta R/R$) with specimen relative variation (i.e. strain) showed a linear relationship, that is:

$$\frac{\Delta R}{R} = K\frac{\Delta L}{L} = K\varepsilon \qquad (1)$$

Type the $\frac{\Delta L}{L}$ for the relative deformation; K is the sensitivity coefficient of resistance strain gauge, generally at a K value of 2.0 [5, 6].

III. SYSTEM DESIGN

A. The system hardware

Strain monitoring hardware system mainly includes the power supply module, the data acquisition unit, the data processing unit and the data transmission unit. The data acquisition unit includes the data communication module, the signal amplifying circuit, and A/D conversion module; the data processing unit is mainly by microcontroller as the core controller. The specific hardware system block diagram is shown in figure 1.

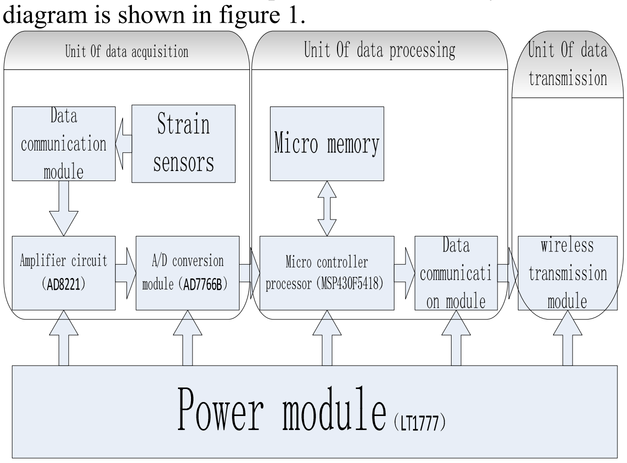

Figure 1. Hardware system block diagram

B. The signal amplifying circuit

The data acquisition unit strain sensors have been the order of magnitude as μV signal, and the signal is generally not easy to handle. So it has to take advantage of the amplifier to enlarge the weak signal, and the zero drift has to less than mu grade μV. At present, general A/D conversion chip requirements input signal in more than 100 μV (0.1 mV) to work normally [7]. The precise instrumentation amplifier is shown in figure 2, the circuit adopts the AD8221, it's a programmable instrumentation amplifier of gain and high performance, its outstanding advantage is the common mode rejection which is widely used for precision data acquisition, like biomedical signal analysis and the system of instrument aerospace.

Figure 2 shows the working principle and the various parameters required of signal amplifying circuit: pin 1 (-IN), pin 4 (+IN) is the signal input end of the amplifier. Through R2 and R3, the sensor signal connects directly to the AD8221 pin 1 and pin 4, and provides the simulation for measuring. Sensor signals come from the outside bridge circuit. R2, R3 work for the signal transmission and limiting effect, its resistance has to choose between 1 kΩ to 10 k Ω, usually choose 4.75 kΩ.

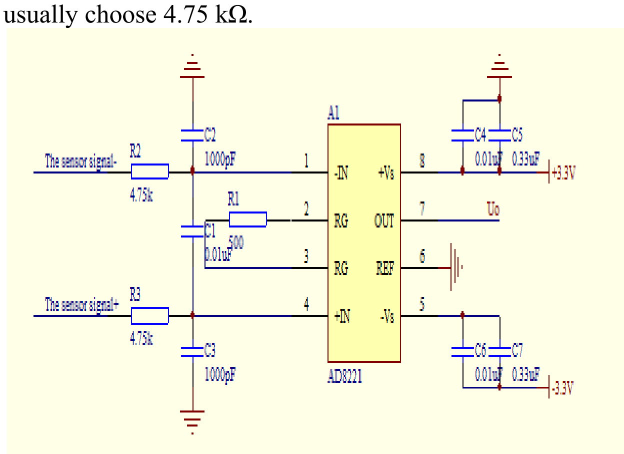

Figure 2. Signal amplifying circuit

Pin 2(RG), pin 3(RG) are gain Settings terminal, by changing the resistance value between the two pin to set the gain size. Set the gain of G, the relationship between G and R1 as formula (2):

$$G = 1 + \frac{49.4K\Omega}{R1} \quad (2)$$

Through R1, the magnification can be set within the range 1 to 1000. According to the formula (2) calculation is 500 Ω (R1), the magnification is set in 100.

Pin 5 (-VS), pin 8 (+ VS) are the chip power supply side, AD8221 have a wide voltage range from ±2.3 V to ±18 V. This design uses the ±3.3 V power supply for it. The capacitors C4--C7 have filtering function, which can filter high frequency noise through different capacitance.

Pin 6 (REF) is the reference voltage side, and it is directly connected to the ground. Pin 7 (OUT) is signal output, and the signal transmission to the A/D conversion module.

C. The A/D conversion module

A/D conversion module converts analog signals into digital signal, after amplification of the analog signal into the digital signal of A/D conversion module to send detail processor for processing. This system has four pieces of A/D conversion chips, and figure 3 is the connection mode of AD7766B. It's one of the A/D conversion chips. AD7766B has high precision, low power consumption, and low temperature drift characteristics, and its built-in has low-pass FIR filter chip.

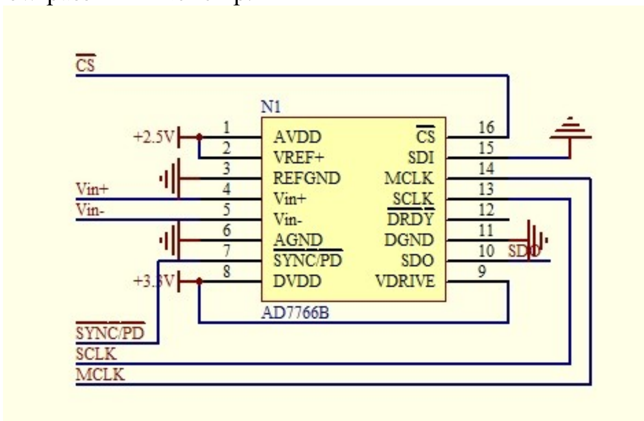

Figure 3. Method of connecting A/D conversion chip AD7766B

The figure 3 shows that the A/D conversion chip AD7766B has 16 pin. Among them, pin 2 (VREF +) for AD7766B reference input voltage, and an external reference voltage must be applied to the input pin, this pin of the input range can be from 2.4v to 5v, this pin directly connected to pin 1(AVDD) here, the reference voltage for the fixed value of 2.5 V.

Pin 4 (VIN +) and pin 5(VIN-), are respectively the same phase input terminal and the inverting input for the differential analog input. Analog signal input come in these two pins, then pass AD7766B for analog-to-digital conversion. The digital signals are controlled in pin 12(DRDY), through pin 10(SDO) to pass to MSP430F5418 pin 70(SDO), and then process the next step.

The system uses four pieces of A/D conversion chip design and four chips of pin 7(SYNC/PD) to connect together to be synchronized. The pin 16(CS) is a piece of signal input terminal. When the pin input signal is in low electricity, the chip works normally; and when the input signal for the pin is in the high electricity, the chip stops working.

In addition, pin 13(SCLK) and pin 14(MCLK), connect respectively with pin 68(SCLK) and pin 25(MCLK) of MSP430F5418 for serial clock and master clock.

D. The digital signal processing (DSP) and controller

After the amplification and A/D conversion, the analog signals collected are fed into the embedded microcontroller processor for digital signal processing, and after processing the signal sent to the computer, the real-time test data can be read from the computer, the circuit as shown in figure 4.

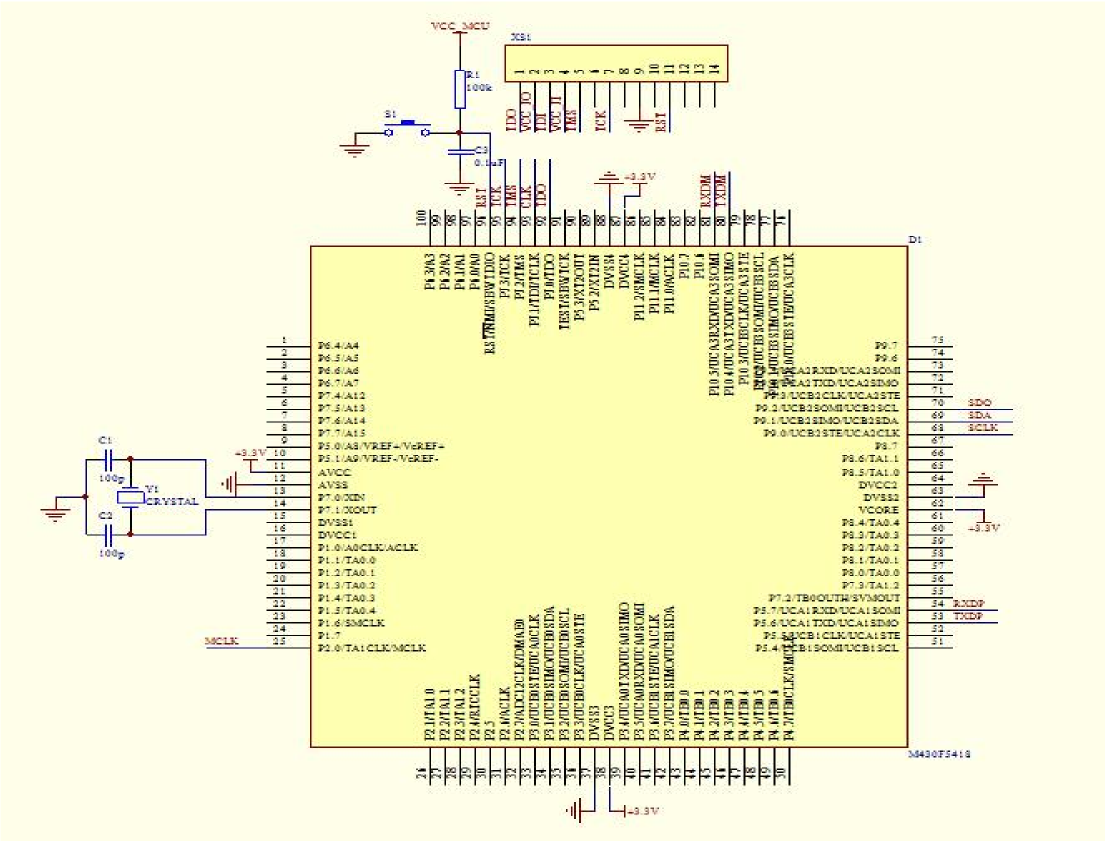

Figure 4. Digital signal processing and control unit (MSP430F5418)

In this system, we adopt the series of MSP430 ultra-low power consumption micro controller of Texas instruments (TI). The series microcontroller has strong 16-bit RISC CPU, 16-bit registers and constant generator. With different sets of peripherals for various applications, it also has highly transparent application.

In MSP430F5418 micro controller, digital controlled oscillator (DCO) is allowed to awaken from the low power mode, and the time of wake up is less than 5μs. It has three 16-bit microcontroller timer configurations, and four universal serial communication interfaces (USCI), the hardware multiplier, DMA, a real time clock module which has alarm function, and 87 I/O pins. Through the software program, it can realize the system control and digital signal processing. Through the system bus, the main function of the interface of I/O interface is to connect the microprocessor with peripheral equipment.

In figure 4 MSP430F5418 power supply voltage from 1.8 V to 3.6 V, here uses 3.3 V power supply.

XS1 connected with MSP430F5418 pin 92 – pin 96, it can download the program for the chip. Among them, pin 96 (RST) is the reset chip, connected with the key switch (S1), and it can realize the chip reset function.

The design of A/D module AD7766B pin 10 (SDO) is to send the digital signal to MSP430F5418 pin70 (SDO). Pin 69 (SDA) is the control end of the pin 70 (SDO), when the SDA jumping from high level to low level (i.e., falling edge), SDO began to transmit data; when the SDA jump from low level to high level (rising), SDO end transmitting data. After data processing through the other I/O pins output to the wireless transmission unit.

In addition, Y1 as a crystal oscillator, linked with C1 and C2 to the MSP430F5418 pin 13 (XIN), pin 14 (XOUT), will have oscillation frequency, which provide a stable clock pulse for the microprocessor. Pin 25 (MCLK), pin 68(SCLK) of MSP430F5418 connected respectively with the pin 14 (MCLK) and pin 13 (SCLK) of A/D conversion module AD7766B. It provides the clock signal for the master clock and the synchronous serial bus.

E. The wireless transmission module

This system adopts ZigBee technology which is a kind with close, low complexity, low cost, low power consumption, low rate of two-way wireless communication technology. It works on the 2.4 GHz ISM band, transmission rate of 20 KB/s - 250 KB/s, and transmission distance is 10 m--75 m [8], fully meets the transmission requirement of large and medium bridges. On the basis of the mesh topology, the transmission distance can be in a honeycomb continues to increase, which can adapt to different working conditions, especially the bad natural environment condition in use. In addition, the mature of ZigBee technology has formed a highly integrated, modular construction, a portable small volume for the requirement.

In this system, a ZigBee emitting module will eventually complete the processing of the launch for digital signals, and the terminal module of data receiving connect with computer to receive signal, which in turn can take the next step of data analysis and processing.

IV. Conclusion

Through the analysis of the current situation of the bridge detection equipment, around the core parameters testing, it developed a new type of portable strain testing instrument includes data acquisition unit, data processing unit and data transmission unit to realize the detection of the strain signals, to solve the current detection equipment cumbersome, difficult installation, circuit complexity, low accuracy, high cost. And explore the maximum extent to improve the efficiency of the bridge detection.

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