

## Design and Realization of Performance Testing System for Infrared Sensors

<sup>1</sup> Haiwang CAO, <sup>2</sup> Wentao GU

<sup>1</sup>Department of Electronic and Communication Engineering, Zhengzhou Institute of Aeronautical Industry Management, Zhengzhou, 450015, China

<sup>2</sup> Northwestern Polytechnical University, Xi'an 710072, China

<sup>1</sup> Tel.: 86-371-68252829

<sup>1</sup> E-mail: bdchw@163.com

*Received: 16 September 2013 / Accepted: 15 October 2013 / Published: 23 December 2013*

**Abstract:** This paper deals with the overall performance testing system for infrared sensors. To test the overall performance and some integral indicators of the infrared sensor, the design and realization of the testing system are discussed. First, the systematic design and functions of the testing system as well as the subsystems are proposed. Then the detailed realization of the system's software and hardware are discussed. In the design and realization of the hardware, the choices on the subsystem are discussed, and the connection and interface relationship between subsystems are proposed. The software is developed using Visual C++6.0 and Measurement Studio 6.0, which realized the function of system control, system self-checking, system calibration, data collection, data processing, network interface and printing. And the relationships between subsystems are also given. The validity of the testing system is effectively verified by the practical testing applications. *Copyright © 2013 IFSA.*

**Keywords:** Infrared sensor, Overall performance, Testing system, Design and realization.

### 1. Introduction

Infrared sensor is an optical instrument for spacecraft attitude information through the measurements of the difference between earth and sky infrared radiation. Usually it is used for measuring the spacecraft attitude angle and roll attitude angle. As infrared sensors provide attitude guarantee for the stable operation of spacecrafts, it is necessary to design the testing system for the overall performance of infrared sensors.

At present, the research on the infrared sensor has different realization and application, and it mainly includes the following topics: 1) System design based on various technologies [1-2]. 2) Control system design [3]. 3) Data processing and precision analysis

[4-5]. 4) Applications of different infrared sensor systems [6-7]. In terms of 1), reference [2] focused on the mechanical and control design of a micrometer range positioning and tracking platform using mathematical models. In terms of 2), reference [3] designed a temperature control system using incremental PID algorithm for a special homemade shortwave infrared spatial remote sensor based on FPGA. In terms of 3), reference [5] proposed a real-time signal processing method for infrared sensor arrays. In terms of 4), reference [7] studied a thermographic diagnosis system and proposed an imaging algorithm by distributed thermal data using single infrared sensor. These system designs about the infrared sensor have been successfully applied to many fields, which is meaningful to the infrared

sensor performance testing system. However, they are specific applications. Though the addition of hardware (for example, sensors) realizes the test and control function, the structure is changed, which increases the system error. In addition, the system is lack of the calibration system, as well as automation test. Therefore, according to the test requirement, the hardware and software system of the infrared sensor performance testing system is designed and realized which is verified by the practical application to be effective.

## 2. Composition and Functions of Infrared Sensor Performance Testing System

The testing system for infrared sensor overall performance completes the test on overall performance and other comprehensive index, as well as the machine adjustment and calibration of infrared sensors. The basic structure of the system is shown in Fig. 1.

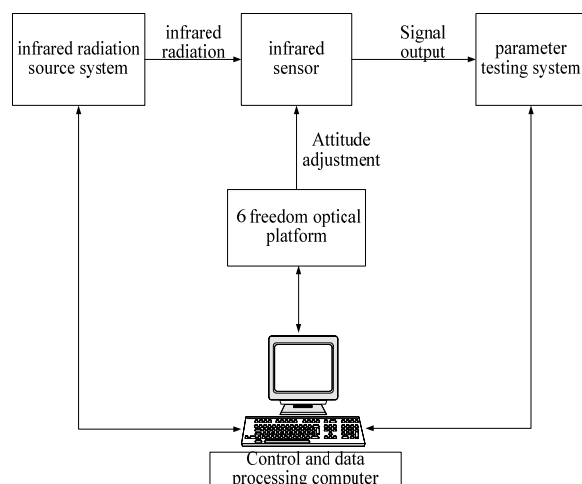


Fig. 1. Composition of the testing system.

Performance testing system consists of four major subsystems: infrared radiation source system, 6 freedom optical platform, parameter testing system, control and data processing system. The whole system is controlled by control and data processing system to complete the modulation mode and radiation amount control of the infrared radiation source. The attitude adjustment, automatically aligning function of the infrared sensor is achieved by adjusting the optical platform attitude. The sensitive axis angle deviation and the frequency response parameter test of the infrared sensor are completed by parameter testing system.

The composition and functions of each subsystem are as follows:

Infrared radiation source subsystem consists of dual band infrared radiation source (blackbody radiation source, radiation modulator, infrared

radiation synthesizer), radiation source controller unit, radiation calibration unit, independent power supply unit etc., as shown in Fig. 2. It produces infrared radiation with high stability, control the temperature of blackbody radiation source, modulate in three ways (constant, sinusoidal, Gauss), regulate infrared radiation, eliminate the stray light and complete the synthesis of two infrared radiation etc.

6 freedom optical platform system is composed of the base, the XYZ straight line displacement adjusting device, the XYZ 3 axis angle adjusting device, infrared sensor, infrared sensor platform fixture, linear and angular displacement sensor, drive unit (including servo motor and driver), interface circuit of computer motion control card, and power supply unit. It can realize left and right translation, height translation, horizontal rotating, pitch and roll, and keep the infrared sensor attitude stable in the testing process.

Parameter testing system is composed of voltage and current testing unit, input and output impedance testing unit, the noise testing unit, the frequency response testing unit, the sensitive axis angle accuracy testing unit, sensor sensitivity testing unit and target recognition testing unit. Voltage and current testing unit mainly completes the function: the current and voltage in the main node, the normal power supply in the electric system, and the satisfaction of the power system. The input and output impedance testing unit mainly completes the function: impedance measurement of infrared sensor and electrical interface (input and output impedance in analog and digital channel, impedance parameters of the control circuit). The noise testing unit mainly completes the function: the noise characteristics and noise level test of the analog electronic circuits in infrared sensor channel, the power spectrum, autocorrelation and cross-correlation analysis, statistic analysis (peak to peak, mean, root mean square value, variance analysis). Frequency response testing unit mainly completes the function: the frequency sensitive test of infrared radiation under different frequencies. The sensitive axis angle accuracy testing unit mainly completes the test on the infrared sensor sensitive axis angle deviation. Sensor sensitivity testing unit mainly completes the function: the infrared radiation light source illumination (radiation energy) control through the computer and the radiation source controller, and then quantitative measurement of light intensity by the light intensity meter, the output measurement of infrared sensor, target detection ability of infrared sensor, automatic completion of all measurement process. Target recognition testing unit mainly completes the function: the testing target recognition for various control signals, judgment on timing through the input specific signal and the base object recognition signal. Digital signal sequence logic testing unit mainly completes the function: after receiving a start signal, 8 road digital channel test, logic relationship and the amplitude of each channel.

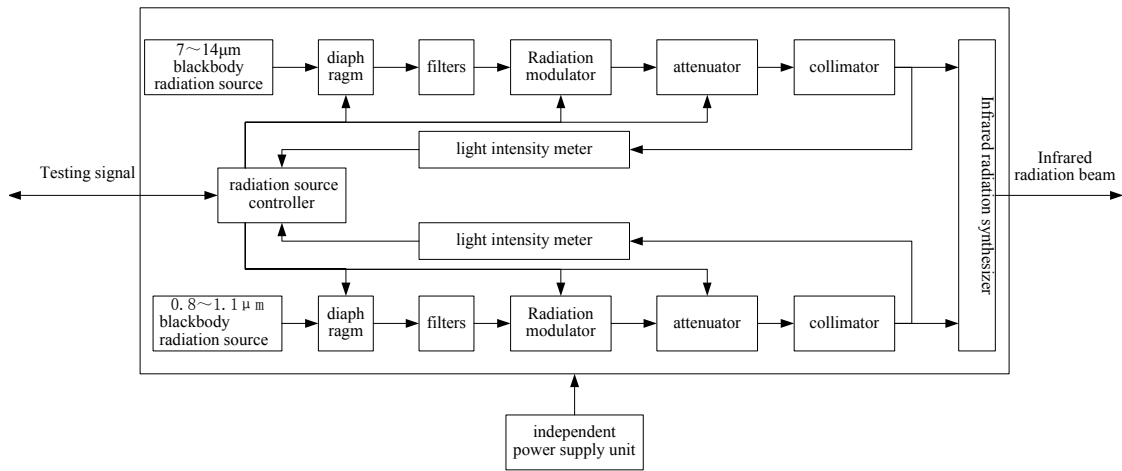


Fig. 2. Composition of infrared radiation source system.

### 3. Design and Realization of Hardware System

#### 3.1. Design and Realization of the Infrared Radiation Source System

Infrared radiation source is the core of the infrared radiation system, and its selection must consider the user's requirement. The radiation source is composed of low temperature blackbody source producing long wave, high temperature blackbody source producing short wave, and the corresponding blackbody temperature controller. The selection of blackbody radiation source is mainly based on whether the signal output distribution of blackbody radiation source can meet Max Planck radiation. By controlling the combination of output energy, the output spectral characteristics of the signal source can maximally simulate radiation characteristics of real targets, thus to satisfy user's technological requirement. Considering the controllability of the blackbody source, it must have interface of RS232 or RS422. So the blackbody radiation source can be controlled by the computer through the RS232 or RS422 communication interface, and the blackbody radiation source can also upload the blackbody current status data through the communication interface, which not only can ensure the requirements in the band of output infrared beam, but also can ensure the infrared radiation intensity index requirements.

Collimating optical system is composed of visible light collimation system and blackbody radiation collimating system. Variable aperture adjustment mechanism is controlled by a radiation source controller, which is realized by specific control actions according to control and data processing system, so as to adjust the variable aperture diaphragm. The infrared interference filter is adopted, whose band is Gauss distribution, and the transmission rate is greater than 45%. Radiation modulator modulates the infrared beam according to preset frequency in constant, sinusoidal, or Gauss

pulse waveform way. There are usually three ways to realize modulation of the infrared beam, namely infrared liquid crystal light valve, circular progressive filter and optical modulation disk. With comprehensive comparison and consideration of modulation frequency, the chopper composed by a high speed motor and modulation wheel is adopted to modulate radiation, which produces a sine and similar Gauss distribution modulation.

The modulation formula of the frequency modulation disk is as follows,

$$\omega = n \times \omega_c \quad (1)$$

where  $\omega$  is the modulation frequency,  $\omega_c$  is the circling angular velocity,  $n$  is the number of teeth of the modulation disk. If the modulating frequency is set, and the appropriate speed of the motor is selected, then the number of the modulation disk teeth can be determined. In this project, the maximum modulation frequency is 2 kHz, rated speed servo motor is 6000 rpm, then the number of the modulation disk teeth is 20. And the speed closed loop control of motor is adopted, the speed stability of which is better than 0.2%, thus, it meets the technical requirements of the modulation frequency in the 1 Hz – 2 kHz frequency range, and the frequency drift less than 2%.

#### 3.2. System Design of 6 Freedom Optical Platform

XYZ straight line displacement adjustment devices adopt screw self-locking mechanism. In order to ensure the accuracy of the reciprocating mechanism, screw is driven by a clearance elimination mechanism to eliminate errors, and to improve the accuracy. Meanwhile, various axis screw mechanism is driven by a unified servo motor to form a complete closed-loop motion control system.

### **3.3. Hardware Design of Parameter Testing System**

As to the parameter testing system, there are many bus structures, such as PCI, CompactPCI, PXI, VXI etc. Considering the advantages and disadvantages of various bus structures, as the PXI bus structure has good characteristics and is supported by a large number of manufacturers, as well as the rich modules and expansion of the system functions, the hardware system structure of the testing system is based on the PXI bus structure. Considering the realization of self checking function, test automation, and switching capacity between different testing functions, system unification and extension, as well as the switching current capacity, the PXI relay module and SCXI relay module are adopted. The test on multiple product voltage, current, resistance adopt multi-meter module PXI-4060 to complete and can work in a dual mode of 5 \* 1 matrix switch. Product noise test module adopts PXI-6115. The output signal characteristics test is realized by PXI-5122, matched with a block PXI-2593 matrix switch, so as to expand channels. In the frequency response test, through the control of dual band infrared light, infrared light source output under different modulation frequency, and when infrared sensor receives the modulated signal, different signal characteristics can be obtained. These signal characteristics is amplified by the lock-in amplifier PRC5302, and different carrier frequency response characteristics can be obtained through the PXI-8212GPIB interface. In the sensitive axis angle test, the turntable with independent control system is adopted. The control of the turntable is realized by the Single Chip Micoyo system, and the main control computer only through the RS422 interface. Instructions is loaded to the Single Chip Micoyo system, the turntable angle is measured and controlled by Single Chip Micoyo system, and the angle value is returned to the master control computer through the RS422 interface, meanwhile, two output signals of the turntable is collected by the data acquisition system. In the light intensity test, light intensity control instructions are given to the light intensity control device through the RS422 interface, the intensity of illumination is controlled by the light intensity control device, and light intensity of 4 channel meter is tested through the data acquisition card and light intensity meter. As to the digital signal test, 8 digital channel sequential logic test is realized by two cascaded PXI-6602.

### **3.4. Hardware Design of Control and Data Processing System**

Various function units must be unified with the control and data processing system to work. Control and data processing system includes industrial computer, display, laser printer, the backup UPS,

CP-132IS double RS422 serial card, MXI-4 zero slot controller interface card.

Control and data processing computer is connected through the MXI-4 zero slot controller interface card and PXI integrated system in the PXI8331 zero slot controller, to realize the exchange of data and instructions in PXI integrated system, complete the functions of parameter test system, and control the motion of 6 freedom optical platform.

Control and data processing computer is connected through CP-132IS serial port card for dual RS422, to realize the serial connection and data and instructions exchange with infrared radiation source controller.

The overall hardware system is shown in Fig. 3.

## **4. Software Design of the Testing System**

According to the system requirements and characteristics, to facilitate the system integration, as well as the plug and play features of mainstream 32 bit high performance operating system, 32 bit operating system is utilized as a software framework, and Visual C++6.0 as the main development platform, as well as the software development tool Measurement Studio6.0 measurement. Thus, the powerful function, the convenience of software development, high reliability, high efficiency, code upgrade convenient of Visual C++6.0 is utilized, as well as the friendly and lively interface, powerful data processing advantage of Measurement and Studio6.0.

### **4.1. Description of Software System Structure**

The subsystem and the relationships between modules are shown in Fig. 4.

### **4.2. Design and Realization of Software System**

According to the function requirement of each subsystem, the functions of each subsystem are designed, and the main modules are as follows:

1) Main control system.

The main control system mainly plays the role of scheduling and delivery of information, thus it builds the news cycle mechanism, is the contact channel with the operator. The resource file of the main control subsystem is composed of main control interface, realizes a response mechanism to user information and returns parameters. At the same time, considering the expansibility of the system, the main control subsystem reserves functional extension interface.

2) Self-check system.

Self-check system is mainly the usability inspection of hardware boards. There are three main functions: usability inspection on hardware board, availability check of signal channel, and communication availability check. In order to improve the reliability of software, the system is divided into four modules: the board self-test module, signal channel availability check module, check module communication availability, fault characteristic database and query module. In the self-

common faults can be put forward for operators, therefore, self-check system itself is also a fault diagnosis system.

3) Calibration system.

The calibration of the system is divided into two aspects: the precision calibration of modules and the precision calibration of testing system. As to the module calibration, there are generally standard procedures for module calibration, and must be carried out by the measurement department, or

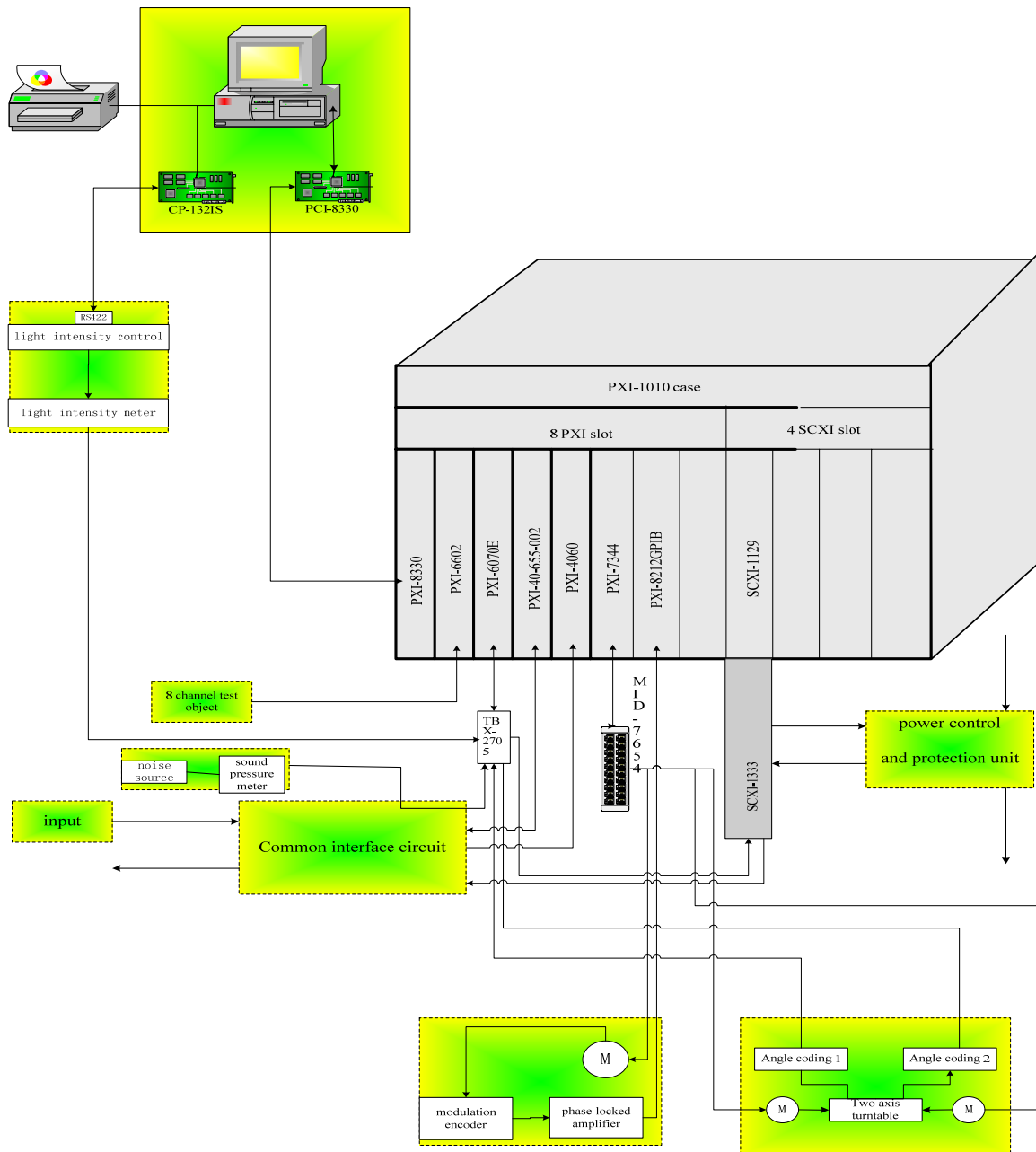


Fig. 3. Composition of infrared radiation source system

check process of the system, the software system can provide the reason and position of fault for the operator, and the troubleshooting solutions to

module provider in the module after a long time use. For the calibration of the testing system, the standard signals are compared to realize the calibration. The

calibration system calls channel switching module and data acquisition module, and stores the calibration parameters into the calibration file.

4) Data acquisition system.

Data acquisition subsystem is mainly to determine the data acquisition parameters of each channel, such as the sampling rate, trigger mode, buffer mode, initialization, parameter configuration, data acquisition, and storage. The success work of this system directly relates to the accuracy of follow-up subsystem data processes, and needs the data acquisition module and channel switching module complete the signal testing and data collection. The data acquisition module mainly completes the initialization, parameter configuration, and is responsible for effective data acquisition and storage.

5) Data processing system.

In this subsystem, the calculation of mean, variance and error analysis and prediction module are provided for the system.

6) Test results management system.

In this subsystem, it achieves the classification, database query, statistics report and printing function of test results.

7) Report generation and print system.

This subsystem is the final output channel of the whole testing system, and the module has five modules: data selection module, text layout module, table generating module, print preview and print module, as well as the external interface with word processing software MS-WORD. The final report document format is the standard WORD document.

### 4.3 Open Design of Software System

In order to satisfy the scalability requirements of software, software system reserves the function expansion menu in the main control subsystem, to achieve the expansion of integrity with the original system design unchanged. The function expanding menu is the dynamic loading menu, and can be generated by the user themselves, and associated with new functional modules, so as to realize the function expedition of the software system.

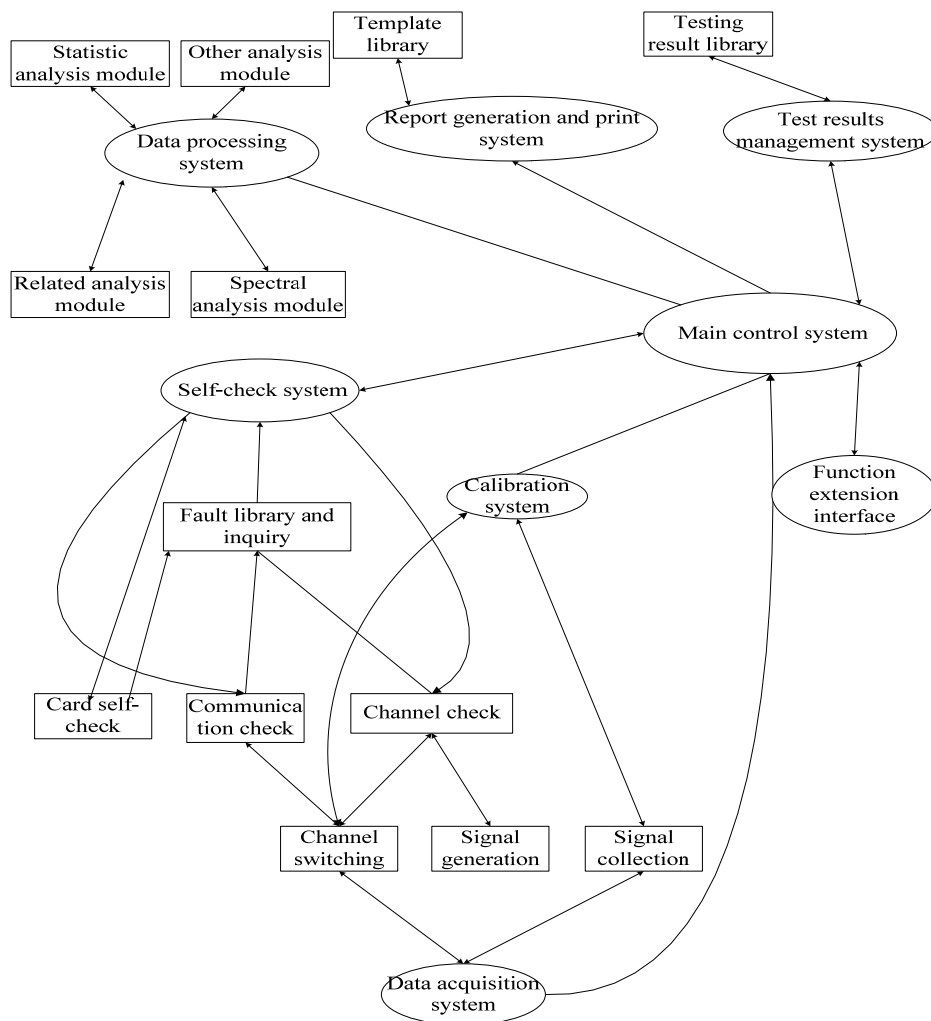


Fig. 4. Subsystems and the relationships between modules

## 5. Conclusions

According to the overall system design and realization above, hardware and software system are developed. And the overall performance testing system for infrared sensors can effectively meet the precision requirement of the infrared sensors and other comprehensive index, as well as the adjustment and calibration of infrared sensors.

The overall performance testing system for infrared sensors adopts master-slave PXI architecture which provides a good platform for the system upgrades and hardware expansion. At the same time, in the design of software system, the dynamic menu function expansion program with low coupling degree is adopted to improve the system scalability. In addition, the concept of automation test is conducted throughout the system design, as well as the system usability and maintainability. Meanwhile, in the design of self-check subsystem, not only the fault can be detected, but also solutions can be given, which effectively reduces the cost.

## Acknowledgements

This work is supported by the National Natural Science Foundation of China under Grant No.70971119; No.70901066.

## References

- [1]. R. William, B. T. Pinhas. Design and FE analysis of integrated sensing using gas compressibility for microdroplet generation, *Journal of Mechatronics*, Vol. 23, Issue 4, 2013, pp. 379-408.
- [2]. J. R. Alfonso, et. al. Model-based mechanical and control design of a three-axis platform, *Journal of Mechatronics*, Vol. 22, Issue 7, 2012, pp. 958-969.
- [3]. Z. P. Xu, J. Wei, J. W. Lia, Q. T. Zhoua. Design of a temperature control system using Incremental PID algorithm for a special homemade shortwave infrared spatial remote sensor based on FPGA, in *Proceedings of the Conference on 'The International Society for Optical Engineering (Proc SPIE Int Soc Opt Eng' 2010)'*, Beijing, China, , 18-20 October 2010, pp. 78531.
- [4]. Q. Y. Fan, P. F. Liu. An Information Processing System for Sun Sensor Based on SOPC, *Opto-Electronic Engineering*, Vol. 40, Issue 6, 2013, pp. 31-37.
- [5]. F. X. Zhang, W.Z. Li. Real-time signal processing method for infrared sensor arrays, *Applied Mechanics and Materials*, Vol. 105-107, 2012, pp. 1835-1838.
- [6]. Z. H. Xin, L.Y. Hu, H. Li. The application of infrared sensors integrating stepper motor based on C8051F120, *Advanced Materials Research*, Vol. 476-478, 2012, pp. 2133-2136.
- [7]. S. J. Yoon, S. C. Noh, H.H. Choi. A study of thermographic diagnosis system and imaging algorithm by distributed thermal data using single infrared sensor, in *Proceedings of the Conference on 'Annual International Conference of the IEEE Engineering in Medicine and Biology(EMBC'07)'*, Lyon, France, 23-26 August 2007, pp. 3319-3322.

---

2013 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.  
(<http://www.sensorsportal.com>)

Promoted by IFSA

# MEMS : Uncooled Infrared Imaging: Commercial & Military Applications Report up to 2017

Market forecasts till 2017 with in-depth analysis of commercial and military markets is provided, along with a description of the main active players and the latest technological evolutions and future trends.

Order online:

[http://www.sensorsportal.com/HTML/Detectors\\_for\\_Thermography.htm](http://www.sensorsportal.com/HTML/Detectors_for_Thermography.htm)