

PAPER • OPEN ACCESS

## Study on Wireless Monitoring Of Strain in Moving Objects

To cite this article: Tong Guo and Qingming Wang 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **252** 032133

View the [article online](#) for updates and enhancements.

# Study on Wireless Monitoring Of Strain in Moving Objects

**Tong Guo, Qingming Wang\***

School of Mechanical and Power Engineering East China University of Science  
Technology Shanghai, PR China

\*Corresponding author e-mail: guotong\_1993@qq.com

**Abstract.** In the working state detection of mechanical system, the strain monitoring of moving object is of great significance. In order to break through the limitation of applicable occasions for the static strain gauge and cable transmission of information, this paper introduces the design of a multi-channel wireless monitoring device which is based on the principle of small volume and convenient carrying, describes the design principle of signal acquisition, processing, transmission and display device. Combined with the actual demand, the power supply of the device is selected and the corresponding circuit is designed. At the same time, the amplification circuit is simulated to verify its feasibility and reliability. Finally, the error analysis of the whole device is made and the corresponding solution is tried to make the device have higher practical value.

## 1. Introduction

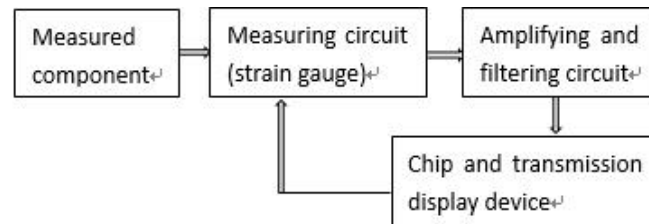
In practical engineering, there are many phenomena that needs to study the motion strain of mechanical components, such as the rotating machine tool power chuck at work, the strain at the root of the wheel axle of the automobile, and the working strain of the cantilever beam when the crane is loaded. In such occasion, the strain of the mechanical component can-not be transmitted to the strain gauge by wire transmission. With the development of science and technology, the research of dynamic strain combined with wireless transmission has also developed. But the existing strain monitoring device is still remains some drawbacks, such as channel is single, measuring range is not large, the operation is not convenient. These deficiencies greatly affect the accuracy and applicable range of the dynamic strain monitoring device. Of course, there exploits some high-precision dynamic strain monitoring device, but the high cost of high-precision does not have high commercial value.

The purpose of this paper is to design a multi-channel wireless dynamic strain monitoring device, which can simplify the circuit and reduce the cost in the premise of improving the accuracy of the equipment as much as possible, so as to make it has higher practical value.

## 2. Design principle

In general, we need gain the physical signal of measured device through the strain gauge of measuring circuit, transfer to chip after amplifying and filtering, and then subsequent process, transmit and display of the signal by program which has been written into the chip. It is shown as Figure 1.



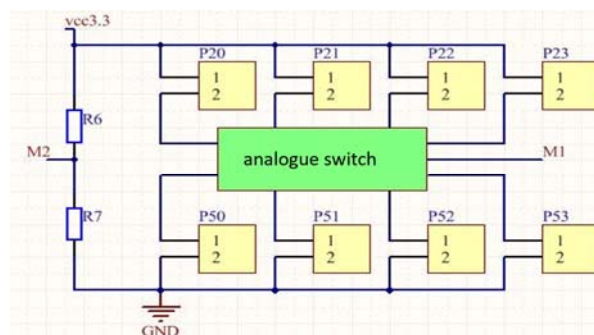


**Figure 1.** Design principle flow chart

Wireless dynamic strain monitoring device usually has three modules: signal acquisition and processing module, signal transmission module, information display module. This paper mainly studies the design idea of signal acquisition and processing module.

### 2.1. Strain collection circuit

There are mainly two ways of measuring strain at present: the Wheatstone bridge circuit and Prague fiber grating measurement. Because the process of Prague fiber grating measurement is complex, the actual operation technology requirements are high and the cost is not low, compared to this, the Wheatstone bridge circuit is more appropriate. In order to achieve the requirements of multi-channel (simultaneously access or disconnection of multiple stain gauges), the corresponding bridge must be deformed. The specific circuit is shown in Figure 2.



**Figure 2.** Strain acquisition circuit (P20~23 and P50~53 can access strain gauges or fixed resistance)

### 2.2. Amplifying and filtering circuit

That the changes of the resistance strain gauge is often very small results in that the voltage range of the circuit strain is very small. But too small voltage change easily losses too large or disappear in the process of signal transfer, so it needs signal conditioning. In the dynamic strain measuring device, signal conditioning is mainly divided into two aspects: signal amplification and signal filtering. Signal amplification is mainly achieved by differential amplifier circuit, while signal filtering is mainly achieved through the two order active filter circuit. In order to minimize the volume of the device, the design of the amplifier and filter circuit needs applied to the operational amplifier. This requires that the operation amplifier be chosen without distortion in amplifying and the filtering circuit (operating the active component in the appropriate region so that the output is linearly proportional to the input amount).

### 2.3. Signal processing and transmission

In this paper, wireless dynamic strain monitoring device requires that the controller module can complete the signal A/D conversion, the storage and operation of the converted information, as well as sent through the Bluetooth module regularly to the display device. So based on the requirements of function, volume, power consumption and cost requirements, it is vital to choose a kind of single-chip which have the superior performance, low power consumption and rich peripherals. By referring to data

and considering comprehensively, the master chip of the dynamic strain monitoring device is selected as AT-mega 328P-AU. This chip has 32 general-purpose registers and a rich instruction set, which greatly improve the efficiency of code. Its running speed is 10 times faster than the traditional micro controller, even can reach 1MIP/MHZ, which can achieve the optimization of system design, power consumption and processing speed.

Wireless dynamic strain monitoring device is based on a master-slave mode that means setting a remote device as the control center, which need complete the selection of data, monitoring, display and other functions. Bluetooth communication technology is a wireless two-way communication technology, which has the characteristics of low power consumption, low complexity, high openness, high security and low cost. It can realize the accurate transmission of information. At the same time, Bluetooth band including guard band is varies at 2400~2483.5MHZ that is short distance radio frequency range and usually used by industries, science and medical care in the world. It has no license required and the range of 1~100 meters, which laid the foundation for the wide application of Bluetooth.

### 3. Experimental analysis

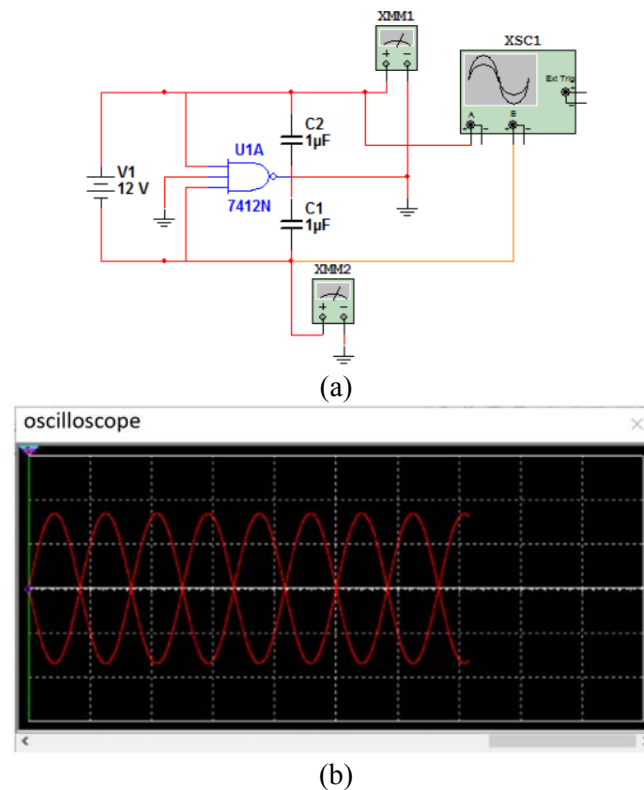
#### 3.1. Power selection

In this paper, the design requires that dynamic strain monitoring device can be carry-on and realize real-time monitoring. Consequently it can apply in various working occasions, even in serious environment. This means it cannot directly use the grid power, so it only can be powered by a lithium battery. The power requirements for each part of the whole circuit are shown in Table 1.

**Table 1.** Power demand for each part of the circuit

Power supply object	Voltage demand
Bridge	$\pm 3 \sim \pm 5V$
Amplifying circuit	$\pm 2.3 \sim \pm 18V$
Controller	1.8~5.5V
Bluetooth module	3.3V

In view of the power demand for each part of the circuit, I choose a DC battery 1604S 6F22 9V. The forward voltage required for the controller and the Bluetooth module can be reasonably and stably powered through the AMS1117 series voltage regulator. As for the bridge and amplification circuit, a single power need be converted to duplicate power. This device can convert 9V to  $\pm 4.5V$  by using the circuit shown in Figure 3 (a) and the analog output is shown in Figure 3 (b).



**Figure 3.** Single power transform to duplicate supply

### 3.2. Amplification circuit simulation

In different measuring occasions and measuring requirements, the strain range of the test object is different. Therefore, choosing the corresponding measuring range for different strain range is helpful to improve the measurement accuracy. In this device, the amplification factor can be changed by changing the access resistance of the amplifying circuit, thereby changing the measuring range. By calculation, the specific relationship is as follows;

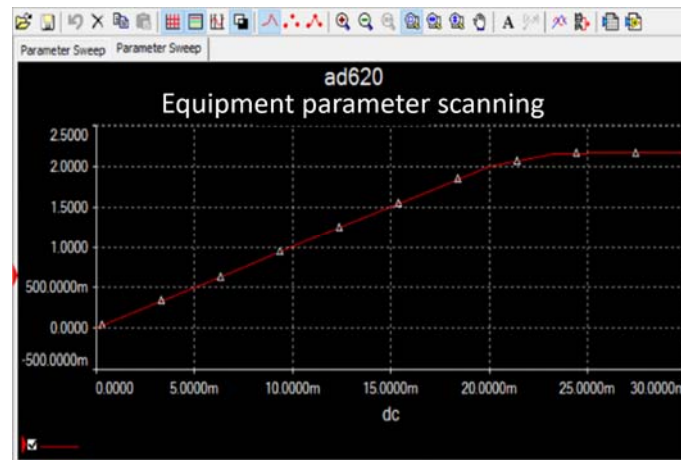
**Table 2.** Relation between measuring range and

Range	$\pm 10000\mu\epsilon$	$\pm 5000\mu\epsilon$	$\pm 2000\mu\epsilon$
Range of strain gauge resistance	0~1.2 $\Omega$	0~0.6 $\Omega$	0~0.3 $\Omega$
Magnification (amplifying and filtering link)	100 $\times$ 1.6	200 $\times$ 1.6	500 $\times$ 1.6
Accuracy	39 $\mu\epsilon$	19.5 $\mu\epsilon$	7.8 $\mu\epsilon$

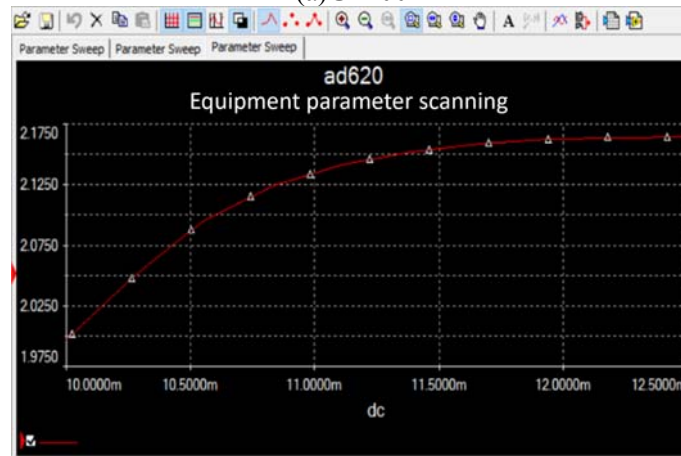
According to the formula (1), the pressure difference of bridge circuit in different measuring range can be calculated.

$$U_{ab} = \frac{\Delta R}{R + R_s} \times \frac{E}{4} \quad (1)$$

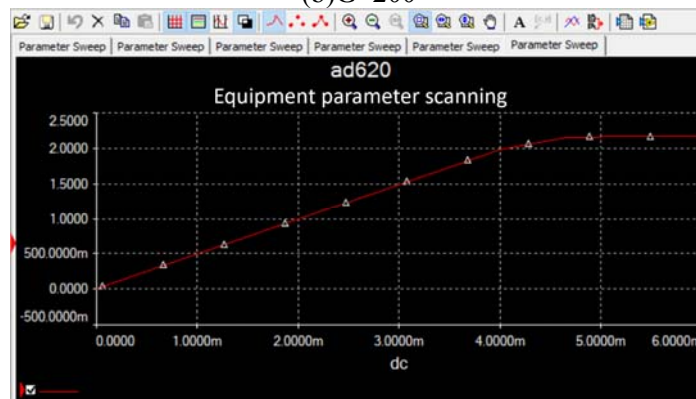
At the same time, the amplifier circuit used by the amplifier has limitation in a certain linear voltage should be taken into account. So we need get some chart that is getting by the simulation software, which is used on the simulation of the amplification part.



(a)G=100



(b)G=200



(c)G=500

**Fig. 4** Simulation under different amplification

According to the simulation shows, we can conclude that in different magnifications times, the output voltage has linear relationship with the input voltage varies with the resistance of the resistance strain gauge in the range of 0~2.5V. This is, the device can meet the un-distortion requirements of all range.

### 3.3. Error analysis

Analyzed the whole dynamic strain monitoring device, we can find that the main factors affecting the accuracy are as follows.

- (1) The resistance of wire and strain gauge causes the unbalanced of bridge;
- (2) The zero drift of operational amplifier;
- (3) The external electromagnetic interference has affect in the whole monitoring device.

In view of the above factors, the following measures can be taken to reduce the error as much as possible during the design process of the dynamic strain monitoring device.

- (1) Design a regular integrated circuit and make a shell which is surrounding the measurement device;
- (2) Realize the self-storage zero in the compilation of controller chip program. At first, record an initial data which is measuring during zero drift. Then the real measured value is obtained by the measured value subtracts the initial one.

## 4. Conclusion

Due to the characteristics of light weight and small size, the wireless monitoring device of dynamic strain can achieve real-time monitoring of the movement mechanism strain, which broke through the applied limitation of wire strain gauge. At the same time, the simple device improves the reliability of the system as well as make the installation and the maintenance more convenient, which can reduce the manual workload and cost. The strain monitoring device designed in this paper has good signal acquisition, processing and transmission ability. Therefore with high practical value in engineering, it can be widely used for strain measurement in mechanical engineering.

## Acknowledgments

This research was supported by National Natural Science Foundation of China (No.51175176).

## References

- [1] Yunfeng Liu, Principle and Design of the Wireless Strain Measurement System for the Tie Rod of the Shore Bridge Crane Mechanical Engineer, vol.4, pp. 191–192, 2016..
- [2] Wenbin You and Jing Zu, The Error Analysis and Adjusting of Dynamic Strain Gauge, Journal of instrument and instrument, vol.25 (s1), pp. 794–795, 2004.
- [3] Guirong Weng and Heming Zhao, High-precision Wireless Transmission Strain-meter, Measurement and control technology, vol. 118 (1999), No 5.
- [4] Shuzhen WANG, Wei SHAN and Lingling SONG, Principle and Application of AD620 Instrumentation Amplifier, Microprocessors, vol.4, pp. 38–40 2008.
- [5] Fuyan Yin, Researching of electronic resistance strain gauge and strain transfer principle, Science and technology application, vol. 39, no. 2, pp. 1-8, 2010.
- [6] Zhihong Qian and Dan Liu, Overview of Bluetooth technology data transmission, Journal of Communications, vol. 33, no. 4, pp. 143-151, 2012.
- [7] Zhang Huizheng and Zhang Peng, Integrated design of electronic products based on Altium Designer, Engineering practice and Application Technology, Vol.6, pp. 56-58, 2008.
- [8] Chen Liheng, Application of Multisim simulation in electrical and electronic experiment. Wireless Internet technology, Vol. 1, pp. 184-184, 2013.
- [9] Zhang Wenhui, Two methods for calibration error of static resistance strain gauge, China new technology, new products, Vol.21, pp.113-114, 2011.