Design and Realization of Test System for Digital Input and Output Module

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Abstract. Aiming at the problems of the various types of digital input and output modules in the anti-harsh hardened computer, the lack of a dedicated test system and the incomplete testing, a dedicated digital input and output test system with a wide test range was designed. The system is based on single-chip microcomputer and FPGA and can provide 64 channels of digital output (0–30V adjustable), 64-channel digital or voltage value input test, 64 channels of switch-type digital signal, and the status of the tested module can be read in real time through the host computer software. The digital input and output modules can solve the current situation of incomplete functional testing, and the test results are accurate, stable, and reliable, with a compact structure and multiple test channels.

1. Introduction
The digital input and output (DIO) modules in the anti-harsh hardened computer have relatively large differences in the number of channels, working levels, coupling methods, and interface circuit types according to different uses[1]. At present, there are more than 10 kinds of modules with digital input and output functions developed and produced, and the types and numbers of modules are increasing year by year. Table 1 shows the situation of several typical digital input and output modules.

Existing related test equipment has incomplete coverage of the output voltage test range and insufficient number of channels; digital output can only test two states of high level or low level, and because the definition of high and low levels of each module is different, test errors are prone to occur. Therefore, it is necessary to design a dedicated test system for a wide range of digital input and output (DIO) modules and complex functional parameters.

2. System Solution
Figure 1 is a block diagram of the overall design of the test system. The DIO signal to be tested is connected to the test system through the DIO module debugging platform, and then the data is transmitted to the monitoring software of the debugging computer through serial communication. Among them, the DIO test system is mainly composed of two parts: the power supply and the control circuit. The power supply part is powered by AC 220V, which can output 5 channels of 0–30V adjustable voltage (30W), and 1 channel of 12V, 10W voltage for circuit power supply; the main control part of the control circuit is a single-chip microcomputer and FPGA, with 64-channel voltage value measured digital inputs is used to test external digital output, 64-channel digital output (0–30V adjustable) is used to test external digital input, and 64-channel switch-type digital signal.
3. Hardware Design

3.1. The overall design of DIO test system hardware

The test system can test the DIO modules currently developed and produced, and mainly completes the following functions:

1) Provide 64-channel digital input test, which can test the input voltage value;
2) Provide 64 channels of digital output (0~30V adjustable), each channel can provide a maximum of 100mA output current;
3) Provide 64 switch-type digital signal test;
4) The system communicates with the PC through the RS232 serial port, which can realize the control of the upper computer of the digital output and the upper computer monitoring and display of the voltage value of the digital input;
5) Accurate display of each output voltage of the power module.

3.2. Power module

The power supply part is powered by AC 220V, which can output 5 channels of 0~30V adjustable voltage (30W), and 1 channel of 12V, 10W voltage for circuit power supply. The panel of the test system provides DC1-DC5 voltage adjustment knobs and 6-channel output voltage display, as shown in Figure 2.

Among them, DC1-DC5 provide 0-30V adjustable output (30W), mainly to test the digital input function of the DIO module under test, designed according to the maximum output of 100mA per channel. Generally, it is divided into 0-10V, 10-15V, 15-20V, 20-25V, 25-30V voltage segments according to the output voltage. Because the output current may be insufficient when the voltage output is high, the voltages of other circuits can also be adjusted higher according to needs. DC6 is 12V output (10W), which is mainly used to power the circuit.

Since the voltage value provided by the system to the main control module is 12V, and the required voltage is mostly 5V, the voltage needs to be converted. The LM2576-5.0 chip is used to convert the
12V voltage to 5V. In addition to powering the main control module, the 5V voltage also needs to supply power to the output MOS tube, the head of the chassis, and the output relay of the adapter board. Considering that a large current may cause the power chip to be overloaded, two LM2576-5.0 chips are used to supply power separately, one of which supplies power to the main control module, output MOS tube power supply and the header of the chassis, and the other is a separate power supply for the adapter board. The output relay is powered.

3.3. Main control module design

The main control module design is mainly based on STC15F2K08S2 and Cyclone II EP2C5Q208I8N FPGA. The system communicates with an external PC through the serial port of the single-chip microcomputer; the single-chip microcomputer communicates with the FPGA through the P0 port and P1 port to realize the read and write operations of the FPGA internal registers. FPGA controls 64 relay output values, according to the internal register value, and selects the input channel to be measured through the 8-to-1 analog switch chip, and then samples the digital output voltage value through the ADC inside the STC microcontroller.

In this design, the STC15F2K08S2 microcontroller mainly completes the digital input, A/D value sampling, communication with FPGA and communication with the host computer through the RS232 protocol. Because 64 channels of A/D values need to be collected in total, and the single-chip microcomputer only provides 8 channels of A/D value sampling, 8 CD4051 analog switches are added in this design to realize sampling through switching. In addition, the 8-channel 10-bit A/D value sampling provided by the microcontroller can meet the design requirements.

STC15F2K08S2 MCU is a single clock/machine cycle (1T) MCU produced by STC. It is a new generation 8051 MCU with high speed/high reliability/low power consumption/super anti-interference. It adopts the eighth-generation encryption technology with super encryption and command The code is fully compatible with traditional 8051, but the speed is 8-12 times faster. Internal use integrated high-precision R/C clock (±0.3%), ±1% temperature drift (-40°C~+85°C), temperature drift at room temperature ±0.6% (-20°C~+65°C), 5MHz~35MHz A wide range can be set, which can completely eliminate the external expensive crystal oscillator and external reset circuit (the internal high-reliability reset circuit has been integrated, and the 8-level reset threshold voltage is optional during ISP programming)[2]. 3 channels of CCP/PWM/PCA, 8 channels of high-speed 10-bit A/D conversion (300,000 times/second), built-in 2K bytes of large-capacity SRAM, 2 groups of high-speed asynchronous serial communication ports (UART1/UART2, available in 5 groups Switch between pins, time-sharing multiplexing can be used as 5 groups of serial ports), 1 group of high-speed synchronous serial communication port SPI, for the occasions with strong interference in multi-serial communication/motor control.

The CD4051 chip is a single 8-channel digital control analog electronic switch, with three binary control input terminals A, B, C and INH input, with low on-resistance and very low off leakage current. A digital signal with an amplitude of 4.5-20V can control an analog signal with a peak value of 20V^3.
3.4. Digital input and output modules

In the digital input and output module, the function of 64-channel digital output (0~30V adjustable) is realized by the circuit shown in Figure 6. The output voltage value is selected by the MOS transistor controls the relay to choose whether to output the voltage, and realizes the digital input function of the digital output measurement DIO module.

The knob switch is a single-pole six-throw switch, the model is KX020-60-1D6WD, and the knob switch is KN6A-102DM. The relay uses single-pole double-throw electromagnetic relay, model G5V-1-DC5.
In the 64-channel digital input test, the input signal is divided into voltage first, and the 64-channel input voltage is connected to the 8 ADCs inside the STC single-chip microcomputer through 8 one-of-eight analog switches CD4051, and the CD4051 gate is controlled by FPGA to obtain the voltage value of each channel, the digital input circuit is shown as in Figure 7.

The 64-channel digital input and output module can provide power output and light-emitting diode display for each channel, solving the current problem of insufficient test channels.

3.5. PCB design
In the system design, the signal transfer adapter board needs to replace the upper cover of the chassis, and the size is 396mm*326mm in line with the upper cover. Because there are many mechanical switches above the circuit and the weight is relatively large, the PCB board is thickened in the design to ensure load-bearing, the board thickness is 3.2mm, and a fixed beam support is added in the design to ensure normal use.

Using an 8-layer board structure, the power signal of this backplane is: DC1~DC6, +12VIN (powered by P1 connected to the board, each signal is a maximum of 30W, 1.1A), the power signal +5Vout0 and +5Vout1 are for external power supply, the maximum output current is 1.5A, power supply and ground each use one layer, and the remaining layers are signal layers.

4. Software Design
The software of the digital input and output (DIO) test system is developed using VC 2008 software, which can realize the functions of 64-channel digital output control and 64-channel voltage reading of the DIO module. The software design flow chart is shown in Figure 9 below:
5. System test

5.1. 64-channel digital input test

64-channel digital input test: input 64-channel 0-30V voltage to the test system, and the upper computer monitoring software can display the current voltage value of each channel in real time, and the comparison error with the multimeter measurement is within 0.1V.

Table 1  64-channel digital input test

| Digital input value | Test value | A/D sampling value |
|---------------------|------------|--------------------|
| 2.000V              | 2.001V     | 2.005V             |
| 5.000V              | 4.998V     | 4.999V             |
| 10.000V             | 9.993V     | 9.990V             |
| 15.000V             | 14.995V    | 14.990V            |
| 20.000V             | 19.995V    | 19.985V            |
| 28.000V             | 27.990V    | 27.983V            |
| 30.000V             | 29.982V    | 29.980V            |
b) 64-channel digital output: The test system accurately adjusts the output voltage through the knob switch and voltage display value on the panel, and then enables the output of the corresponding channel through the control circuit switch and the host computer software. The output voltage value error is within 0.05V, and the control accuracy is high.

Table 2  64-channel digital output test

| Digital output value | Test value |
|----------------------|------------|
| 2.000V               | 2.001V     |
| 5.000V               | 4.999V     |
| 10.000V              | 9.998V     |
| 15.000V              | 14.993V    |
| 20.000V              | 19.996V    |
| 25.000V              | 24.995V    |
| 30.000V              | 29.998V    |

64-channel switch-type digital signal test: The test system can test 64 switch-type signal at the same time, when the switch is closed, the light-emitting diode is on and the time delay is within 1s, the test system has a large number of channels and the result is accurate.

6. Conclusion
The digital input and output test system solves the problems of complex and incomplete testing of the DIO module in the current anti-harsh hardened computer, and the test result is accurate with more test channels, and the test efficiency of the DIO module is greatly improved.

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