Reading and processing of analog signals of the software complex “Automated control system for the technological process of the associated production of concentrates of nanostructures MD1 and MD2”

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Abstract. In this paper, the main order to automate the control of the technological process of the associated production of concentrates of nanostructures MD1 and MD2 is presented. The algorithm has been developed for processing incoming raw integer data into a real format in the parameter range, which is implemented in software and hardware at the level of the analog input module. The configuration of the algorithm is performed by specifying the input data using the program. The developed algorithms make it possible to implement an effective automated control system for further implementation in production.

1. Introduction

The main technological processes of silicon production are constantly evolving [1-5]. However, in addition to improving the main processes, it is necessary to develop the processing of waste from this production [6] and its automation [7-9]. Industrial waste from silicon production is used in construction [10-12] and other industries [13-15]. One of the main criteria for the applicability of the technologies being developed is the payback and economic efficiency for the business. One of the main ways to reduce costs is scaling up production and automating production processes. The efficiency of the developed automation systems, their algorithms and the minimization of hardware without losing the quality of the system operation are some of the key tasks of any production automation. The development processes of fundamentally new technologies require economical approaches to the development of automation systems to increase the investment attractiveness of the technological process as a whole.

2. Purpose and characteristics

This algorithm is designed to process incoming raw integer data into real format in the parameter range. The whole algorithm is implemented in software and hardware at the level of the analog input module OWEN MV110-8AS. The configuration of the algorithm is performed by specifying the input data using the M110 Configurator software.

It is used to process signals in a unified format (4-20 mA, 0-10 V, etc.) and signals from resistance thermometers, ohmic resistance, thermocouples. Input data are represented in the WORD, REAL types; output data in type WORD and REAL.
### Information used

#### Table 1. Input data.

| No. | Input information array name | Description | Data type | Range of values | Notes |
|-----|------------------------------|-------------|-----------|-----------------|-------|
| 1   | ComF                         | Input filter type (common to all channels of the module) | WORD 0 .. 4 | 0 - filter off.  |       |
|     |                              |             |           | 1 - 50 Hz 1st ord. |       |
|     |                              |             |           | 2 - 50 Hz 2 ord. |       |
|     |                              |             |           | 3 - 50 Hz 4 ord. |       |
|     |                              |             |           | 4 - 200 Hz 1 ord. |       |
|     |                              |             |           | 0 - channel off. |       |
|     |                              |             |           | 1 - 4..20 mA |       |
|     |                              |             |           | 2 - 0..20 mA |       |
|     |                              |             |           | 3 - 0..5 mA |       |
|     |                              |             |           | 4 - 0..10 V |       |
| 2   | In-t                         | Connected sensor type | WORD 0 .. 4 | 0 - filter off.  |       |
|     |                              |             |           | 1 - 50 Hz 1st ord. |       |
|     |                              |             |           | 2 - 50 Hz 2 ord. |       |
|     |                              |             |           | 3 - 50 Hz 4 ord. |       |
|     |                              |             |           | 4 - 200 Hz 1 ord. |       |
|     |                              |             |           | 0 - channel off. |       |
|     |                              |             |           | 1 - 4..20 mA |       |
|     |                              |             |           | 2 - 0..20 mA |       |
|     |                              |             |           | 3 - 0..5 mA |       |
|     |                              |             |           | 4 - 0..10 V |       |
| 3   | Ain.H                        | Upper limit of the measured parameter | REAL -3.402823e38 .. 3.402823e38 | Default 20000.0 |       |
| 4   | Ain.L                        | The lower limit of the measured parameter | REAL -3.402823e38 .. 3.402823e38 | Default 0.0 |       |
| 5   | dP                           | Decimal point offset | WORD 0..4 | Default 0 |       |
| 6   | Peak                         | Peak filter | WORD 0..200 | Default 200 (range / sec) |       |
| 7   | in.Fd                        | Constant time for exponential filter | WORD 10..10000 | Default 10(ms) |       |
| 8   | Out.F                        | Output filter type | WORD 0..16 | 0 - filter off.  |       |
|     |                              |             |           | 1 - exponential |       |
|     |                              |             |           | 2..16 - the length of the moving average |       |
Solution results

Table 2. Output data.

| No. | Input information array name | Description | Data type | Range of values | Notes |
|-----|-------------------------------|-------------|-----------|----------------|-------|
| 1   | SRD                           | Signal processing output flags | WORD      | 0 .. 61455     |       |
|     |                               |             |           | 0 - measurement is successful |       |
|     |                               |             |           | 61440 - Value knowingly wrong |       |
|     |                               |             |           | 61446 - Data not ready |       |
|     |                               |             |           | 61447 - The sensor is disabled |       |
|     |                               |             |           | 61450 - Measured value too big |       |
|     |                               |             |           | 61450 - Measured value too little |       |
|     |                               |             |           | 61453 - Open sensor |       |
|     |                               |             |           | 61455- Incorrect calibration factor. |       |
| 2   | Read                          | Output processed parameter value | REAL      | -3.402823e38 .. 3.402823e38 |       |

Mathematical description

The ADC converts an analog signal into a digital code. The conversion frequency for each measurement channel is 1600 Hz.

Low Pass Filter:
- cutoff frequency, 2 kHz;
- slope of the frequency response in the far zone - minus 40 dB per decade

Peak filter: limiting the rate of change of the signal provides effective filtering of impulse noise.

The operation of the signal change rate limiter is carried out in accordance with the formula:

\[
Y_i = \begin{cases} 
X_{i-1} + P & \text{if } (X_i - Y_{i-1}) > P \\
X_{i-1} - P & \text{if } (X_i - Y_{i-1}) > -P \\
X & \text{else}
\end{cases}
\]  

(1)

where \(X_i\) - signal at the input of the limiter at the current time; \(Y_i\) - signal at the limiter output; \(X_{i-1}\) - signal at the limiter input in the previous cycle (5 ms) of measurement; \(Y_{i-1}\) - signal at the output of the limiter in the previous cycle (5 ms) of measurement; \(P\) is the speed limit parameter calculated by the formula:

\[
P = \frac{\text{Peak} \cdot \text{measurement range}}{200}
\]

(2)

Rate limiting is controlled by the Peak parameter. The value of the limiting parameter is set in fractions of the change in the input signal relative to the measured range per second.

The input filter provides suppression of interference with frequencies that are multiples of the frequency of an industrial network of 50 Hz, increases the resolution of the meter by averaging and decreases the sampling frequency of the measured signal from 1600 to 200 Hz.

The control of the input filter for all eight measuring channels simultaneously is determined by the ComF parameter.
Output filter: The sampling frequency of the input and output of the output filter is the same and equal to 200 Hz. The output filter control determines the OutF parameter:

0 - output filter is disabled;
1 - filter with exponential impulse response is on (analogue of RC filter).

The filter has an attenuation of minus 3 dB at a frequency of 1 / 2πT (T is the filter time constant in ms, set by the inFd parameter).

The frequency response of the filter has a slope of minus 20 dB per decade.
2 ... 16 - a first-order moving average filter with a length of, respectively, from 2 to 16. When the filter length is a multiple of four, the filter provides suppression of industrial frequency 50 Hz noise.

Coercion to measuring range:
Read = (Ain.H - Ain.L) / 1023 * Val + Ain.L

For more details on the operation of the input and output digital filters of the device, see the Help "Functioning of the input and output digital filters of the MV110-AC device" posted on the company's website: www.owen.ru.

Test case requirements

Input data are selected from valid ranges of values.

**Table 3.** Input data for testing.

| No. | Input information array name | Selection for testing |
|-----|------------------------------|------------------------|
| 1   | ComF                         | 3                      |
| 2   | In-t                         | 0 or 1, 2-4 not used   |
| 3   | Ain.H                        | Upper range limit      |
| 4   | Ain.L                        | Lower range limit, Ain.L < Ain.H |
| 5   | dP                           | 0                      |
| 6   | Peak                         | 4                      |
| 7   | in.Fd                        | 10                     |
| 8   | Out.F                        | 8                      |

**Table 4.** Output data.

| No. | Input information array name | Test results |
|-----|------------------------------|--------------|
| SRD | Should take values depending on the value of the current at the module input, which is in the range 0..24 mA: 0 - measurement is successful 61440 - Value knowingly wrong 61446 - Data not ready 61447 - Sensor disabled 61450 - Measured value is too big 61451 - Measured value is too little 61453 - Open sensor 61455 - Incorrect calibration factor |
| 1   | Read The numerical value of the output value in real format, reduced to the range Ain.L..Ain.H, with the value SRD = 0, in other cases the value NAN (English Not-a-Number, "not number") is displayed |
3. Conclusion
In order to automate the control of the technological process of the associated production of concentrates of nanostructures MD1 and MD2, an algorithm has been developed for processing incoming raw integer data into a real format in the parameter range, which is implemented in software and hardware at the level of the analog input module. The configuration of the algorithm is performed by specifying the input data using the program. The developed algorithms make it possible to implement an effective automated control system for further implementation in production.

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