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Switching Module Basic Concept

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Abstract:

The use of integrated systems allows you to improve and optimize the production process, reduce human impact and speed up production. In this article, the authors considered the integrated switching system with applied devices in automated control systems, provided the basic concept of the module that will be developed, and described the principle of working with analog and discrete signals.

Key words: Automated Control System, Switching Module, Integrated System, Manufacturing Innovation, Industrial Innovation

Introduction

This article is the first in a planned series of articles devoted to the development of the switching module.

Many scientific works are devoted to management problems, including the creation of control Systems [1]-[25]. Various methods and approaches can be used [26]-[40].

Automated control system is a complex of hardware and software designed to control various technological processes.

Depending on the role of a person in the management process, the forms of communication and interaction of the "man-machine" link, the distribution of information and control functions between the operator and means of control and management, all systems can be divided into two classes: information systems that ensure the collection and issuance of information and control systems that ensure, along with information collection, the issuing of commands to executors or executive mechanisms.

Separate automatic control systems and automated devices that are linked into a single complex can be components of the automatic control system. Industrial communication interfaces are used for information communication of all subsystems. The most important parameters of the communication interface are bandwidth and maximum cable length.

Industrial interfaces usually provide galvanic isolation between connected devices. The most common serial interfaces in industrial automation are: RS-485, RS-232, RS-422, Ethernet, CAN, HART, AS-interface [2].

To exchange information, devices must have the same exchange protocol. In its simplest form, a protocol is a set of rules that govern the exchange of information. It defines the syntax and semantics of messages, control operations, synchronization and communication status. The main communication protocols at the moment are: https, SMTP, FTP, SSH, Modbus, Modbus TCP, PROFIBUS [3].

Having a large stack of protocols, combining various control devices into one centralized system does not cause difficulties. It is much more difficult to connect devices that differ in exchange protocol and communication interface to the system. In this case, interface switches or "hubs" are used, the main purpose of which is to ensure communication between connected devices and the control system via one channel.

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The developed device provides a more flexible system of connection and switching of various protocols and interfaces due to the architecture and special structure of the exchange between the switch and the master device.

Related works

The creation of switches is currently an extremely pressing scientific and technical problem. Naturally, many scientists devote their scientific work to this issue. Let us look at just a few of them.

Paper [41] notes that it is difficult to achieve an ideal control effect with traditional control theory. To optimize the core power control performance, a compound control scheme is formulated that is composed of multiple controllers by weighting and switching.

Jooshaki, M., & et al. in [42] write that judicious placement of disconnecting switches is an efficient means to enhance the reliability of distribution networks. Aiming at optimizing the investment in these switches, this paper presents a mathematical programming-based model considering the installation of remote-controlled and manual switches at various locations in the distribution network.

The study [43] presents an adaptive control method for a class of uncertain strict-feedback switched nonlinear systems.

Scientists in [44] propose a positively coupled inductor based paralleling scheme for basic semibridge switching cells, which are formed by power MOSFETs and diodes. Both the semibridge switching cells and the inductors are split into two parallel parts, and thus, a small differential mode (DM) inductance is formed between the midpoints of the parallel semibridge switching cells.

Researchers in [45] present Int-Plex@ binary genome memory switch system can be applied to produce genetic circuits combined with omics tools and sgRNAs to engineer and modulate plant metabolic pathways temporally and reversibly.

The basic concept of the switching module by applied devices in automated control systems

Before starting the development of any device, a design engineer, circuit engineer or programmer needs to build a concept, that is, a representation of the solution to the problem, taking into account all the advantages and disadvantages.

The use of integrated systems allows you to improve and optimize the production process, reduce human impact and speed up the production of products. An integrated system can consist of a large number of different component parts, the component parts of the system can be divided into workshops, lines, enterprises, etc. But the presence of industrial mechanisms that interact with people remains unchanged.

Improvement of the interaction between man and machine, carried out with the help of information collection and processing systems, the process of centralized payment of information, prompts the decision-making algorithm and reduces the risk of error when making changes to the production process.

The integrated system consists of three production lines, a module for switching exchange interfaces, an information processing system, and a line control panel. Production lines can be different and have different interfaces for communication with control mechanisms, which can lead to the complexity of the system scheme, as it will be necessary to use different interface converters to connect them. Therefore, it is advisable to install a communication interface switching module between the information processing system and line management mechanisms, which simplifies connection and reduces the number of switching nodes.

If we consider the main requirements, it can be noted that the main task of the module is the switching of various types of digital and analog signals, which will minimize the number of

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points of failure of the system, thereby increasing its reliability. In addition to the main requirement for reliability, the main tasks of the module include:

1. Connecting the module to networks with serial communication interfaces: RS-485, RS-422 and Ethernet.
2. Support of exchange protocols based on stacks: ModBus (RTU, TCP, ASCII), TCP-IP and Profinet.
3. Connection to the device module via UART, SPI, I2C, and CAN.
4. The ability to set a +24 V signal at the output of the module.
5. The ability to read and filter the +24 V signal.
6. The ability to set analog signals at the module outputs in the range from 4 mA to 10 mA.
7. The ability to measure analog signals with a given sample discreteness.
8. The possibility of configuring the module both individually and as part of an industrial network.
9. Transmission and processing of commands with specified discreteness.

The concept should describe the principle of operation, key components, basic functionality and form the basic requirements for choosing the means of its implementation. Since the main task of the module is to minimize the number of points of failure, signal switching and support of the main industrial communication interfaces, the concept construction algorithm can be divided into four parts:

- work with discrete and analog signals;
- switching of digital interfaces and communication with ACS;
- module management objects;
- operator interaction interface.

The proposed concept of the module for switching digital and analog signals is shown in Figure 1.

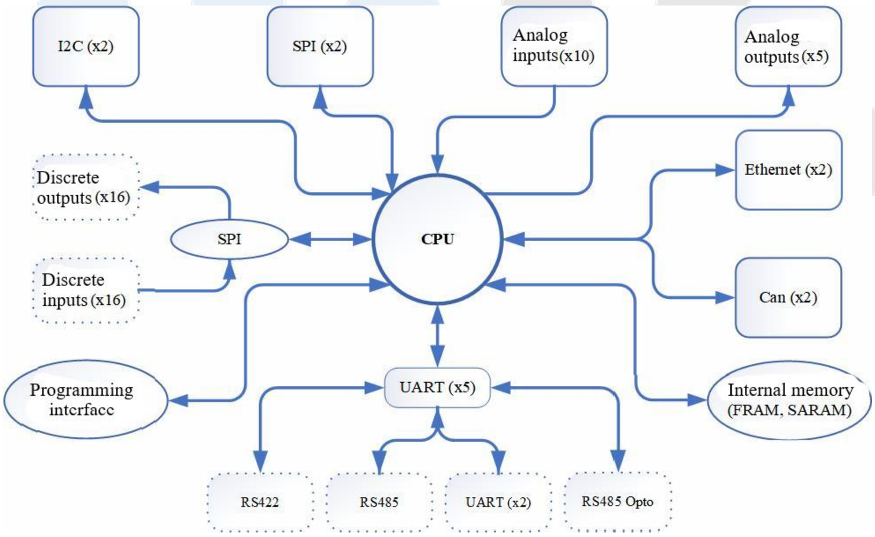

Figure 1: Switching module concept

The figure shows the key parts of the module, the rectangles mark the components that solve the main task: signal switching and communication with the central control system, the oval shows the components for programming and maintaining the module's operation, the circle shows the central control controller.

Let's consider the principle of working with analog and discrete signals.

Taking into account the analysis of the market of equipment for automatic control system and technological process automatic control system, it can be seen that basically all presented

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devices for controlling discrete and analog signals work in the ranges of 24 V and from 4 mA to 10 mA. At the same time, if we consider the main topologies of automatic control schemes, the number of devices connected to analog and discrete inputs in one node does not exceed 5-10 units, based on this, 16 discrete inputs and outputs, 10 analog inputs and 5 analog outputs are laid out in the module concept .

To implement discrete logic and reduce the number of input/output ports of the controller, it is advisable to use shift registers. Shift registers are a chain of bit circuits connected by carry chains. The main mode of operation is the shift of code bits from one trigger to another on each pulse of the clock signal. The principle of operation of shift registers is simple, when a clock signal appears, the content of the main register is rewritten in an additional one, and when the next signal appears, it is returned to the main register, but already in neighboring bits, which corresponds to the shift of the word. SPI is used to connect the shift register to the microcontroller.

SPI is a serial peripheral exchange protocol. It is designed to connect microcontrollers to each other, as well as to all kinds of peripherals: sensors, ADCs, memory chips, clocks. Four lines are used for data transmission in SPI:

- Master Input Slave Output (MISO) for receiving data from the slave;
- Master Output Slave Input (MOSI) for data transmission to the slave;
- Serial Clock (SCK) for clocking the line;
- Slave Select (SS) for selecting a slave device.

An analog-to-digital converter (ADC) is used to measure analog signals, an ADC is a device that converts an input analog signal into a digital one. For tasks of measuring the value of a signal at an arbitrary moment in time, the asynchronous mode of operation of the ADC with single analog-digital conversions that are not rigidly tied to time is used.

Synchronous mode of operation is used for tasks of measuring the functional dependence of analog signal changes. The synchronous mode of operation of the ADC without data skips for an arbitrarily large time interval is also called streaming mode. Synchronous ADCs, as a rule, support the frame-by-frame principle of data collection, when the digitized measurement data form conditional frames with a given number, which corresponds to the given measurement channels.

The use of the internal ADC of the microcontroller in this case gives a great advantage, because the operator can adjust the range of the channel, the quantization time and the number of samples per period.

To implement the requirements for the formation of analog output signals in different ranges, there are two options:

1. Digital-to-analog converter, for converting a digital code into an analog signal.
2. Timers for pulse width modulation (PWM) generation.

Using the first option, that is, a digital-to-analog converter, inevitably leads to an increase in the price of the module, because basically all microcontrollers have 2-3 built-in digital-to-analog converter (DAC) modules. Therefore, to implement 5 analog outputs in the scheme, it will be necessary to use external DAC microcircuits. In this regard, a more profitable option is the use of timers and the formation of PWM.

PWM is a way of controlling the power supply to the load. The control consists in changing the duration of the pulse at a constant frequency of passing pulses. Pulse width modulation can be analog, digital or binary.

Bipolar and field-effect transistors operating in the key mode are used as switching elements when forming PWM. This means that part of the period the transistor is completely open, and part of the period it is completely closed.

Counters or timers are used to form PWM in digital electronics, which, due to the presence of comparison registers, form a sawtooth signal of different duration and duty cycle.

Digital PWM devices operate at a constant frequency, which necessarily exceeds the response time of the controlled device. Between the edges of the clock pulses, the PWM output

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remains stable, either high or low, depending on the current state of the output of the digital comparator that compares the levels of the counter signals. An example of PWM formation is shown in Figure 2.

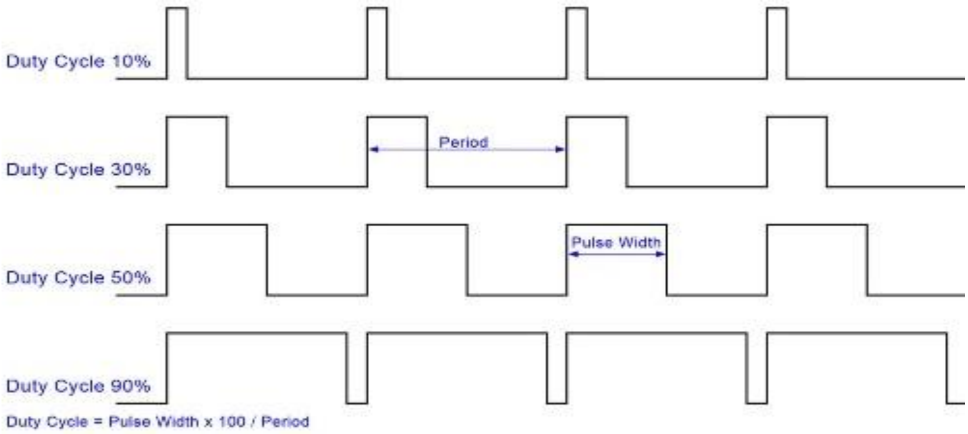

Figure 2: Principle of forming a PWM signal

Setting the pulse period to full strength before the turn-on hour is called the pulse replenishment factor. So, since the turn-on hour is 10 μs, and the turn-on period is 100 μs, then at a frequency of 10 kHz, the duty cycle will be equal to 10 .

Conclusion

As a result of the construction of the digital signal switching module concept, it can be noted that the concept takes into account all the disadvantages and advantages of the considered devices, as a result of the development, the main criteria for the selection of key components of the module were obtained.

Based on the conducted research, these criteria must be fulfilled:

1. Selection of the necessary components: microcontroller, communication chips, calculate the power supply, etc.
2. Build software architectures.
3. Make a choice of means for implementing and debugging the program.
4. Model the operation of the module and draw conclusions about the expediency of its use, taking into account the obtained results.

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