Design of Reconfigurable Test System for Information Interface Between Space Station Combination with Multi-aircraft

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Abstract. Aiming at the need for space station assembly flight information engineering functional verification, test system design method is proposed reconfigurable. Platform for high-performance system can be configured to be equipment design, combined with relatively flexible, the software system can be configured using the graphical programming software virtual instrument, comprising on the one hand to support a plurality of interfaces between different aircraft designed by reconfigurable Verification capabilities. On the other hand, in the absence of real aircraft docking, the newly developed aircraft can be effectively verified on the ground. Through simulation test verification, the system can quickly realize the simulation verification of the interface with a variety of manned spacecraft, which makes the test process forward, improves the parallelism of test and development, can effectively cover various failure modes, and the system framework is reliable and significantly reduces cost.

Keywords: Space station · Combination · Information interface · Reconfigurable

1 Introduction

One of the characteristics of the space station project is that multiple manned spacecraft are in orbit for space rendezvous and docking. After forming a composite body, it will operate for a long time in orbit. It is necessary to fully verify the interface between the aircraft and the function of the composite body on the ground. Traditional manned spacecraft interface verification test systems generally have the following situation: after the completion of the construction, it is difficult for ordinary users to change its relatively fixed functions, and the special aircraft is dedicated, which cannot meet the diverse tests. The developed test system cannot share software and hardware components due to its strong professionalism, incompatibility, poor scalability, lack of generalization, and modularity. This not only makes the development efficiency low, but also makes the development of a complex test system expensive.

Reconfigurable: In a system, its hardware module or software module can reconfigure the structure and algorithm according to the changed data flow or control flow.

Reconfigurable technology has the following advantages:

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1) Reconfigurable technology can efficiently realize specific functions. Reconfigurable logic devices are hard-wired logic, which changes the function by changing the configuration of the device. 2) The reconfigurable technology can dynamically change the device configuration and flexibly meet the needs of multiple functions. 3) Reconfigurable technology has strong technical support to accelerate product development. 4) The use of reconfigurable technology can greatly reduce system costs. Using dynamic reconstruction technology to implement them in different demand periods to achieve “one machine with multiple uses”.

2 System Framework

The design of reconfigurable test system includes two parts: hardware and software reconfigurable. Hardware reconfigurable means that data acquisition cards with different interfaces are universal, and the multiple channels of the data acquisition card can be arbitrarily allocated to each instrument. Software reconfigurability refers to the reconstruction of the framework and functions. The framework is a reusable, semi-finished application, and the final application can be generated by customizing it [1]. To realize the reconfigurability of virtual instruments, the software must be modularized, the physical layer and the data layer must be separated, and a unified data interface must be defined to facilitate data transmission and calling between different modules. When adding new functions, as long as the interface definition conditions are met, the new function modules can be added to the framework, and the existing modules can be improved without changing other settings.

The design process of a typical reconfigurable test system is shown in Fig. 1. It involves system decomposition, function modeling, reconfigurable module design, data interface design, system testing, etc.

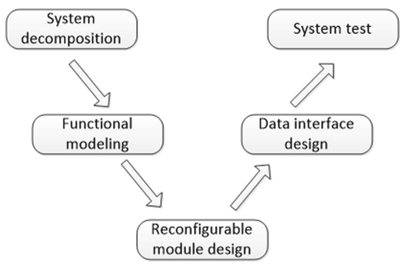

Fig. 1. Flow chart of the development of a reconfigurable test system

The composition of a typical reconfigurable test system is shown in Fig. 2. A complete reconfigurable test system should include the following functional modules: reconfigurable configuration module, real-time processing module, multi-source data acquisition, simulation excitation module, and data analysis module [2].

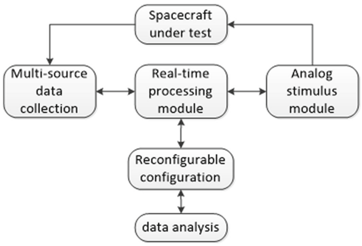

Fig. 2. Composition of a reconfigurable test system

3 Hardware Composition

The reconfigurable test system consists of four parts of hardware: PXI platform, CompactRIO module, external interface and signal conditioning module, and the object under test (Fig. 3).

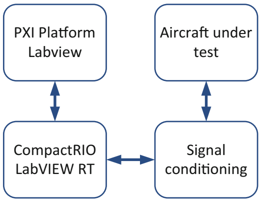

Fig. 3. Hardware composition diagram

Choose PXI as the core module of the manned spacecraft reconfigurable test system platform. The PXI platform (PCI extensions for Instrumentation) combines the electrical bus characteristics of PCI and The ruggedness, modularity, and the characteristics of Eurocard mechanical packaging of CompactPCI (compact PCI) have developed into mechanical, electrical and software specifications suitable for applications in test, measurement and data acquisition applications [3].

Choose CompactRIO as the pre-module of the in-the-loop system. CompactRIO is a rugged, reconfigurable embedded system, mainly composed of three parts-real-time controller, reconfigurable FPGA And industrial grade I/O modules.

First, design the transfer module and jumper module according to the various connectors involved in the tested object to facilitate the plugging of the device's proprietary connectors and the communication of electrical signals. And merge the corresponding signal into the corresponding conditioning module; design the signal conditioning module to adjust the analog voltage and current signals of the external device from the input aspect, and adjust the analog signal to the range that the sampling circuit can adapt, and the digital signal of the external device Perform level conversion, from the output aspect, amplify and adjust the output voltage and current signals to facilitate driving the corresponding circuits of external devices, and perform level conversion on the output digital signals in accordance with the external interface electrical protocol.

4 Software Design

In the overall design of the virtual instrument, the reconstruction function module is the core part of the virtual instrument. The reconstruction process of the entire instrument is displayed in the reconstruction module. All the functional instruments in the instrument function module can be added, modified and deleted in the instrument configuration module. There are sub-modules such as physical channel selection module, instrument configuration module, instrument trigger setting module and data analysis module in the reconstruction function module.

4.1 Physical Channel Selection Module

In the physical channel selection module, determine the number of channels, channel names and channel IDs of the data acquisition card, and set the acquisition range, sampling frequency and buffer size of the data acquisition card.

4.2 Instrument Configuration Module

All instrument function modules must be configured in the instrument configuration module. In the instrument configuration module, set the parameters for the instrument used, and assign the instrument ID and physical channel. For instruments with the same function, due to the different instrument IDs, the parameter settings of the same instrument are independent of each other. Therefore, different functions of the same instrument can be used for different channels.

4.3 Instrument Trigger Setting Module

There are many similarities between the instrument trigger setting module and the instrument linkage setting module. The trigger module is the inheritance of the linkage module and is reconstructed on the basis of the linkage module. In the instrument trigger setting module, different trigger combinations are distinguished by the trigger ID, and the instrument trigger condition, trigger initial value, trigger channel and trigger sequence are set.

4.4 Data Analysis Module

The instrument functions in the instrument function module are all independent of each other. The instrument function modules include voltmeter module, ammeter module, ohmmeter module, frequency meter module, spectrum analyzer module, oscilloscope module, signal generator module, counter module. Data analysis is to display the data to be analyzed in the form of a curve.

4.5 Main Software Design

The PXI platform runs Labview development program, configures and monitors the data flow and test process of the entire system in the loop. Veristand is a configuration-based real-time test software. The internal engine is the execution core that controls the communication timing between the entire system, the execution host and the user interface. It is responsible for executing model operation, hardware I/O and the system definition file [4]. The system definition file contains the setting options for executing Veristand engine tasks, such as target configuration, hardware I/O configuration, model import, interface mapping, custom device import, etc.

In the software, the start and end of the simulation test are controlled through shared variables, and the data in the lower computer is recorded with global variables, and then uploaded to the upper computer through the network. The three parts of the program all adopt the state machine method, which is convenient for software upgrade and maintenance.

Labview monitoring software is mainly divided into two parts, simulation process monitoring and viewing simulation data. Simulation process monitoring includes functions such as parameter call, simulation control, real-time parameter monitoring, and driver input during simulation. And can configure the simulation mode, shift strategy, simulation time, initial state, road adhesion, etc. It is convenient and flexible to realize the simulation of various situations (Fig. 4).

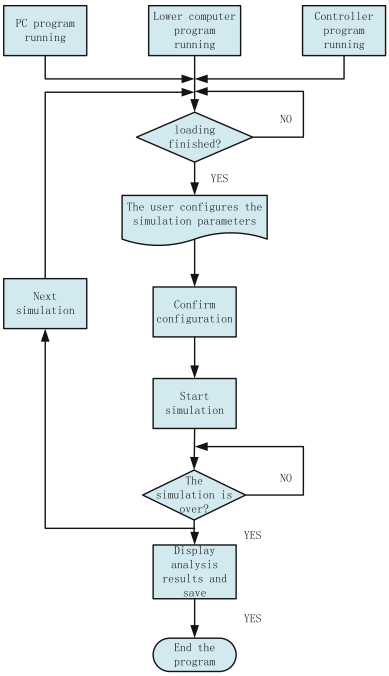

Fig. 4. Software structure diagram

CompactRIO runs the Labview RT real-time operating system, and develops applications based on Labview RT, which can realize precise timing operation and respond to various events in time. The timing arrangement mechanism of the operating system ensures that high-priority tasks are executed first, and the execution tasks are sorted according to preemptive and time-sliced cycles. When low-priority threads execute, high-priority threads require processor time, and low priority Threads stop running to ensure that high-priority threads run; when threads of the same priority execute, time slice cyclic ordering allocates equal processing time to threads. Task sequencing that mixes preemptive and time-sliced loops can ensure that LabVIEW RT has time determinism and can reduce time jitter.

Running on the Labview FPGA module requires logic such as parallel execution, repeated execution, and data processing. Ensure the parallelism of various logic executions, the cycle rate can reach above MHz, and complete a large number of data filtering, data framing and other functions.

5 System Verification

A test simulation system based on reconfigurable technology is used for simulation verification of a certain aircraft information interface. Connect the rear PXI platform with the front CompactRIO and signal conditioning module through the environment construction, and electrically connect with the real electronic equipment installed on the corresponding structure. The built-in power supply supplies the normal power supply for the tested equipment. According to the agreed electrical protocol, CompactRIO controls the corresponding module to send digital signals, complete the protocol handshake with the measured object, and start data communication. Various analog signals and digital signals that indicate the state of the measured object are normally collected by the front module through the electrical interface, and sent to CompactRIO for processing after signal conditioning and filtering, and the data is displayed and stored on the PXI platform; The device under test sends simulated data injection, and monitors the response of the device from status monitoring; simulates fault simulation and fault injection, observes the response of the device from the input interface, and simulates the real interface of the simulated device and the device under test. After testing and verification, the system can effectively cover various interfaces of the tested object, cover various normal and fault conditions, comprehensively cover information flow and status telemetry, and can quickly reconfigure configuration to support another aircraft's information interface.

6 Conclusion

This article discusses the reconfiguration design method of the interface verification between aircrafts from the two aspects of hardware and software. Through the reconfigurable design of hardware and software, a variety of verification combinations can be flexibly matched and the verification efficiency is high. Through system design and environment construction, a reconfigurable manned spacecraft interface verification system has been constructed. Simulation verification shows that the system has the ability to simulate real equipment, can be configured quickly, and simulate a variety of spacecraft interfaces, and The failure mode can be set. The establishment of a unified interface reduces the difficulty of secondary development and significantly reduces the development cost. Solve the problem of high production and maintenance costs and waste of resources caused by the complexity of test objects, multiple test equipment, and low utilization of test resources. It has significant application value for large-scale space rendezvous and docking spacecraft development and assembly operation technology verification, and it can also be applied to the rapid verification of low-cost commercial aircraft.

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