Automation of a Sun Tracking System for Photovoltaic Panel with Low Concentration of Solar Radiation

Laurentiu Alboteanu*, Florin Ravigan*, Alexandru Novac†
* University of Craiova/Department of Electromechanical,Environmental and Industrial Informatics, Craiova, Romania, lalboteanu@em.ucv.ro, ravigan.florin@gmail.com
† S.C. Promat S.A., Craiova, Romania, alexandru_novac@yahoo.com

***Abstract*— Over the last decades, because of the pollution and awareness of limited resources of fossil fuels, the renewable sources of energy production gained increasing confidence as appropriate solution for humankind. Within the south region of Romania, due to the high solar potential there have been developed numerous photovoltaic stations. Still, one could note that these solar plants take a considerable part of agricultural land. This paper is the starting work of a study that aims to address meaningfully the issues of increasing efficiency of the photovoltaic systems by utilization of solar radiation concentrator elements, as well as of reducing of costly photovoltaic surface. In the literature there are three types of solar concentrators: high, medium or low concentration (LCPV). To have a maximum efficiency the LCPV must include automatic sun tracking system. In practice there are two types of automatic tracking systems, those using solar sensors and those that follow a predetermined trajectory. This paper combines the two types of systems thus achieving low power consumption. It also allowed the monitoring and control of tracking system both locally and remotely using standard interfaces. Solutions and algorithms proposed in this paper are verified experimentally on a prototype developed by the authors.**

I. Introduction

Use of renewable energy sources is gaining more ground, because the price of fossil energy carriers continuous increased. Lower stocks and management waste resulting from nuclear energy are also true problems [2].

For increasing energy production of PV systems are used sunlight concentration elements. To focus sunlight on photovoltaic surface and increasing thus the energy absorbed, the concentration solar PV systems used either optical elements retractable (usually Fresnel lens) or reflective elements (usually mirrors) [3].

Usually are used tracking systems for maintain the concentrating sun rays perpendicular to PV panels surface. The tracking systems using controlled mechanisms that allow maximization of direct normal sunlight received on PV panel [3].

II. Description Of Hardware Part Of Automation

A. Requirements of automaton design

Automaton of orientation photovoltaic panels, purpose for design must meet the following requirements [1], [2]:

- development will take around a microcontroller;
- will contain a circuit for time and date;
- allow command to two stepper motors;
- memorizing the settings will be done in the internal EEPROM;
- user interface will be provided by tandem liquid crystal display and minimal keyboard consists of three buttons;
- it must be possible to link information between it and a PC in RS232 standard interface;
- it must be possible the automatic orientation of PV panel using five photoresistors.

B. Structure of automation

It is possible to ensuring the requirements above by a structure built around a microcontroller 18F4520 product type MICROCHIP (Fig. 1) [27].

We can identify three functional entities: the command module, stage amplifier and power supply.

Control block, besides PIC18F4520 chip, contains a keyboard, alphanumeric display, real time clock and TTL / RS232 adapter. Amplifier block ensures adaptation in power of signals to control two stepper motors. Also here is a signal processing hardware initialization for azimuth and elevation position (S1 and S2). For the power supply, was chosen an industrial model.

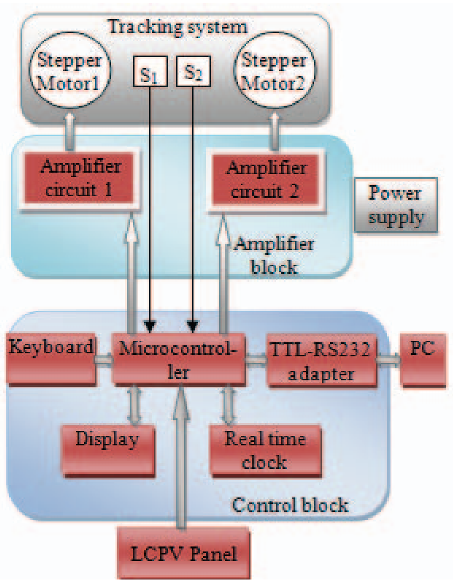

Fig. 1. Block diagram of the automation

C. Design of electronic circuits of automation

Designing electronic schemes (Fig. 2, ..., 7) was performed using Orcad 9.1 program, capture module [26].

The block of microcontroller (Fig. 2) contains, in addition to circuit U3 - PIC18F4520, a power connector (J1), a programming connector (J4) and a connector of interface amplification floor (J19). Diode D1 is designed to provide protection to the electronic assembly of accidental occurrence of large voltages 5,6V. Capacitors C7,..., C10 have a decoupling role. C1, Y1, C2, and R3 serves as a clock source for the microcontroller U3. J2 connector mediates access to the analogue input channels.

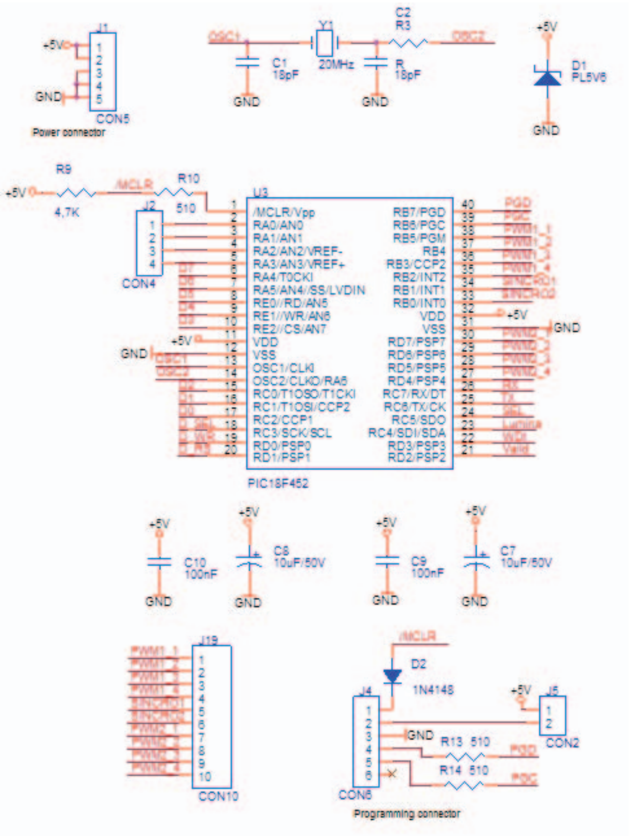

Fig. 2. Electronic circuit of the control module - microcontroller block

Date and time are generated by a special circuit, RTC72421 (Fig.3). Signals D0, D2, D4 and D5 are used for data transfer and D1, D3, D6 and D7 for setting of addresses. D_RS, D_WR, SEL and PWL are control signals. Capacitors C3, C4, C5 and C6 are used as decoupling.

Switching between 5V power supply and battery (J9) is done with MAX691 circuit by PWR signal. Also, the circuit can reset the microcontroller (U1) through U3 / MCLR if it does not transmit pulses with a period less than 0.1 s signal through WDIA (watchdog function). In the J3 connector can be disabled watchdog function (by removing jumper).

The operator interact with the control module via a keyboard consists of three buttons (Fig. 4) and using an alphanumeric display.

Interface between the control module and PC is intermediated by TC232 circuit (fig. 5). Capacitors C15, ..., C18 are used as higher voltage thus is possible to translate TTL electrical signals into RS232 standard.

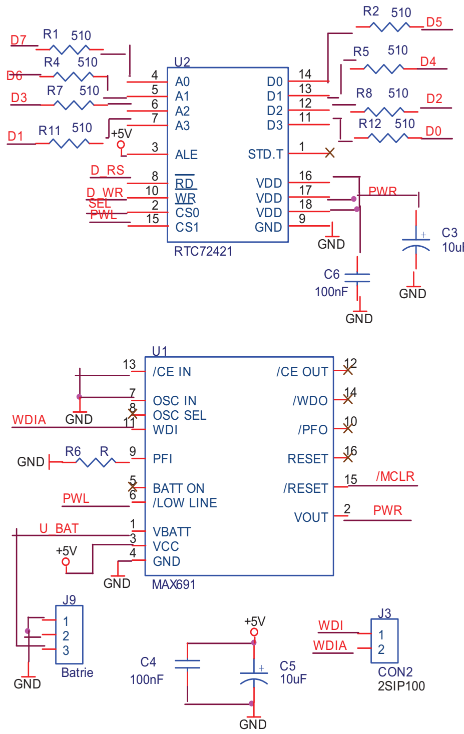

Fig. 3. Electronic circuit of the control module – real time clock block

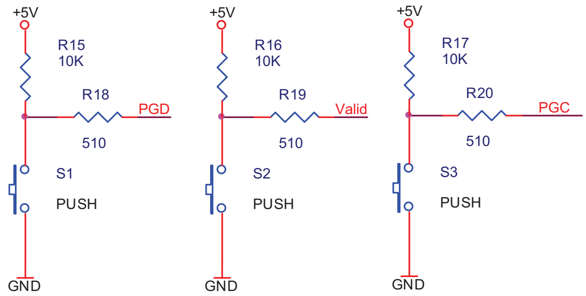

Fig. 4. Electronic circuit of the control module – keyboard block

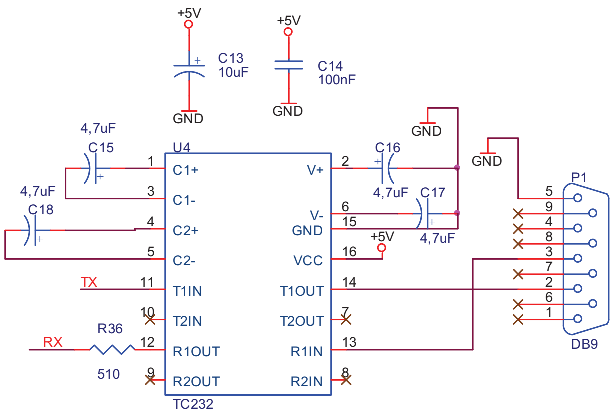

Fig. 5. Electronic circuit of the control TTL module - RS232 interface

Amplifier stage contains two blocks dedicated to each stepper motor. In Figure 6 is shown the electronic circuit for motor 1. The amplifier stage was performed with transistors IRL530N able to provide a current of 9A to closing a gate voltage of only 5V (TTL standard). Diodes D7, D8, D19, D20 take self-induced voltages when transistors which command windings corresponding of stepper motor 1, are blocked. Similarly is realized electronic circuit for driving of stepper motor 2.

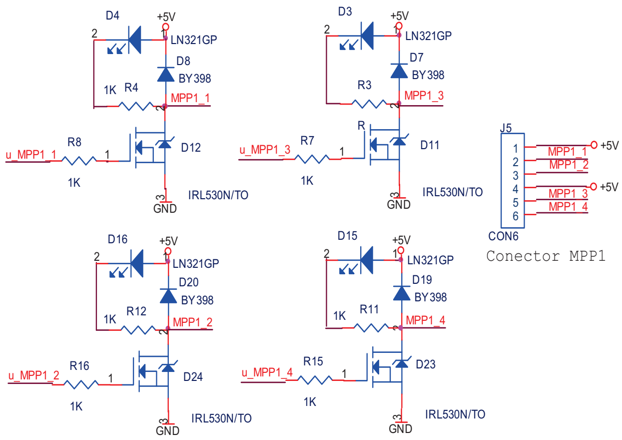

Fig. 6. Electronic circuit of the amplifier block 1- azimuth motor

The LCPV panel orientation towards the sunlight is possible with photoresistors R3, R4 to azimuth direction, and R6, R7 to elevation direction (Fig. 7). The photoresistor R5 provides general information on the light intensity for photovoltaic panel.

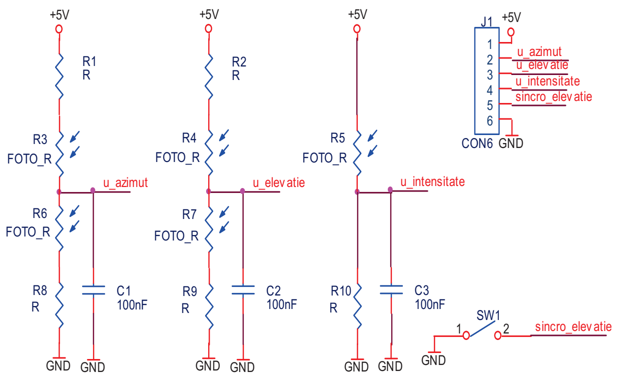

Fig. 7. Electronic circuit of the illumination sensors

The switches present in scheme belong to a reed switch and closes when it is around a permanent magnet, ie when the PV panel is in position of initialization to elevation direction.

When photoresistors R3 and R6 are exposed to the same light intensity the signal "u_azimut" will have a value of 2.5V voltage. An uneven exposure will cause different voltages to obtain a previous value presented. A voltage less than 2.5V shows that photoresistor R6 is exposed to light stronger. A value higher than 2.5V is obtained when the light is stronger in the photoresist R3..

A strong light of photoresistor R5 results in increased voltage 'u_intensitate' (strong illumination of a photoresistor has the effect of reducing the internal resistance). Capacitors C1, C2 and C3 have effect to filtering of "u_azimut", "u_elevatie" and "u_intensitate" signals.

After elaboration of electronic schemes were designed and realized wiring routes and then assembled components [6].

The final board of automaton with assembled components is shown in igure 8.

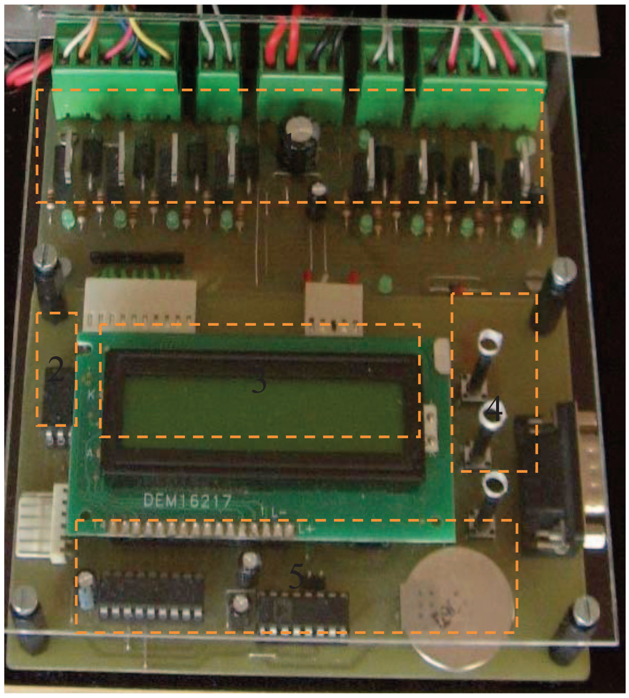

Fig. 8. Final hardware board of automaton: 1-amplifier circuit; 2- microcontroller; 3- display; 4 – keyboard; 5- RTC circuit

Achieving wiring was done in laboratory conditions, quick and very common solution for low and medium complexity applications.

Electronic wiring assembly involves performing the sequential of several phases. Usually passive components are assembled first and then the active components.

III. Description Of Software Part Of Automation

A. *Requirements of microcontroller software*

The program must provide:

- control of two stepper motors (movement and initialization)
- scan of three analogue channels;
- setting and maintaining EEPROM memory sizes that define the operation of automaton;
- interconnection of electronic computer serial port via a UART;
- transmission of data packets to the PC organized by a predetermined protocol;
- reception of the PC data packages organized by a predetermined protocol;
- speed control to two stepper motors;
- choice of four work modes: testing, tracking after light; simulation calendar and tracking after calendar;
- keyboard scanning consists of three buttons;
- functional display messages on a 2x16 character alphanumeric display;
- use the possibility to set up a proper watch;
- display of error messages when it detects abnormal operating regimes.

B. General description of microcontroller software

The program (Fig. 9) starts with initializing of microcontroller and variables used and then enters a loop that executes a group of procedures, scans three keys of user interface and will use a new loop, with a similar structure, depending of "Contor Meniu" variable value.

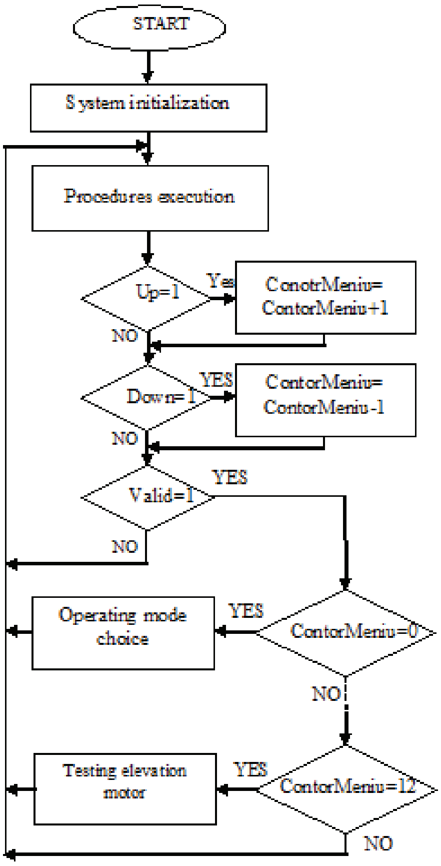

Fig. 9. Flowchart of microcontroller program

Regardless of loop always, the program will run group procedures. Here is first system decrementing counters are then scanned three analogue inputs, also are scanned three keys will manage the motor for azimuth, respectively elevation motor. The sequence ends with the serial communication and control alphanumeric display.

C. PC software description

The core program is represented by the routine for receiving incoming data from device designed (Fig. 10). The chosen solution involves using a timer programmed to 5 ms. The regular presence of a serial character is tested. If it is greater than 127 (identification header), then it is initializes a counter. The next step is saving the information received and the increment counter reception. After filling the buffer then it is tested the CRC, it extract the data received and will complete fields of application for PC.

The procedure can be used in any other application written in Visual C ++ [24] which involves a serial transfer between an electronic system equipped with microcontroller and a PC.

Chosen language is Visual C++, 2010 [24] for application development. Main program window contain: device name, two buttons to control the data acquisition, information on serial number packets received system status, time and fifteen buttons through which you can send data to the automaton of orientation photovoltaic panels (Fig. 11).

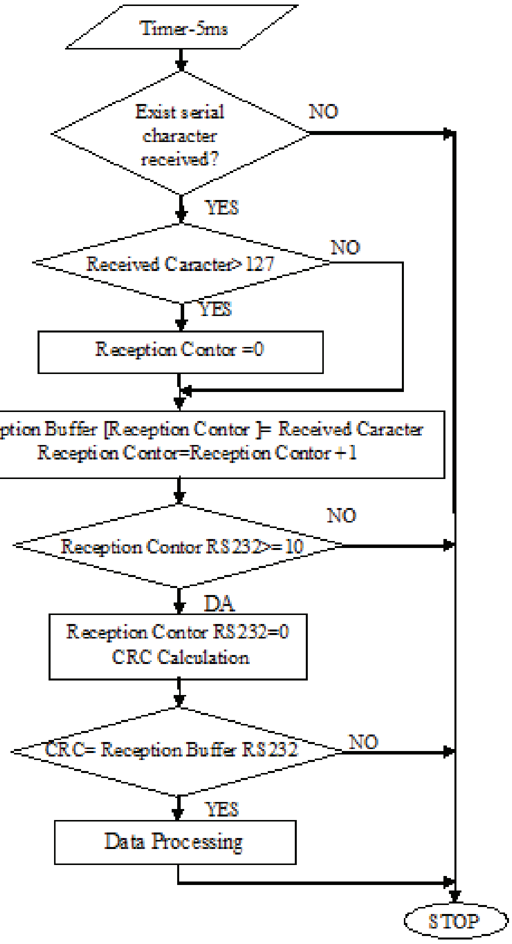

Fig. 10. Flowchart of PC communication procedure

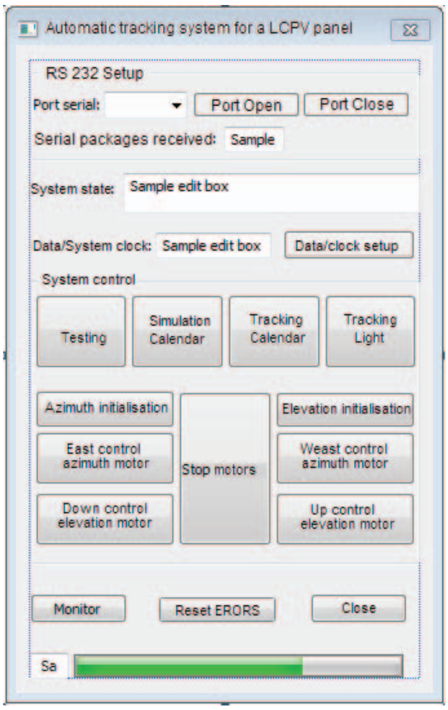

Fig. 11. Main window of PC program

IV. Experimental Results

The experimental results were obtained using the automaton, a serial cable, a PC, an oscilloscope and the LCPV panel.

The experimental prototype of tracking system for low concentrating photovoltaic panel is shown in Figure 12.

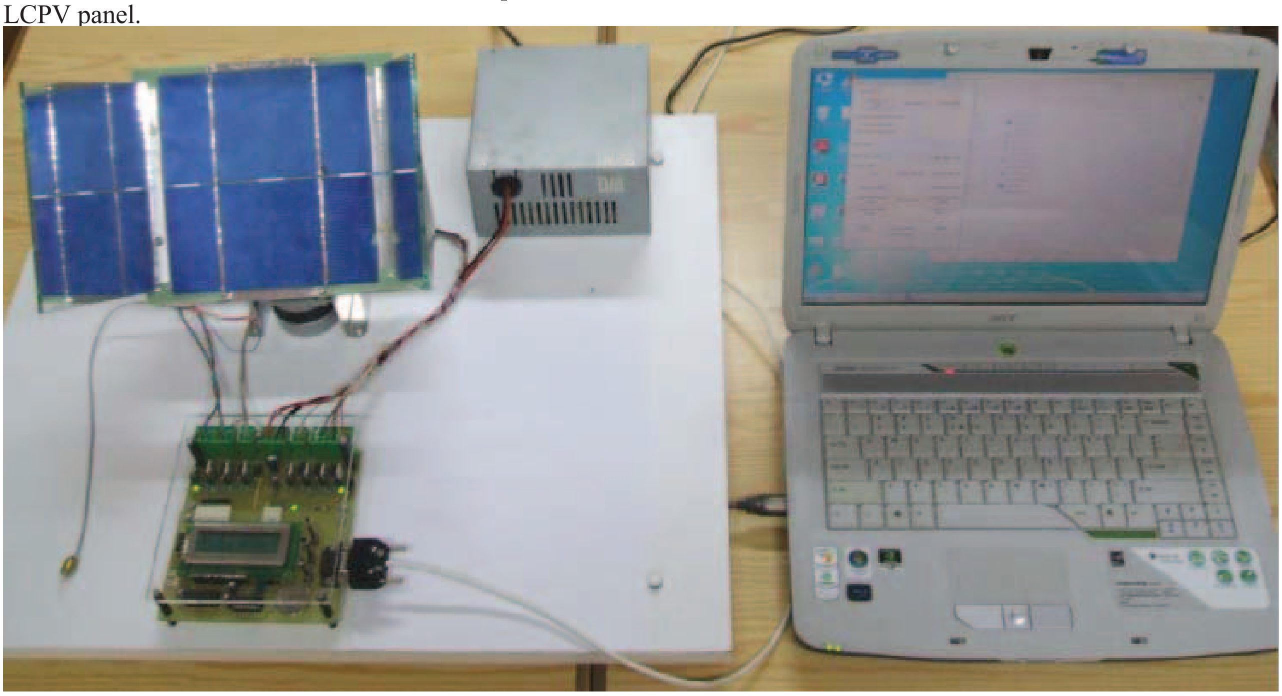

Fig. 12. Experimental model of tracking system for LCPV panel

Experimental verification aimed at highlighting the correctness operation of tracking system both in terms of the tracking and as well in terms of the data acquisition and processing.

Figure 13 presents the main window of the program during the process of communication between PC and automaton.

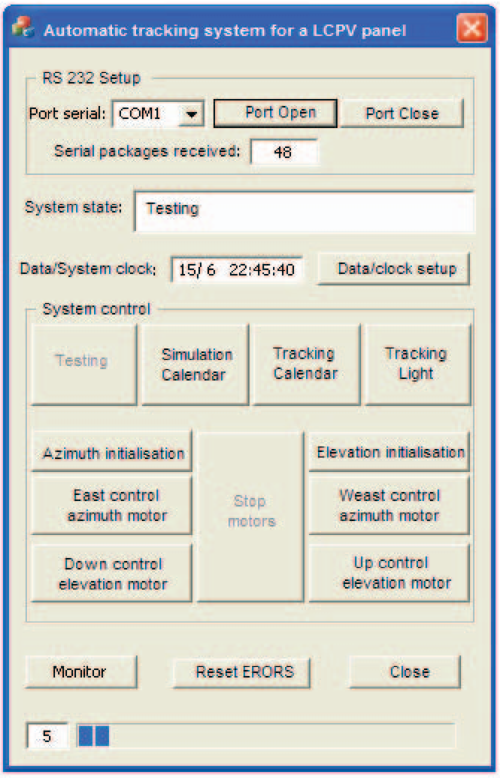

Fig. 13. Main window of PC program during of communication process

Establishing serial connection between the two devices is highlighted by the meter serial packets received. By clicking "Monitor" will be activate the second window of the program (Fig. 14). Here it can see the contents of the serial packet received, scanned values of three analog channels and digital values imposed and carried out by two stepper motors.

The PC commands are available only when PLC is in the first screen (status screen).

In Figure 14 it is found that the two stepper motors are moving. The current index is 165 for the azimuth direction and should reach to 171 and for elevation is 20 and should reach to 28. System Status tab can be seen in the calendar simulation mode for PLC of orientation photovoltaic panels.

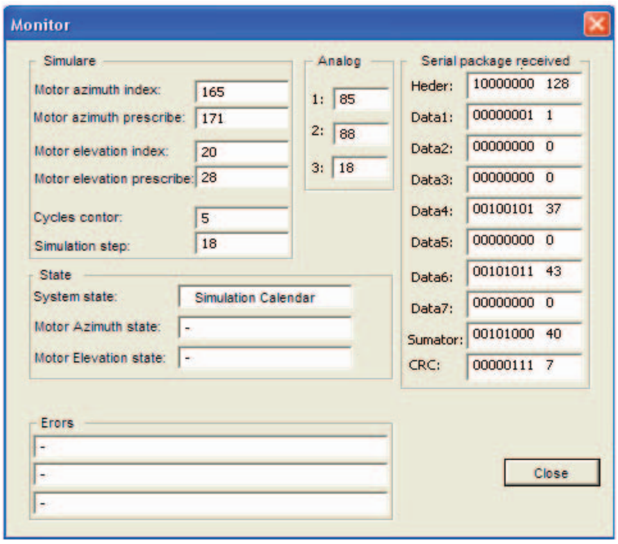

Fig. 14. "Monitor" Window – stepper motors are enabled

In developing the program for PC was considered as that the data acquisition and processing to be performed with an accuracy as high as possible in a short time interval.

Programs designed for microcontroller or PC is based on a permanent exchange of information between PC and automaton.

In Figure 15 is showing the transmission of a data packet from the microcontroller to PC.

In Figure 16 are presented the call pulses generated by PC to microcontroller.

According to the algorithm developed for the PC program at a time constant of 2.5 seconds, the PC automatically generates a call to the microcontroller, (Fig. 16).

This interrogation in a very short period of time leads to the transmission of more precise information on the data acquired from the tracking system developed.

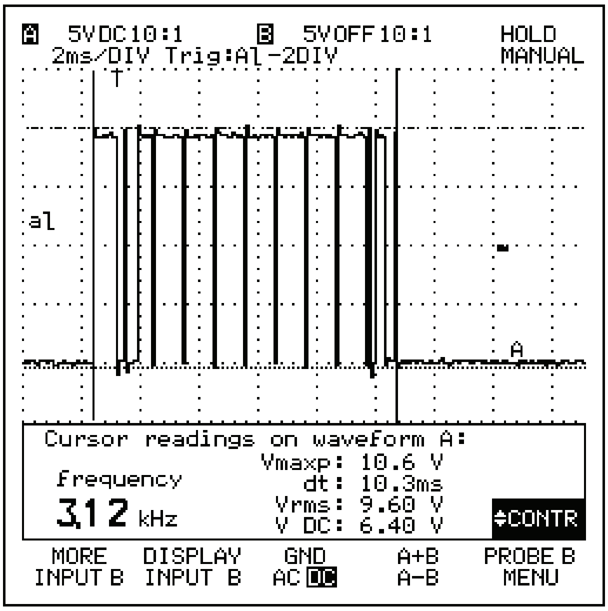

Fig. 15. Sending of a data packet to PC

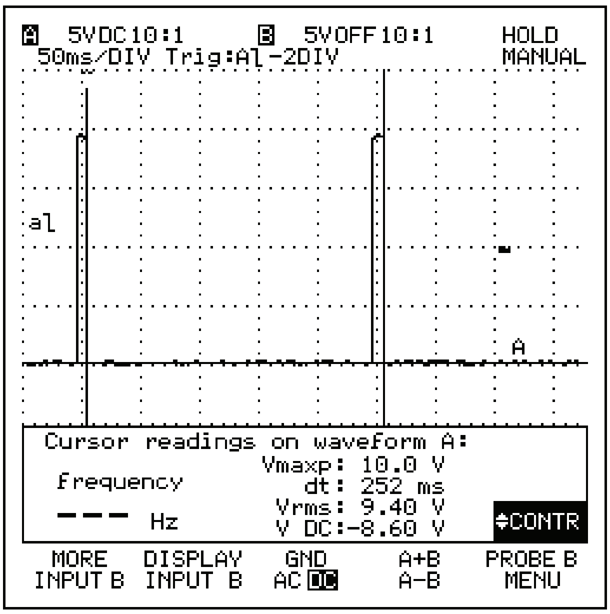

Fig. 16. Illustration regarding to regularity of serial data packets transmitted

Figures 17 and 18 show the control of the stepper motor at full speed and to half that speed. Considering that is a mixed command is checked the phase switching interval 10 ms and 20 ms.

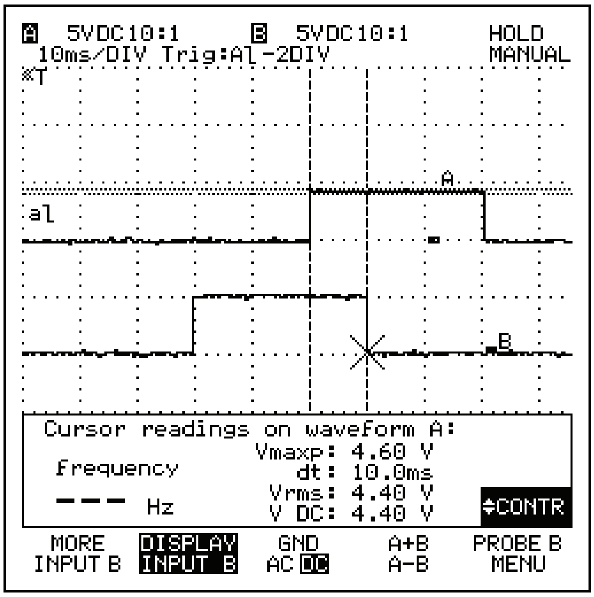

Fig. 17. Illustration regarding to command of stepper motors at full speed

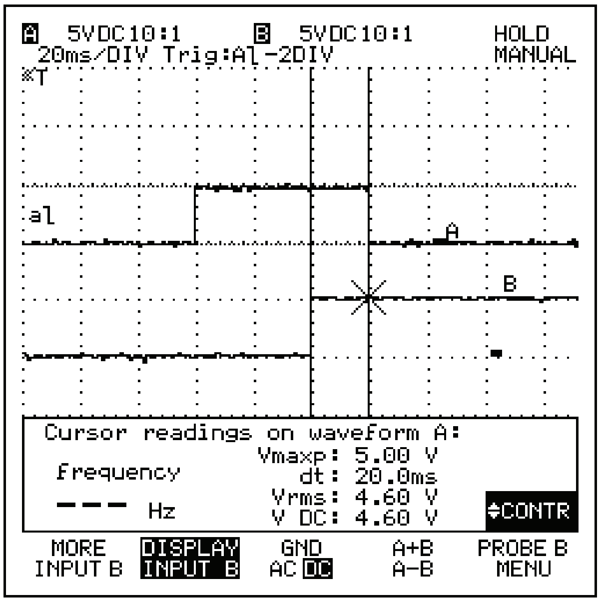

Fig. 18. Illustration regarding to command of stepper motors at half that speed

The experimental results have revealed a perfect correspondence between the algorithms implemented and viewed signals, or in other words, proves the correctness of the algorithm designed and the developed program.

V. Conclusions

Infrastructure hardware and software used allows monitoring and control of sun tracking for LCPV panel.

Sensors, electrical equipment and electronic components used for automaton design have a high degree of accessibility and performance using software and standard interfaces.

Using a microcontroller for automation and monitoring of sun tracking for LCPV panel is a solution that can significantly reduce the number of electronic components and cost of design and development of the made equipment.

The results of the experiments carried out of the local and remote automation-monitoring system of the sun tracking for LCPV panel, have emphasized the functionality of all elements and of the overall system

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