Design of elevator control system based on DE10-Nano board

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Abstract. In today's society, the elevator has become an indispensable tool in people's production and life. Due to the obvious advantages of FPGA in digital circuit control system, the control based on FPGA has become one of the most widely used control methods of elevator. DE10-Nano board provides a powerful hardware design platform based on Intel system on chip (SoC) FPGA, which can flexibly and conveniently complete the elevator control function. In this paper, based on DE10-Nano board, the function analysis and design of elevator control system are completed, and the effectiveness of the control system function is verified through time sequence simulation.

1. Introduction

With the rapid development of urbanization, a large number of high-rise buildings rise rapidly, and the impact of elevators on people's production and life is becoming more and more important. How to control the elevator quickly, accurately and safely has become the most basic requirement of elevator development. As a product of modernization, elevators appeared in the public's view as early as the 19th century. With the progress of the times and the development of science and technology, elevator control technology has also been rapidly developed. In daily life and production, there are mainly three kinds of elevator control modes: PLC control, microcomputer control and FPGA control. From relay control circuit to programmable logic controller and then to microcomputer control system, elevator control has gone through a long and long process[1-2].

Relay and contactor control is the earliest way to control elevator. Its advantages lie in simple schematic diagram and easy to understand circuit diagram. But its disadvantages are also very obvious, such as unstable operation state, single control mode, not having certain regulation ability, high risk coefficient. Therefore, it is gradually replaced by programmable controller or microcomputer control system with strong reliability and wide application range. The principle and programming technology of microcomputer are used in PLC control. It has the advantage of strong logical correlation, so it plays an irreplaceable role in elevator control. Microcomputer control has been approaching to the intelligent construction standard, which shows great advantages in technology, and of course, it has its shortcomings. Its anti-interference performance is poor, and the system design process is very complex. With the high research and development costs, the business operation cost will be greatly increased, and the risk will be correspondingly increased. Once the fault occurs in the operation, the general maintenance personnel are helpless[3-4].

The control system based on FPGA, at the technical level, its operation reliability is very strong, the program is easy to understand, and the elevator failure rate is basically zero. On the economic level,
the design cost is low. This kind of elevator control mode is affordable and popular, which means that the control based on FPGA is in an unshakable position in the elevator control mode. Now it has become the most widely used elevator control mode\cite{5}.

2. Control function requirements of an elevator

Elevator is a kind of transportation equipment which is operated by control system and power system. It has external signal button and internal signal indication button. It uses its own signal trigger device to determine the location of the elevator, so as to complete a series of operation. The control system uses the internal or external request signals of the elevator to control the operation of the elevator, including the basic elevator up and down process. After receiving the response of the request signal, the elevator opens the door to carry passengers. When the passenger presses the button on the target floor, the elevator control system will respond to the input signal to realize the corresponding operation of the elevator ascending and descending. At this time, where the elevator is on the floor, or how the elevator moves, can be displayed through LED digital tube and state device respectively.

Fig. 1 shows the functional control system block diagram of the elevator.

![Figure 1. Functional control system block diagram of the elevator.](image)

3. Structure and working characteristics of DE10-Nano board

The DE10-Nano board presents a robust hardware design platform built around the Intel System-on-Chip (SoC) FPGA, which combines the latest dual-core Cortex-A9 embedded cores with industry-leading programmable logic for ultimate design flexibility.

The DE10-Nano board contains all the tools needed to use the board in conjunction with a computer that runs the Microsoft Windows XP or later. Users can now leverage the power of tremendous re-configurability paired with a high-performance, low-power processor system.

The component configuration of DE10-Nano board is shown in Fig. 2 and Fig. 3.

![Figure 2. DE10-Nano board.](image)

![Figure 3. Block diagram of DE10-Nano.](image)
The following hardware is provided on the board:

FPGA
- Cyclone® V SE 5CSEBA6U23I7NDK device
- Serial configuration device – EPCS64
- USB-Blaster II onboard for programming; JTAG Mode
- 2 push-buttons
- 4 slide switches
- 8 green user LEDs
- Three 50MHz clock sources from the clock generator
- Two 40-pin expansion header
- A/D converter, 4-wire SPI interface with FPGA
- HDMI TX, compatible with DVI v1.0 and HDCP v1.4
- One Arduino expansion header (Uno R3 compatibility), can connect with Arduino shields.
- One 10-pin Analog input expansion header. (shared with Arduino Analog input)

HPS (Hard Processor System)
- 800MHz Dual-core ARM Cortex-A9 processor
- 1GB DDR3 SDRAM (32-bit data bus)
- 1 Gigabit Ethernet PHY with RJ45 connector
- port USB OTG, USB Micro-AB connector
- Micro SD card socket
- Accelerometer (I2C interface + interrupt)
- UART to USB, USB Mini-B connector
- Warm reset button and cold reset button
- One user button and one user LED
- LTC 2x7 expansion header

Compared with DE0-Nano-SOC, DE10 Nano development board is a new SoC development kit with more FPGA les and more HDMI output interfaces besides the same small size and almost the same periphery. The replacement of DE10-Nano's FPGA with cyclone V SOC FPGA (5cseba6) increases FPGA Les by 275%, which enables users to carry out more complex planning and development. A new HDMI output interface supporting full HD resolution is added in the periphery, so that users can develop image applications without purchasing a sub card. Intel’s SoC integrates an ARM-based hard processor system (HPS) consisting of processor, peripherals and memory interfaces tied seamlessly with the FPGA fabric using a high-bandwidth interconnect backbone. The DE10-Nano development board is equipped with high-speed DDR3 memory, analog to digital capabilities, Ethernet networking, and much more that promise many exciting applications.

4. Design of elevator control program
In this paper, taking the six floor elevator as an example, the control system program of the elevator is designed and its function simulation is completed.

4.1. Operation function and state analysis of elevator

4.1.1. Elevator request signal. The request signal of the elevator is divided into the internal request and the external request. From this perspective, it is difficult to analyze the possible situation of the elevator operation, because the operation of the elevator is controlled by the request signal and travel signal inside and outside the elevator, and the request inside and outside the elevator is random and cannot be explained by limited rules. Therefore, it is difficult to make a unified analysis of the operation of the elevator. For this reason, this design divides the request signal of elevator into two kinds, which are request to rise and request to descend. After receiving the request signal, the elevator will start the pre operation. The rising request signal is that there is a request signal to make the elevator in the pre rising state. Specifically, when the floor sending the request signal is higher than the floor where the elevator is located, if the elevator wants to reach the destination floor, the elevator must be in the ascending operation state in the next operation, which is the ascending request. Otherwise, it's a descent request.
4.1.2. Operation function and state analysis of elevator in each floor. When the elevator is on the first floor, the elevator will only have an up request response, provided that the elevator does not generate an alarm signal. At this time, the elevator will enter the pre rising state and start to prepare to rise. If the elevator detects that there is no request signal input, it will be in standby mode on the first floor, and the elevator door is also closed.

When the elevator is on the 2nd, 3rd and 4th floors, the following conditions may occur:

① When the elevator does not detect the input of request signal, the elevator is in standby sleep state;
② When the elevator is requested to go up, the elevator will enter the pre rising state;
③ When the elevator receives the descent request signal, it enters the pre descent state.

When the elevator is on the fifth floor of the top floor, the elevator will only respond to the descent request, provided that there is no fault. At this time, the elevator will enter the pre descent mode, ready to descend at any time. If the elevator does not receive the request signal, the elevator will be in standby sleep state.

In the process of elevator operation, there is the problem of how to deal with the priority signal. Elevator control system adopts human-computer interaction, which is obviously the way of communication between people and computers. If only using sequential or logical control can not meet the design requirements, so signal priority is solved by using random logic control method. That is, based on the sequence control, using the randomness of the input signal, the elevator is controlled according to the previous running state of the elevator. The advantages of this method are convenient, fast and reliable. The law of elevator operation is: Based on the previous running state of elevator, that is, when the previous state is down, all descent requests are operated and then the ascending request is operated; when the previous state is ascending, the opposite is true.

4.1.3. Status of elevator (open, close, fault, etc.). When the elevator receives the request signal, it will arrive at the request floor in the way of random logic control. After the elevator opens the door, passengers enter the elevator, and then relevant door delay signal, overweight and fault detection. After the closing countdown of the elevator is finished, and the overweight and troubleshooting are completed, the elevator door will close and enter the pre operation state.

① If there is an early door closing signal, and the elevator has finished overweight and troubleshooting, the elevator will close the door and enter the pre operation state.
② If the overweight signal "full" is sent out during the overweight detection, the elevator will send out the overweight alarm signal by closing the door interrupt signal, and the elevator will open the door to wait for the weight of the elevator to be reduced, then the elevator will enter the passenger carrying operation state again.
③ If it is found that the elevator has failed during fault detection, the door closing interruption signal will also make the elevator send out fault alarm signal and open the door at the same time. At this time, the elevator will also end the door closing delay state, and enter the fault standby state, waiting for the arrival of professional maintenance personnel.

In case of power failure during standby or normal operation, the elevator should automatically return to the first floor or stop nearby.

4.2. Block diagram of control program structure
In order to realize the elevator control function, the program design flow based on Verilog HDL programming language is shown in Fig. 4.
4.3. An example of elevator control program design

In this paper, taking the six floor elevator as an example, the control system program of the elevator is designed and its function simulation is completed. The main function pins of elevator function controller are shown in Fig. 5.

The input signal ports of elevator controller signal are: clk, full, stop, close, clr, and other pin numbers are up1, up2, up3, up4, up5, down2, down3, down4, down5, down6, k1, k2, k3, k4, k5, k6, g1, g2, g3, g4, g5, g6, etc., with a total of 27 input ports. These signals are mainly used to detect overload, door closing interruption, early closing and alarm signal clearing. In addition, at each floor, there are external input signal, internal input signal, floor position signal and so on.

The output signal ports are: door [1..0] and led [6..0], up, down, ud, alarm. It is mainly used for elevator up and down indication and drive, door opening and closing indication and driving, floor indication, fault alarm and so on.

The function simulation of the ascending and descending control of the 6th floor elevator is shown in Fig. 6.

(a) elevator ascending control
5. Conclusion
As an important tool in our daily production and life, the control research of elevator has always been the focus of our engineers. Based on the DE10-Nano board, this paper analyses, designs and simulates the elevator control system, and completes the design of elevator control system based on DE10-Nano board. In the future, we can continue to develop the image function of the elevator based on the powerful DE10-Nano board.

References
[1] Wang X.J., Liao Y., Li C.Y., et al. (2018) Analysis on the Technology and Development Trend of Elevator in China. Henan Science and Technology, 640:137-139.
[2] Pian W.J. (2016) Analysis on the current situation and development trend of elevator industry in China. Metallurgical collections, 224:93-94.
[3] Liu C. (2020) Design and implementation of elevator control system based on MCU. Technology and Market, 27:112-113.
[4] Ma D.G. (2020) Design of elevator control system based on Siemens PLC. Scientific and Technological Innovation, 10:146-147.
[5] Luo M. (2017) Application of EDA Technology in digital circuit design. Journal of Wuhan Engineering Institute, 29: 27-28.