# Design of Small Satellite Power Supply Interface Test System Based on PXI Bus

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**Abstract.** This paper investigates the design scheme of intelligent power supply interface test system for small satellites in order to satisfy the requirements of mass production of small satellites and achieve the goal of intelligent test system for small satellites. First, the functions and performance indicators required for the small satellite power supply interface test are introduced. Second, the hardware and software scheme of the small satellite intelligent power supply interface test system is designed. Finally, the feasibility of the design scheme is demonstrated. Compared with the manual test mode in the past, the small satellite intelligent power supply interface test system studied in this paper improves the test efficiency and accuracy, providing guidance for the development and production of subsequent ground test equipment.

**Keywords:** Small satellite · Integrated test · Power supply interface test

## 1 Introduction

Various countries pay more attention to the development and application of small satellites with the expansion of global space resource needs and space applications [1, 2]. In recent years, the development trend of small satellites has gradually developed towards the direction of system complexity, functional diversification and mass production according to the mission requirements [3]. As an important part of satellite manufacture, the integrated test of small satellites is the basis for ensuring the normal operation of satellites in orbit. The integrated test for small satellites not only needs to meet the integrated test of electrical performance and various functions, but also needs to be more automated and intelligent to meet the requirements of mass production of small satellites [4].

Automatic test systems have been widely used in the integrated test of small satellites in recent years. Among them, NASA's Jet Propulsion Laboratory has developed a power test system based on the GPIB bus for the power test of the Mars rover [5]. Astrium, a subsidiary of the European Space Agency, has developed a power supply and distribution test system based on GPIB and network cables for Galileo and other projects [6]. However, the test system based on GPIB bus has the shortcomings that it cannot meet the high-speed data exchange, and the system is greatly affected by the external environment (poor robustness) [7, 8]. In order to improve the stability of the


Y. Wang et al. (Eds.): ICSINC 2022, LNEE 996, pp. 198–206, 2023.
https://doi.org/10.1007/978-981-19-9968-0_24

system and the real-time performance of data transmission, research has been carried out on the small satellite test system based on PXI bus technology at home and abroad [9]. The advantage of the small satellite test system based on PXI bus technology lies in the scalability of the system, that is, on the basis of the original design, new hardware devices or technologies are introduced to improve the overall performance of the system. Therefore, it is very important to develop hardware based on PXI bus and small satellite test interface to meet the test of different functions of small satellite.

The detection of the power supply interface of the small satellite is related to the safety of the power supply of the satellite and the smooth progress of the test as an important content in the test of the power supply system of the small satellite. In the past, power supply interface inspections were measured, recorded and interpreted manually. This method is not only inefficient but also prone to errors, causing hidden dangers to satellite security. Therefore, with the trend of small satellite batch testing today, it is necessary to develop a small satellite intelligent power supply interface test system to replace the manual mode in the past, improve the test efficiency and accuracy, and adapt to the intelligent and batch testing of small satellites. This paper introduces the hardware and software scheme design of the intelligent power supply interface test system for small satellites in detail, demonstrates the feasibility of the scheme design, and provides guidance for the subsequent development and dismantling of ground test equipment.

## 2 Function and Performance of Power Supply Interface Test System

In order to ensure the intelligent detection of the power supply interface of the small satellite, the designed system should include the following functions:

- Power supply interface inspection function: The power supply interface test system has the power supply inspection function for the cable interface on the satellite. It can measure the voltage between any two points of all the contacts in a single power supply cable.
- Contact table automatic loading function: Before the actual test, the power supply interface test system can import the contact relationship to be measured in two ways.
- Power supply interface test system self-inspection function: Based on safety considerations, before the power supply interface test system is used, the on-site self-inspection of the power supply interface test system must be performed. Self-checking includes conducting conduction and insulation self-checking for each channel. The test can be carried out after the self-check is passed.
- Automatic report generation function: The system can automatically generate a Word (Excel) report according to the agreed template according to the test results.

On the basis of ensuring the above functions, the measurement voltage, resistance and channel number indicators of the system are shown in Table 1.

**Table 1.** Test equipment functions and performance indicators

| Serial number | Function | Performance index |
|---|---|---|
| 1 | Voltage measurement | Range: 0−150 V<br>Maximum error: ± (1% + 10 mV) |
| 2 | Resistance measurement | Resistance measurement range: 100 mΩ<br>Resistance measurement accuracy: ± (5% + 10 mΩ) |
| 3 | Number of channels | 400 cores |

## 3 Design of Power Supply Interface Test System

The power supply interface test system is designed as a PXI standard stand-alone machine, which includes a standard 3U voltage and resistance measurement board as well as 14 standard 3U channel switching matrix boards. The upper computer software communicates with the main control board of the lower computer and issues test instructions. The main control board completes the automated test of the object under test by parsing the instructions and controlling the corresponding daughter board. In order to ensure the continuity of the test equipment, the external interfaces of the test equipment such as power supply, communication and other interfaces are unified standard interfaces. As shown in Fig. 1, users can switch the corresponding adapter cable for different types of interfaces during the test.

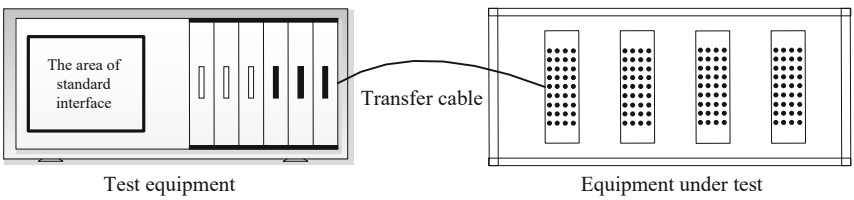


**Fig. 1.** Overall test diagram

### 3.1 Hardware Design

As shown in Fig. 2, the hardware of the entire power supply interface test system consists of a host computer, a control board, a self-inspection module, a voltage measurement module, a power supply module and an isolation module. The description of each part is as follows:

- Host computer: Run software to realize human-computer interaction.
- Power supply and isolation module: Convert 220 V AC into low-voltage DC to supply power for control board, self-test module, and voltage measurement module.

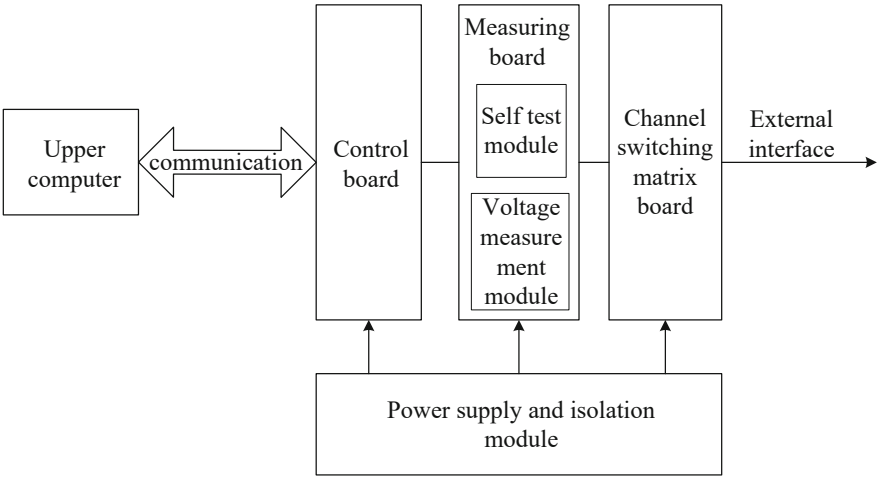


**Fig. 2.** Overall hardware framework

- Control board: It is mainly composed of XC3S1000 type FPGA in XILINX company as the core. Its function is to realize the control and data reception of other sub-functions, and complete the communication with the upper computer.
- Channel switching matrix board: It is composed of a single-pole double-throw relay based on a combination of MOSFET optocoupler relays. Using a single-pole double-throw switch, any 2 of the 48 cores can be connected to form a measurement loop.
- Measurement board: The measurement board includes a self-test module and a voltage measurement module. The function of the self-test module is to cooperate with the control board to complete the conduction and insulation test functions between each channel. The function of the voltage measurement module is to cooperate with the control board to complete the voltage test function. Both modules are designed based on NI's six-and-a-half-digit digital meter PXI-4065. Its advantage lies in its small size, which is convenient for the host computer to control its range and read the measurement data.

### 3.2 Software Design

The software development platform of this project is to choose Microsoft Visual Studio 2010 as the integrated development environment, choose C# as the development language, and then use Windows Form related tools to develop on the.NET platform.

The main functions of the software are shown in Fig. 3. The functions of the software are mainly divided into four categories, including connection configuration, conduction self-test, insulation self-test and voltage measurement. Each function has an interface corresponding to it.

**Connection Configuration Function**

The connection configuration is used to configure the connection between the transfer cable and the device card, as well as to establish the corresponding relationship between

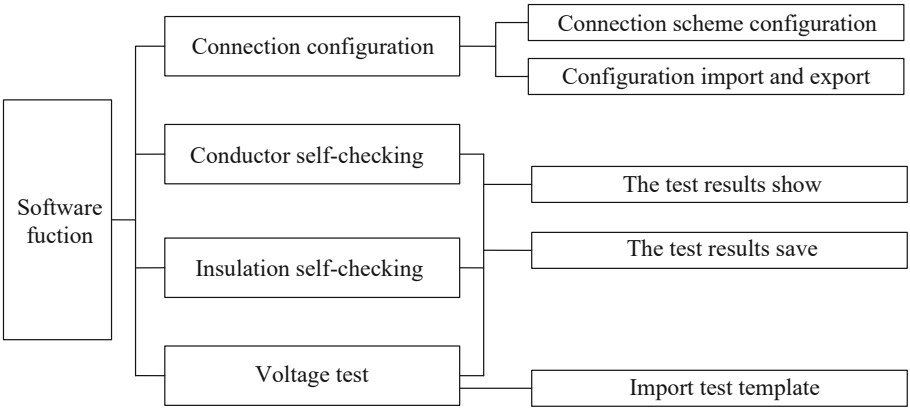


**Fig. 3.** Software function of power supply interface test system

the terminals on the transfer plug and the terminals on the device card. Before testing, the connection configuration needs to be made according to the case of the adapter cable. There are two types of connection schemes: single-cable power supply scheme and multi-cable power supply scheme. Considering that there is no essential difference between the two schemes, configure the single-cable power supply scheme as a special case of the multi-cable power supply scheme.

When configuring the connection, first configure the board grouping. The card terminals in the same group correspond to the nodes in the transfer cable in order from small to large. A group of boards may correspond to one or more adapter plugs, so the number of adapter plugs in each board group is required. After configuring the board grouping situation, configure the specific situation of different groupings. In addition, it is also necessary to configure the number and number of pins of each type of adapter plug.

After completing the configuration, click the OK button to make the configuration take effect. If there is an unreasonable configuration (the total number of terminals of the switch broadcast head exceeds the total number of terminals in the board group; the range of plug serial numbers overlaps, etc.), the test software will pop up a pop-up window to prompt an error message, and the current configuration will not take effect. After a certain configuration of the program is completed, the connection scheme can be exported to a file, and the configuration file can be imported into the program next time when there is the same requirement.

**Test Flow Control**

In the test software, the continuity self-test test, insulation self-test test and voltage test provide the same process control function. As shown in Fig. 4, the user informs the device to start the test according to the test sequence by starting test interface. The test software performs the test according to one line in the test result list, and displays the test result in the corresponding result column in one line. The test software provides pause and resume functions. While the test is in progress, pressing the pause button will pause the test software after completing the current test entry. At this time, press the continue

button, and the test will continue. A termination test interface is provided, through which the user can terminate the test at any time. If the user does not terminate the test, the software will automatically end the test according to the number of test sequences. When all the test items in the result table are completed, the software will automatically stop the test. The testing software displays the current testing progress through a progress bar. After the test is complete, the test results can be exported as needed. The test results are saved in the format of an Excel document.

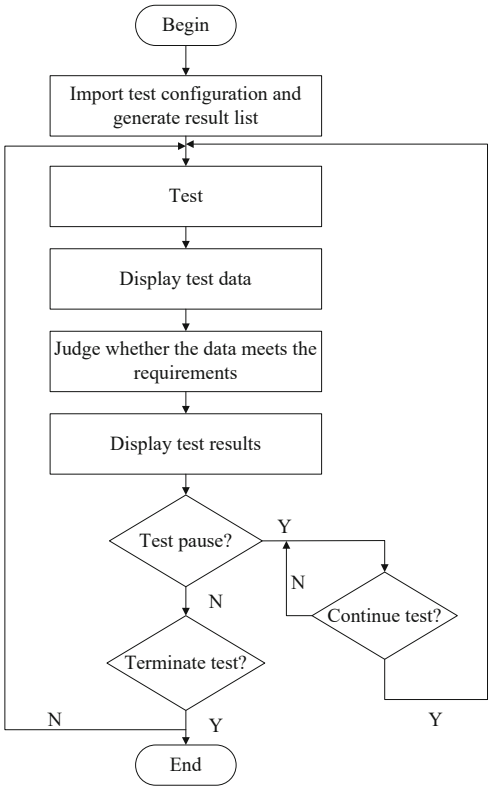


**Fig. 4.** Test flow chart

**Self-check Test Function**

The self-test test is used to check the patch cable and the system for abnormal conditions such as open circuit or short circuit. Specifically, it can be divided into continuity test and insulation test. Tests provide functions such as start, stop, pause, and resume for flexible control of the test process. The program displays the current test progress through a progress bar, and the test software that completes all the items provides the function of exporting reports, so as to record the test results.

When conducting self-check, use the TK/TJ short-circuit head of the core at the right end of the transfer cable (connecting device) according to the connection configuration,

and the adjacent two points in each short joint are shorted. Connect 2 Pins in the 48 cores of each board in turn in the order of the point numbers to test the resistance to check whether there is an open circuit in each channel. The test software can automatically generate test templates for continuity testing according to the connection configuration. When conducting a continuity test, the resistance of each entry is measured separately. If the resistance is greater than the set threshold, it is considered that there is a short circuit, and the overrun will be prompted at the specific situation on the right.

During the insulation self-test, remove the short connector at the end of the transfer cable, that is, all channels are open-circuited. According to the configuration of the external cable, group 9 boards for insulation resistance test, and check whether there is a short circuit in each channel. When conducting insulation test, it is necessary to test all terminal combinations in each board group, and the required test items are relatively large. Therefore, all test results are not recorded, only abnormal terminal combinations are recorded.

**Voltage Test Function**
The voltage test mainly realizes the automatic test of the voltage of the tested interface. Before the voltage test, import the corresponding test template. After importing the template, the voltage test can be performed. The voltage test panel displays all the contents of the template, and measures the voltage and whether it exceeds the limit. After clicking Start Test, the items to be tested will be tested in turn. After clicking Stop Test or testing all items, the test will stop. If the voltage obtained by the test exceeds the reasonable range, it will display Yes at the limit, otherwise it will display No.

**Fault-Tolerant Design**
The fault-tolerant design of a software system mainly considers the errors to be avoided, including errors caused by incorrect system configuration, errors caused by inputting unqualified data, and sending wrong instructions. In order to solve the above errors, the added fault-tolerant design includes: reminding the user to confirm the connection configuration before execution; presetting the range of each input data in the software and verifying it after input; sending the command operation to provide confirmation measures.

## 4 System Verification

The system needs to be strictly tested to ensure that its functions are correct and meet the performance index. The test content is as follows:

According to the requirement description, build the hardware environment, carry out the self-box test with the object as the unit, and the test method adopts the method of self-compiled test program and backup program. According to the requirement description, build a hardware environment, and conduct black-box testing with the system interface as a unit, and the testing is carried out manually. The functionality of the complete system is confirmed, and the code is manually reviewed through the use of workshops.

The intermediate results of the test are managed and tracked with a software problem report (SPR), detailed test plans and use cases are prepared and reviewed before the test,

and the test report is submitted for acceptance as a part of the software product. The indicators of the main quality attributes of the software are shown in Table 2. It can be seen from the table that this scheme can fully meet the technical requirements put forward by users.

**Table 2.** Main quality attributes

| Main quality attributes | Detailed indicators |
|---|---|
| Correctness | The software is completely designed according to the requirements, and the functions are reasonable and correct |
| Easy of use | Reasonable layout of human-computer interface and simple operation |
| Robustness | The software can run 15 × 24 h continuously without error |
| Safety | The command operation will be executed is to use the pop-up dialog box and other methods to provide confirmation options. When carrying out certain items, some command operation buttons can be grayed out according to the piping file to prevent misoperation. There is an alarm function when the read or send data exceeds the set threshold |
| Scalability | Analysis projects can be extended |
| Maintainability | More than 35% of the software code is guaranteed to provide Chinese comments. It is convenient for the operator to understand its working principle |
| Openness | Provides an interface with the master control software of each system, and can establish a communication protocol with the master control software |

## 5 Conclusion

This paper designs a small satellite intelligent power supply interface test system from the perspective of hardware and software based on the functions and performance indicators of the small satellite power supply interface test. Compared with the manual test mode in the past, the small satellite intelligent power supply interface test system measures, records and interprets the test data, which ensures the accuracy, simplifies the test process and improves the test efficiency. After being put into use in the future, it will greatly improve the satellite testing technology and mode, and can better meet the needs of intelligent batch testing of small satellites.

## References

1. Joseph, R., Roman, H., Jason, R.: Small satellites an overview and assessment. Acta Astronaut. **170**, 93–105 (2020)
2. Raghunath, K., Kang, J.: An exploration of the small satellite value chain and the future of space access. In: Proceedings of the AIAA/USU Conference on Small Satellites: Mission Operations & Autonomy, Logan, UT, USA, pp. 7–12 (2021)
3. Bai, Z.: Development achievements and prospects of China modern small satellite. Spacecraft Eng. **28**(2), 1–8 (2019)
4. Dai, J., Chen, F., Li, P., Wang, Z., Lu, W., Li, L.: Developments and prospects of China small satellite integrated test technology. Spacecraft Eng. **30**(6), 173–181 (2021)
5. Sun, F., Ye, W., Liang, C.: Research on semi physical test system of PCU on satellite. Manufact. Sci. Technol. **295**, 2540–2543 (2011)
6. Huang, J., Peng L., Zhou, Y.: Research on electromagnetic environmental measurement system based on GIS and GPIB technology. In: The 8th International Symposium on Antennas, Propagation and EM Theory, pp. 1244–1247 (2008)
7. Wu, J.: An overview of Rocsat-1 electrical ground support equipment design. Microsatellites Res. Tools **10**, 170–174 (1999)
8. Lee, S., Kim, B.: A study on the construction of ground test segment for the time synchronization system using the geostationary satellite. J. Korean Soc. Aeronaut. Space Sci. **32**(5), 104–108 (2004)
9. Li, Y., Liu, X.: Research on simulation system of on-board computer based on PXI-Bus. Comput. Measur. Control **27**(12), 157–165 (2019)