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MICROPROCESSOR ANALOG I/O MODULES

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Abstract

The article considers the possibilities of algorithmic solutions when creating interfaces based on microcontrollers, which make it possible to reduce the number of mandatory procedures in the organization of multiplex channels with galvanic isolation. The issues of elimination of interferences that affect the accuracy of measuring input signals in the measuring channels are considered. Methods for input and processing of signals in the form of currents and voltages in analog modules of measuring channels of the control system are presented.

Keywords: *automatic control systems, analog input-output devices, microprocessors, galvanic isolation, analog-to-digital converter, data error, electrical signal, clock pulse generator,*

harmonic signal, noise.

1. Introduction

In automatic control systems (ACS), analog input-output devices are widely used to organize communication interfaces for multiplex channels of controllers with real control objects. Ensuring the recommended speed of the process of information exchange between a programmable logic controller (PLC) and measuring sensors depends on the optimal choice of the configuration of switching devices, rational use of resources and interface parameters.

In modern systems, various topologies, levels and methods of interrogating the measuring data module are used. The data input/output modules used are equipped with built-in microprocessors that programmatically poll channels in accordance with the algorithm for the operation of the servicing system for all active channels[1].

In the course of executing the algorithm for the functioning of the control system, the automatic mode of parallel servicing of all input modules or transfer of processed data to the interface through output modules is often switched on. In this case, using special system commands of the microprocessor, the data of the simplified modules is temporarily transferred to the buffer circuits, and then the received measured or processed data are cyclically loaded into the processor with the priority of servicing micro-operations[2].

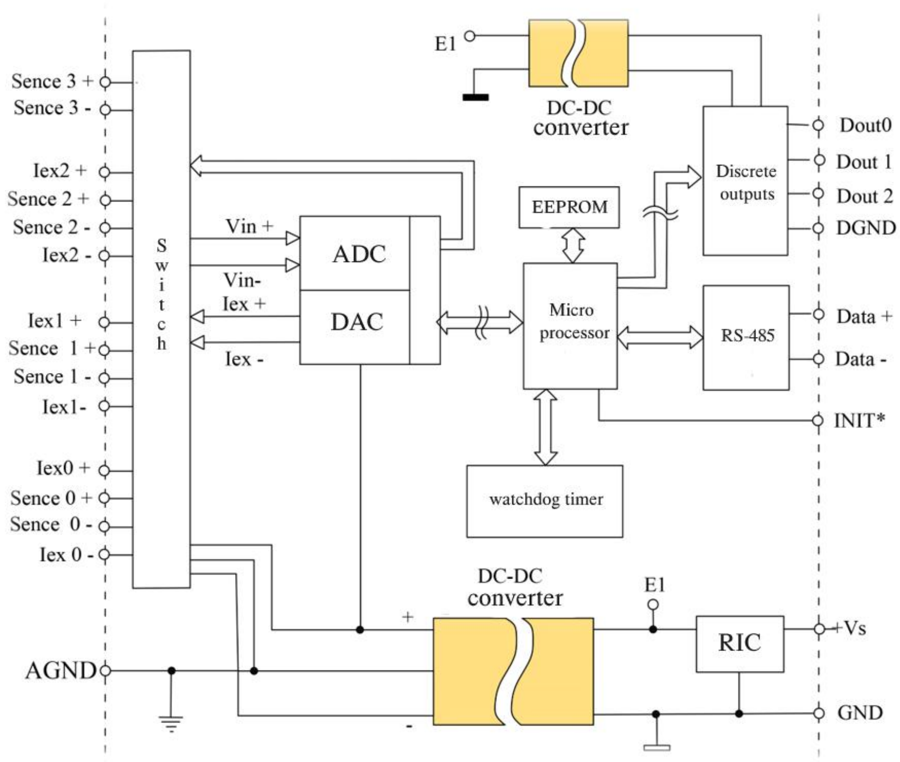

Figure 1. Block diagram of the input-output module.

All I/O modules, as part of the system interface, must be connected in strict compliance with the rules of galvanic isolation. There are two ways to perform galvanic isolation: the first method is through an individual channel, when all interfaces are isolated separately, and the second method, in which group channel isolation is mainly used[3].

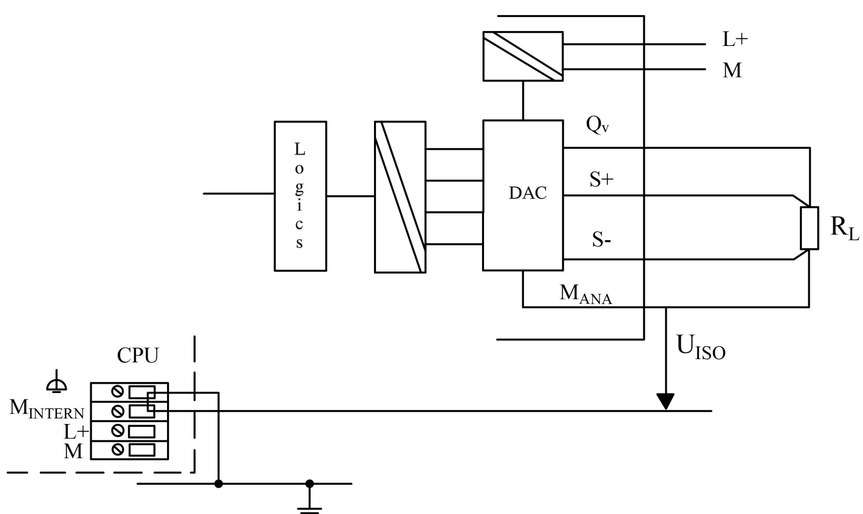

Figure 2. Connecting loads to the potential output of an isolated analog output module.

2. Main part

The analog-to-digital converter (ADC) is an integral part of the input module of the system. Measuring sensors are connected to the ADC input of the system using analog switches assembled on MOSFETs. Parallel signals from sensors according to the established priority are entered sequentially and, if necessary, parallel data input is carried out according to a predetermined algorithm[4].

In figure 3 ADC of push-pull integration is shown. The signal conversion is carried out in two levels:

- in the first one, integration is performed
- in the second, pulses are counted.

To start the "Integrator" circuit, which performs the integral calculation of the input voltage U_{in}, the switch S_1 is turned on and the switch S_2 is switched to the open position[5].

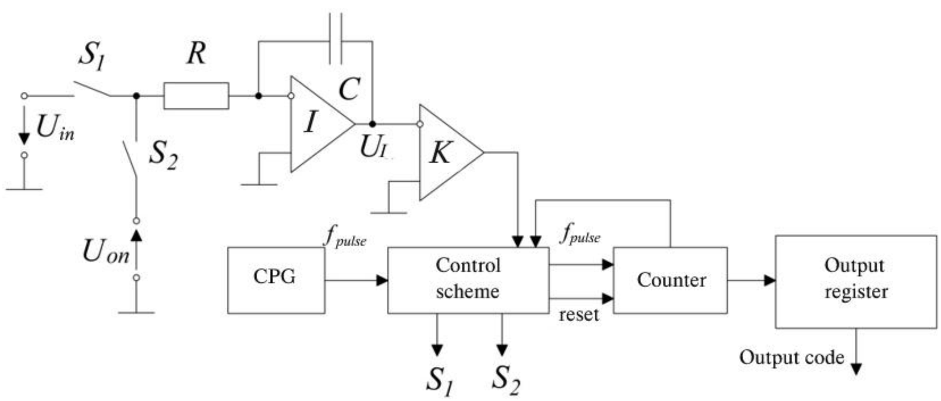

Figure 3. Structural diagram of ADC push-pull integration.

The constant component of the time intervals of the integral calculation of the input voltage t_1, the time interval and the counting module K_{avr} for synchronous counting of binary pulses is determined by the choice of structural components[6].

$$t_1 = \frac{K_{avr}}{f_{pulse}} \tag{1}$$

The voltage at the output of the integrator circuit is calculated by the formula

$$U_I(t_1) =- \frac{1}{RC}\int_0^{t_1} U_{in}(t)dt =- \frac{U_{in.avr}K_{avr}}{f_{pulse}RC} \tag{2}$$

where $U_{in.avr}$ is the average value of the input voltage after .

At the next stage, when the key S_1 opens and, accordingly, the key S_2 goes into the closed position, allowing the reference voltage to flow to the input of the integrator circuit[7].

Analog-to-digital conversion is carried out periodically by dividing the input sinusoidal analog signal by a certain modulus. In the control circuit of the pulse that determines the beginning of the conversion tn, the counter is reset and a counting T is installed - a trigger that allows the receipt of pulses from the clock pulse generator (CPG) to the corresponding (direct or inverse) input of the digital pulse counter. Simultaneously with the receipt of clock signals, the counter generates an increasing digital binary code at its output. The digital code is synchronously fed to the input of a digital-to-analogue converter (DAC) and converted into a sawtooth voltage U_K, the step of which is determined by the increment ΔU. Accordingly, the voltage of the time interval for counting pulses is calculated by the expression[8]:

$$U_I(t_1) = -\frac{1}{RC}\int_{t_1}^{t_1+t_2} U_{on}(t)dt = 0 \quad (3)$$

Having that

$$t_2 = \frac{n_2}{f_{pulse}} \quad (4)$$

where n_2 is the code of the final account, which is determined

$$n_2 = \frac{U_{in.avr}K_{avr}}{U_{on}} \quad (5)$$

The average value of a harmonic signal with an oscillation frequency f and an initial phase j in the integration time interval t_1 can be determined[9]:

$$U_{avr} = \frac{1}{t_1}\int_0^{t_1} \sin(2\pi ft + \varphi)\, dt = \frac{\sin(2\pi ft_1+\varphi) sin\, \pi ft_1}{\pi ft_1} \quad (6)$$

for $\varphi = \pm\, \pi k, k = 0,1,2, \ldots$. Then we can calculate the noise coefficient for the two-stage integrator

$$K_N = \left|\frac{\sin^2 \pi ft_1}{\pi ft_1}\right| \quad (7)$$

Using the following expression, you can calculate the effective value of the measured signal

$$V = \sqrt{\frac{1}{T}\int_0^T v^2 dt} \tag{8}$$

You can also determine the value of the mains voltage[10]

$$V = \sqrt{\frac{1}{N_1+N_2}\left(\sum_{i=0}^{N_1} V_i^2 + \sum_{i=0}^{N_2} V_i^2\right)} \tag{9}$$

And accordingly, the voltage frequency is determined by the expression:

$$F = \frac{F_D}{N_1+N_2} \tag{10}$$

where F_D is the sampling frequency

We draw up a block diagram for the real measuring part of the integrator[11]

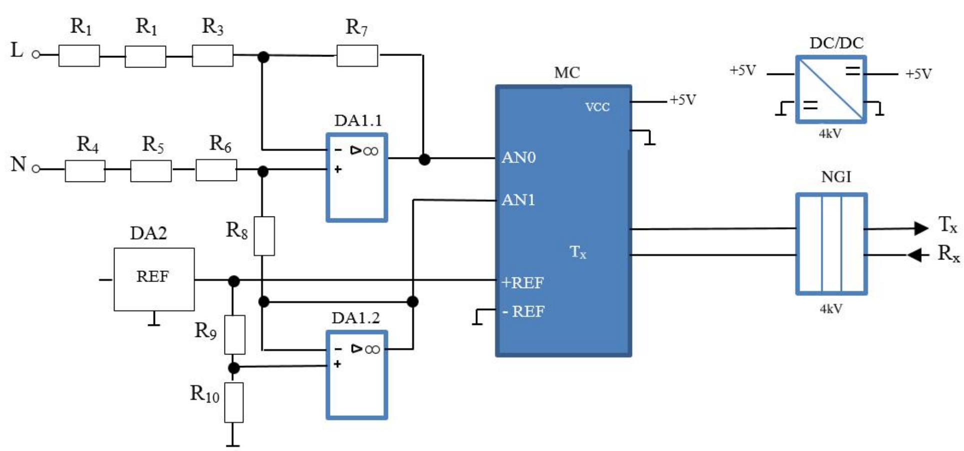

Figure 4. Block diagram of the real measuring part of the integrator.

To protect the input circuits from static electrical disturbances, from an accidental increase in the supply voltage and from switching the polarity of the signals, special circuit solutions are used in which the active component of the generation is a unipolar transistor circuit. An example of the use of such circuits is the key locking circuit when an increased voltage appears at the input of the transistor[12].

In the process of designing the measuring channel, it is necessary to foresee the switching modes of the transistor switch, which can adversely affect the quality of the useful signal input, since the MOS switch is simultaneously used both for transmitting a potential signal and for inputting a signal in the form of current.

Information from the regulated object comes in the form of an electrical signal that can be transmitted in various ranges: ±15 mV, ±50 mV, ±100 mV, ±500 mV, ±1 V, ±2.5 V, ±20 mA. Circuit solutions based on unipolar technology allow designing analog input circuits with a data error of no more than ±0.05%[13].

In circuits for standard current signals within 4 ... 20 mA, resistor current-to-voltage converters with ratings: 125 Ohm, 250 Ohm or 500 Ohm are used, therefore, the voltage drop across the converters according to Ohm's law will be 2.5 V, 5 V or 10 V. In the standard current ratings of 0 ... 20 mA, the current-to-voltage conversion signal is determined by the formula $V_0 = R_0 I_i$

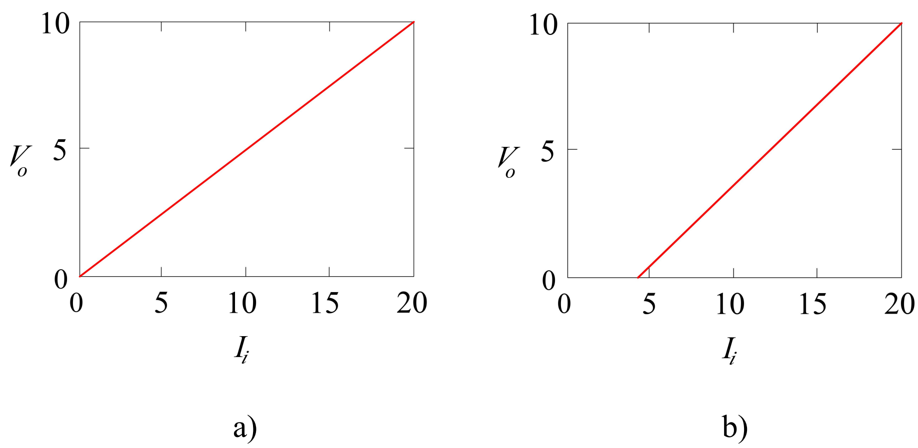

Figure 5. Graphs of current signal conversion into voltage: a) 0...20 mA and b) 4...20 mA

When using the module to measure current values, the potential input terminals of the channel are connected in parallel with the corresponding resistor for current measurement. This is done by connecting the jumper of the channel input terminals to the adjacent connector terminals.

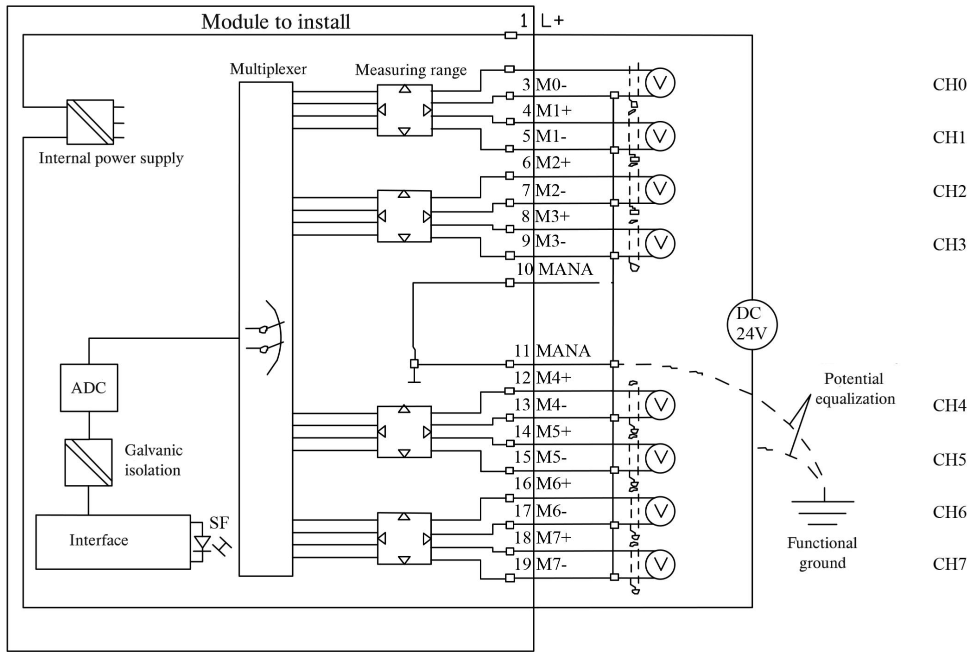

Figure 6. Graphs of current signal conversion into voltage: a) 0...20 mA and b) 4...20 mA

3. Conclusion

In the process of designing automatic control systems, it is necessary to foresee the rational use of resources and ensuring the recommended speed of information exchange between the programmable logic controller and the communication interfaces of multiplex channels with real objects and measuring sensors to make the optimal choice of the configuration of switching devices. At the same time, all input-output modules, as a component of the system interface, must be connected in strict compliance with the rules of galvanic isolation.

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