• the generator pulses of time $T$ must be as stable, as possible, therefore a control device, such as an oscilloscope, can be added to the site;
• the PMT must satisfy several requirements, such as the low response time, ability to work with intense light.

**Experimental results.** Using this method, the size of the two types of particles was measured in testing purposes. The first one was the colloidal solution of silver nanoparticles produced by Nature Sunshine Products and used as active food additives (code 4074-4). Obtained dependence $\sigma^2(T)$ and the approximation with the theoretical curve are shown in fig. 4.

![Fig. 4. Approximation of the normalized variance by the theoretical curve for colloidal solution of the silver nanoparticles in water](image)

After approximation, the time of coherence was determined and equal to $(66.8 \pm 7.3)$ ms. Assumed that these particles are spherical, their radius can be calculated and it is 9 nm. Declared by a manufacturer, the range of nanoparticle sizes is 1 .. 50 nm. The approximation relative error of 11% in this case indicates a rather large variability in sizes, which is confirmed and specified by the range of values.

The second sample was a solution of fullerene molecules C60 in toluene. The result is depicted in Fig. 5.

![Fig. 5. Approximation of the normalized variance by the theoretical curve for solution of the fullerene C60 in toluene](image)

After approximation, the coherence time was determined and equal to $(2.09 \pm 0.07)$ ms, which corresponds to the radius of spherical particles of 0.40 nm. It is known that the radius of a spherical fullerene molecule is 0.375 nm. Given that the technique of dynamic light scattering determines not the geometric radius of a specific particle, but its hydrodynamic radius, which is associated with the diffusion coefficient, the result may be higher than actual size. Therefore, in this case, the excess of the known size of 7% can be considered valid. Also the fact that the relative error is 3% shows a high uniformity of particle size.

**Conclusions.** The described method of measuring the size of nanoparticles in solutions using coherence time of scattered light, makes it possible to avoid usage of the complex correlator. This means that hardware costs of the device used for measuring the size of particles are reduced. The experimental results showed in this article prove the possibility of applying this method of measurement in practice.


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**CONTROL SYSTEM OF MONOCHROMATORS MDR 12/23**

В даній роботі розроблено пристрій дистанційного керування монохроматорами МДР-12/23 на основі двох мікроконтролерів ATtiny2313. Створена схема керування кроковим двигуном ШДР-711, що забезпечує струм в обмотках до 2,5A. Розроблені програмні алгоритми на мові асемблера дозволяють: – змінювати швидкість крокового двигуна дискретно на 9 позицій; – виводити на світлодіодний індикатор значення довжин хвилі спектральної лінії та швидкість сканування спектру.

In this paper the results of development of remote control system of monochromator MDR 12/23 at the base of two universal Atmel microcontrollers ATtiny2313 are shown. The control scheme of the ШДР-711 step motor is realized. The current in each winding is up to 2.5 A. The special original software algorithms of controllers are designed to provide: – the discrete change (9 positions) of motor scanning rate in the both directions; – the dynamical indication of wavelength and rate of spectrum scanning.

**Keywords:** remote control, step motor, microcontroller, dynamical indication.

**Introduction**

In the optical emission as well as absorption spectroscopy such spectral system as LOMO KSVU still are widely used. Depending on the current problem or version of such system the monochromator MDR-12 or MDR-23 as a spectral device can be utilized. The step motor ШДР-711 is used in both models of monochromators to provide the spectrum scanning by the rotation of the diffraction grating. The manufacturer developed initially in this system an additional control unit in the aim of such scanning or choosing of required in the investigations fixed spectral wave length. Nowadays this unit is unsuitable for applications. The matter is that the resource base of electronic components are now out of date in this unit. It leads to unreliable performance over a long period of the operating time. Therefore, in the recent scientific studies such units must be improved in the purpose of the experiment automatization.
The main aim of this paper is the development of the remote control system on the base of two Atmel microcontrollers ATtiny 2313. This device is dedicated to the spectrum scanning of monochromators by the step motor ШДР-711. The principal performance availability of the seven segment light emitting diode (LED) indicator for the purpose of the current position indication of the diffraction grating is considered.

Development and discussion
The application of unconditional logic on the base of JK triggers and logic functions [4] is a prototype of systems of step motor control. The principal feature of this approach is the determination of triggers truth tables, which define the required pulses sequence. The micrologic are used with the aim to switch the direction of motor rotation. As a variant of such systems on the base of unconditional logic is an application of Erasable Programmable Logic Device (EPLD) [1, 2]. It enclosed the counters, summarizers, triggers, multiplexors, registers etc. The distinctive feature in a comparison with a previous control approach is an application of programmable chip as logic unit. It provides the required switching of step motor windings on the base of software algorithm. The application of special-purpose Pulse-Duration Modulation (PMD) controllers [9] is a next one another approach in a step motor control. In this case the software algorithm of individual model or type motor is designed. Whole technical features and performance specification of this motor are taken into account in such algorithm to form control signals. But a complicity, a specificity, relatively high cost and limitation of functional capabilities are principal disadvantages in such control system.

We developed the remote control system on the base of such controllers. In Fig. 1 the block diagram of suggested system is shown.

Two Atmel microcontrollers ATtiny 2313 are used as the base elements of this system. The microcontroller (1) (MC1) is destined for the control of the step motor ШДР 711 and the rate of rotation (9 values). This rate can be graded in the range 0,2 nm/s – 80 nm/s. The microcontroller (2) (MC2) is destined for the processing of control monochromators signals and the indication of the current position of the diffraction grating in spectrum as well. The next control signals of monochromators are used: limit sensors (3, 4) of the diffraction grating and the benchmark units (5, 6) – calibration signals in grating passage through wavelength 0,1 nm and 1 nm. The serial interface USI is used to provide the communication between both microcontrollers. The information about scanning rate is transferred from (1) to (2) in the reload mode. Motor stoppage signals in the operating mode and acquisition signals of current spectrum value for the purpose of the monochromator adjustment in the reload mode as well are transmitted from (2) to (1).

Fig. 1. The remote control system of monochromators MDR 12/23
The connected to MC1 control buttons are used to set the appropriate rate and the direction of scanning and to start-stop motor as well. The indication of the value of the scanning rate (1 digit position) and of the position of the diffraction grating in spectrum (4 digit positions and 1 light-emitting diode as well) is realized on the light-emitting diode display (LED indicator).

The software multiplex mode is used in the indication scheme. It realized on the controller (2). There are two decoders in this scheme: decoder (8) is destined for the sequential switching of the indication digit positions; decoder (7) is destined for the output of the absolute number to the active LED indicator. As soon as the output power of decoders is insignificant, the transistors adapter circuits are used for the connection to LED indicator unit.

**The software algorithm of microcontroller (1) (MC1) (the control of the step motor)**

Let us mark out the base functional levels of the software algorithm of microcontroller (1) (see Fig.2). The main program is the base element in the block diagram. It performs such functions:

1. the configuration of performance parameters of the built-in peripheral equipment;
2. processing of signals which are inputted to the controller from the buttons unit;
3. the subprocesses call and coordination of their performance.

The subprocesses are as a separate program modules which are destined for the execution of the separate functions of algorithm:

1. the control of the step motor;
2. data exchange by interface USI;
3. the operation with memory EEPROM (data write and read).

The next built-in peripheral equipment and registers are used in program operation

1. general-purpose registers R16-R24;
2. registers of 8-bit timer/counter T0:
   a. coincidence registers OCR0A, OCR0B;
   b. counter register TCNT0;
   c. control registers TCCR0A, TCCR0B;
   d. register of interrupts mask TIMSK;
3. input-output ports:
   a. data registers PORTB (8-bit port B) and PORTD (7-bit port D);
   b. registers of data direction DDRB (port B) and DDRD (port D);
4. 8-bit register of stack pointer SPL;
5. Random Access Memory (RAM): addresses of storage (memory) cells 0x60, 0x61;

During the process of program loading the configuration of performance parameters of the built-in peripheral equipment is realized:

1. the initialization of general-purpose registers (R16-R24);
2. the backup of storage cells of memory RAM;
3. the configuration of stack;
4. the configuration of input-output ports;
5. the configuration of timer T0;

The main task of MC1 program is the control of the step motor. The last one is operated in a two-phase winding switching mode. The timer T0 is used for this purpose. There are two coincidence registers OCR0A and OCR0B in this timer.

The timer T0 is operated as a counter [5]. If its count of pulses, which are inputted from the clock oscillator of MC1, coincides with the content of one of two registers OCR0A or OCR0B then the interrupt is generated. In this case the value of number in OCR0A is always more than in OCR0B.

In our case the register OCR0A is used to specify the frequency of control signal pulses of the step motor. And the register OCR0B is used to change their phase. The interrupts themselves are destined to call the subprocess which specifies according leads of port B (PB0-PB3) to binary one ("1") or binary zero ("0").

After the specifying of performance parameters of the built-in peripheral equipment the entry of signals from the buttons unit is testified:

1) *depressed button S1*: the rate of rotation (9 values) of motor performance is specified by variation of generated signals frequency (phase is stationary). Two parameters, which will be loaded into registers OCR0A and OCR0B, are sequentially read out from storage cell of memory EEPROM. These are two constants which values are fitted in such a way that fixed phase quadrature between control pulses is provided. If the rotation direction is changed then the loading order of constants into coincidence registers will be backward;

2) *depressed button S2*: the direction of motor rotation is specified. This parameter is able to take two values (1 – clockwise motor rotation, and 0 – counterclockwise motor rotation);

3) *depressed button S3*: interrupt enable of timer T0. The motor starts to rotate in the specified direction and at re-depressed button S3 – motor’s stop is realized (interrupts are disable).

The motor phases are separated on the program level. If the interrupt is caused by the coincidence in register OCR0A, then the leads PB0 and PB2 of port B are set to "1" and to "0", accordingly (on repeated interrupt the swapping of 1 and 0 is realized). If the interrupt is caused by the coincidence in register OCR0B, then the leads PB1 and PB3 of port B are set to "1" and to "0" (on repeated interrupt the swapping of 1 and 0 is realized as well). So, two motor windings are simultaneously enclosed, which are sequential switching.
The software algorithm of microcontroller (2) (MC2) (information signal processing and indication) (Fig. 3)

The next built-in peripheral equipment and registers are used in the controller operation:
1) general-purpose registers R16-R25, R30;
2) registers of 8-bit timer/counter T0:
   a. coincidence register OCR0A;
   b. counter register TCNT0;
   c. control registers TCCR0A, TCCR0B;
   d. register of interrupts mask TIMSK;
3) input-output ports:
   a. data registers PORTB (8-bit port B) and PORTD (7-bit port D);
   b. registers of data direction DDRB (port B) and DDRD (port D);
4) 8-bit register of stack pointer SPL;
5) Random Access Memory (RAM): addresses of storage (memory) cells 0x60-0x67;
6) registers of external interrupts:
   a. main register of interrupts mask GIMSK;
   b. register of mask interrupts on sweep at the arbitrary contacts – PCMSK;

The main tasks of MC2 program are next:
1) to perform the processing of signals from limit sensors;
2) to perform the processing of signals from benchmark units;
3) to perform the output of the absolute number to the LED indicators.

Initially the adjustment of monochromator is performed. The signal from one of two limit sensors (the leads PB2-PB3 of port B) is waiting to realize it. In so doing the setting of program counter of benchmark unit pulses (channel 0,1 nm) to 200 or 2000 (according to the wavelength in nm) is performed. The output of the absolute number to the LED indicators is enabling after this procedure.

Signals from the benchmark unit (accurate within 0,1 nm) are used to pulses count by program counter. If the logical level is low at the lead PB0, then value of counter is incremented. But sometimes in this benchmark unit operation the error can be realized. The last one will cause the incorrect pulses count. As the results the obtained number can be more (or less) than it is in real situation. To solve this problem the additional benchmark unit with step of 1 nm is used. At moments, when the logical level is low at the lead PB1, the program is testing of the counter’s content. If its value is other than ten, then the correction is performed.

The pulses count is performed in the order of digit-to-digit operation:
1) if lower order digit has nine value (in a result of addition), then it sets to zero and high-order digit is incremented etc.;
2) if high-order digit has unit value (in a result of subtraction), then it sets to zero and lower order digit is set to nine etc.

To store the every value of number the one-dimensional array is used. It is formed by storage cells of memory RAM (every address of cell corresponds to single digit of result number).

The value of the rotation rate is stored in the separate cell of memory RAM (in the next cell after wavelength).

With the aim of software realization of dynamical indication mode it is necessary to form at the output of port B the special binary code. It will be provide simultaneously such functions:
1) switching of digit positions of indication unit;
2) output of digit to the necessary indicator.

For this purpose only register OCR0A of timer T0 is used. The content of this register will define the frequency of switching of indication unit digits (100 Hz). During the every process of interrupt the sequentially reading of storage cells of memory RAM (according to addresses) is realized. The content of these cells will be inputted to the leads PD0-PD3 of port D. The high-order bits (PD4-PD6) of this port are responsible for the switching of digit positions of indication unit. The values of numbers from 0 to 4 are sequentially inputted to these leads (accordingly to the number of used digit positions).

The forming of resulting binary code is realized in the next manner:
1) the separate program counter is counting from 0 to 4 (the content of this counter is stored as single byte);
2) then tetrads of this byte are swapped;
3) new (obtained) value of this byte is logically added with a number from the storage cell of memory RAM.
Let us consider, as an example, the outputting of absolute numbers 1468 (the wavelength in angstroms without the fifth high-order digit position, which is outputted by the light-emitting diode) and 7 (the rate of scanning) to LED indicator array by assistance of port B of microcontroller 2. The leads PORTB0 – PORTB3 are destined to outputting of the digit to a single digit position; the leads PORTB4 – PORTB6 are used to switch of digit positions of indication unit. These values will correspond to absolute number 14687 (5 digit positions) in a case of dynamical indication (see Fig.4).

![Fig. 4. The forming of resulting binary code for the indication](image)

**Conclusions**

The remote control system of monochromator MDR 12/23 at the base of two universal Atmel microcontrollers ATtiny2313 was developed. The special original software algorithms of these controllers are designed to provide the next functional capabilities:

- the control of the step motor of type ШДР-711. The current in each winding is up to 2.5 A. It is sufficient for this type motors operation;
the discrete change (9 positions) of scanning rate in the both directions (the step frequency is up to 400 Hz);
the dynamical indication of wavelength (four decimal digit positions) and rate of spectrum scanning (single decimal digit position).


COMPARISON OF PLANETARY MAGNETOSPHERES

In this work we present the results of comparative analysis of magnetospheres of the following planets: Mercury, Earth, Uranus, and Jupiter. Features of magnetic reconnection and its role in plasma processed are described.

Keywords: plasma, magnetosphere, reconnection, magnetic field.

Introduction. The study of the solar wind interaction with planetary magnetospheres basically is the investigation of the physics of flowing magnetized plasmas. Thus the Mercury, the Earth, the Uranus, and the Jupiter might all interact in much the same way except for some differences in the shapes of the magnetospheres obstacles to the flow. There are major differences however. Some of these are due to the varied driving forces and boundary conditions at each planet. Some of these are due to differences caused by their varied sizes relative to gyroradius of the ions [1]. Microscale process on both the ion and the electron scale matter greatly. It is clearly seen obvious that reconnection must be influenced by electron kinetics, and just as clearly reconnection influences the flow patterns throughout planetary magnetospheres. It is also evident from the controversies surrounding its functional dependences that reconnection is poorly understood.

Reconnection is the process whereby magnetic field lines from different magnetic domains are spliced to one another, changing their patterns of connectivity with respect to the sources. It is a violation of an approximate conservation law in plasma physics. The most common type of magnetic reconnection is separator reconnection, in which four separate magnetic domains exchange magnetic field lines. Reconnection plays an important role in the energetics of the magnetospheres of both magnetized and unmagnetized planets, but it seems to play the most dominant role in the dynamics of the magnetized planets. Most of our observations of magnetized planets have been obtained at the Jupiter and the Earth. The magnetospheres of the Earth and the Jupiter both undergo substorm-like cycles as part of an unsteady magnetospheres-wide circulation despite the fact that they are driven by quite different processes: the solar wind interaction in the case of the Earth and mass loading by the moon Io in the case of Jupiter. Each magnetosphere provides lessons for the other and together they give a clearer insight as to how reconnection works at a magnetized planet.

Mercury. The Planet Mercury is the closest planet to our Sun and is the smallest planet in the solar system. It has no natural satellites and no substantial atmosphere. Despite its small size and slow 59-day-long rotation, Mercury has a significant, and apparently global, magnetic field. The magnetic field strength at the Mercurian equator is about 320 nT. Like that of Earth, Mercury's magnetic field is dipolar in nature. Mercury's magnetosphere is the contrast to other planetary magnetospheres this magnetosphere has no natural satellites and no substantial atmosphere.

The Planet Mercury is the closest planet to

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