Article Identifier
DOI: 10.22032/dbt.58742
URN: urn:nbn:de:gbv:ilm1-2023isc-006:3

60th ILMENAU SCIENTIFIC COLLOQUIUM
Technische Universität Ilmenau, 4 – 8 September 2023
URN: urn:nbn:de:gbv:ilm1-2023isc:1

DEVELOPING OF THE SPACE SATELLITE-BASED POLARIMETER

Yu. Hirniak [1], O. Ivakhiv [1], P. Nevodovskyi [2], A. Vidmachenko [2], M. Geraimchuk [3], O. Zbrutskyi [3]

[1] Lviv Polytechnic National University, L'viv, Ukraine,
[2] Main Astronomical Observatory of Ukrainian National Academy of Sciences, Kyiv, Ukraine,
[3] National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine,

ABSTRACT

The climate changes of the Earth are mainly caused by changes in the energy balance of the system Sun – Earth. To correctly model and forecast the deviations in concentration of the stratospheric ozone over Earth surface it's necessary to obtain data on the physical characteristics of aerosol particles. Unfortunately, the available information on the subject is quite limited.
As the part of the ecological space mission the ultraviolet polarimeter is planned to be installed on the observing satellite that would work on the lower orbit. The main task of this device is the aerosol density monitoring in the top layer of atmosphere with the remote analysis of the gathered data on land.
The implementation of the planned experiment requires the development, creating and installation of the ultraviolet polarimeter onboard of the microsatellite platform. This device must be compact and lightweight and fully autonomous in the automatic mode. So, aside from the sensitive measuring parts the efficient control system need to be developed as well.
This ultraviolet polarimeter is a passive optoelectronic device that can remotely acquire polarimetrically sensed data. It is the one-point single-channel ultraviolet polarimeter with rotated polarizing element. The position of the polarization plane of the polarizing element managed by hardware and software aids according to the selected task. Therefore, the device control system must provide fully autonomous functioning for automatic data gathering.
The paper summarizes early state of the automatic UV polarimeter development which planned to be installed on the observing satellite which works on the low Earth orbit as the part of the ecological space mission.
There is an operating model of the compact on-board ultraviolet polarimeter to consider as the basic model for the carrying out of space experiment on the effects of stratospheric aerosols, changes in global and local climate of the Earth. The designed device allows its modification depending on the variety of the problems in setting such a complex space experiment.

Index Terms **–** space mission, space instrument, environmental pollution monitoring, aerosol, UV polarimeter.

1. INTRODUCTION

The different information can be acquired by the atmosphere state analysis. One of it is the information about atmosphere pollution [1-8]. Obviously, the most convenient information

about pollutions is the information as widespread as it can be. Currently the most efficient way of gathering large amount of information about wide areas is the space satellite usage. To gather information about state of the atmosphere the various measuring and monitoring devices are used. One of them is the device that measures the intensity of the reflected from or passed through the atmosphere sunlight in various specters with or without polarization.
As the part of the future ecological space mission, the UV polarimeter planned to be installed on the observing satellite which works on the low Earth orbit. The main task of this device is the aerosol density in the top layer atmosphere monitoring with the remote analysis of the gathered data on land. This device must be compact and lightweight and fully autonomous in the automatic mode. So, aside from the sensitive measure parts the efficient control system need to be developed.

2. DEVELOPMENT TASKS

This ultraviolet polarimeter is a passive optoelectronic device that can remotely acquire polarimetrically sensed data. It is the one-point single-channel ultraviolet polarimeter with rotated polarizing element. The position of the polarization plane of the polarizing element managed by hardware and software aids according to the selected task. To manage all the tasks development of the fully functional control unit and the designing entire device. Also, the full review of the functioning principles and the numerous experiments are needed to be conducted.
The sensor unit consists of one photosensor with rotatable polarization head which must continuously change polarization angle for the data gathering with wider bandwidth. The photosensor output after signal conditioning is the pulses with the width of 20 ns and the rate up to 10 MHz in levels of TTL. The intensity of the pulses at output brings information about light that goes through the optical window of polarimeter. So, generally speaking, we need to count these pulses within fixed time periods – exposure time.
It is possible to improve the measurements precision using the temperature corrections. So, another task is the multiple point temperature measurements for the acquired polarimetric data corrections.
The polarization head with polarizing element moves with a single-cycle start-stop mode or continuous mode. Additionally, the polarization head typically needs to be stopped at the fixed angle position in step of 45 deg. For this purpose, the motor needs to be controlled precisely to stop rotation of the polarization head at exactly determined position. To achieve this the photoelectric sensor used inside the polarization head transmission. Regarding control unit design, it needs to contain the motor driver and optical sensor input.
The motor that are used in this device is the piezoelectric ultrasonic motor, with working frequency of 200 kHz and voltage of 60 V. The current motor and transmission of the polarization head unit are the subjects to change according to the entire design modifications.
All the data from photosensor and number of thermosensors and other values need to be logged as packs with timestamps for farther analysis after its transmission to Earth.
All this functions with some other functionalities needed to be done within portable electronic control unit so it should be the device with low mass and volume, with high power efficiency.
Considering all the tasks, the functional diagram of the control unit can be represented like on Fig. 1.

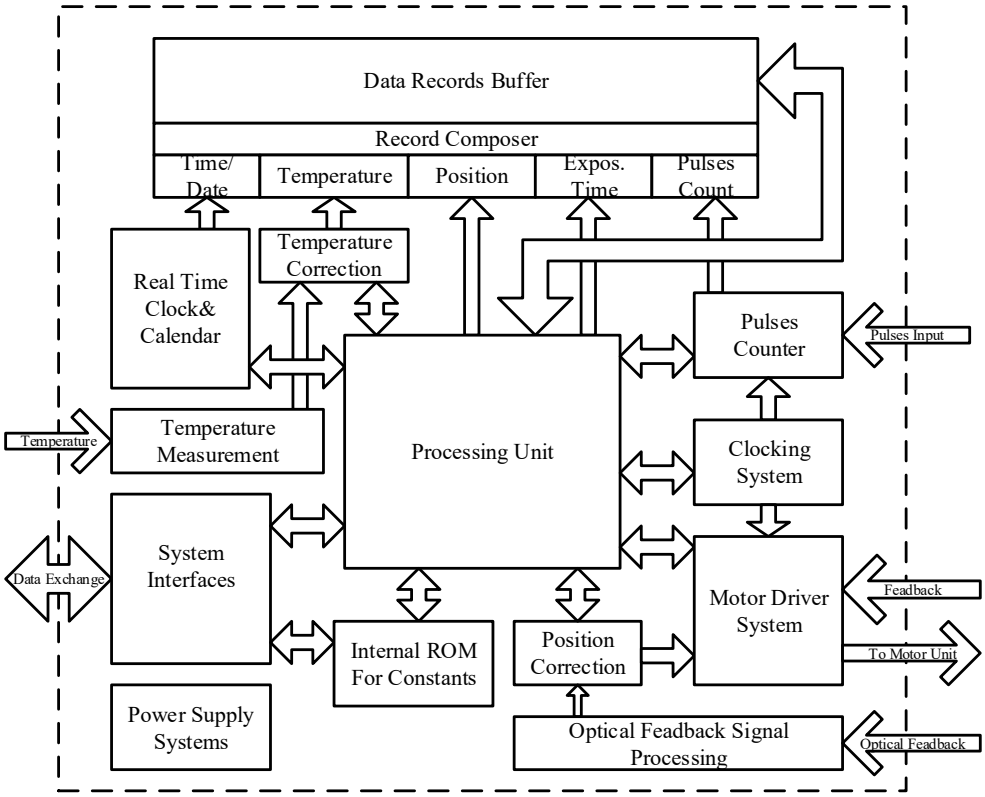

Fig. 1. Functional schematic of the UV polarimeter control unit

3. IMPLEMENTATION

Currently designed device can be considered as the early stage of the future space satellite-based instrument which provide valuable experience of working with the all the units and possibilities to analyze the system performance. There is also an experience of processing data from the polarimeter along with the developing and improvement of the processing methods. Also, currently developed control unit provides the possibility to build and test the communication interface between polarimeter and other devices onboard of the satellite. It also used for practicing with gathering polarimeter data, setting up the work mode parameters, experimenting with sensitive analog electric circuit architecture, modeling automatic continuous mode of the polarimeter.

The control unit together with specially developed communication application for PC can transfer data packets through USB interface and stored to the local or remote database for farther analysis and reports generation.

The main tasks for the control unit are:

- The piezomotor control,
- Rotating of the polarization head to the specified angles,
- Gathering photosensor information,
- Gathering thermosensors information,
- Providing the real-time time and date for package timestamps generation,
- Storing some of the datapacks in the internal buffer in case of communication issues,
- Communicating with PC through USB interface,
- Provide possibility for firmware update through USB interface,
- Provide fully automatic and manual control remotely.

With the aid of specially developed communication application all transferred data storing in the MS Access database, locally deployed on the PC. The remote database also can be used. The data can be accessed with other application for further usage

To achieve the possibilities to have more precision measurement by the temperature corrections several temperature sensors were added to the system and their measured data needed to be included in every data sample. Currently temperature measurements option provided by 3 digital thermo sensors Maxim© (former Dallas Semiconductor©) DS18B20 with their main features [9]:

- unique 1-Wire® interface requires only one port pin for communication;
- measures temperatures from -55°C to +125°C (-67°F to +257°F);
- ±0.5°C accuracy from -10°C to +85°C;
- programmable resolution from 9 Bits to 12 Bits.

All the data from photo sensor and number of thermo sensors and other values need to be logged as packs with timestamps for farther analysis after its transmission to Earth. All this functions with some other functionality needed to be done within portable electronic control unit so it should be device with low mass and volume, with high power efficiency.

Even if the polarimeter designated application is the space instrument device, to develop entire device and solve all the tasks, and then to test all units' performance, and to make needed reductions to entire design many experiments needed. Therefore, before building final version of hardware the test control unit is developed.

The control unit design based on the single microcontroller Microchip© PIC18F27J53 with its main features [10]:

- Integrated full speed USB 2.0,
- Hardware RTCC provides clock, calendar & alarm functions,
- 3 Enhanced Capture / Compare / PWM modules,
- 2 MSSP serial ports for SPI or I2C™ communication,
- 2 Enhanced USART modules,
- 8-bit Parallel port,
- Three analog comparators,
- 10 ch., 12-bit ADC,
- Self-programming Flash supports 10k erase/write cycles & 20 years retention,
- Operating voltage 2.0 - 3.6V, 5.5V tolerant digital inputs

Regarding the programming capabilities features this microcontroller is low power and high performance 8-bit MCU with Integrated Full-Speed USB 2.0, high memory density and peripheral flexibility with 128 KB of program memory and 3,800 bytes RAM [10].

The firmware for the control unit MCU designed with the aid of the native integrated development environment.

The simplified general algorithm of polarimeter control unit operation in automatic mode is as follows:

1) Measurement of temperature;
2) Moving of the engine rotor to the next position - rotation by 45 degrees;
3) Launching the exposure timer and starting to count pulses from the photosensor;
4) Counting of pulses until by the exposure timer ends its countdown of the exposure time;
5) Forming record with information on the time, temperature from all sensors, the position angle of the rotor, exposure time and the number of pulses received on the measuring channel during the exposure from the photosensor with the next transferring it to the cumulative buffer;
6) Repeat from 1.

The information from the cumulative buffer is periodically transferred through USB interface to the PC on the initiative of the information gathering (communication) program that runs on the PC.

This control system together with specially developed communication application for PC can transfer data packets through USB interface and store to the local or remote MS Access database for farther analysis and reports generation [11-14]. Additionally, communication application maintains additional service tasks to provide remote control of the system functioning modes, to change some parameters of the motor drive unit, etc.

4. CONCLUSIONS

Developed control system for the UV polarimeter currently provide valuable experience of working with the all the units and possibilities to analyze the system performance. There also the experience of processing data from the polarimeter along with the developing and improvement of the processing methods. Also, this control unit provides the possibility to build and test interface for the communication with the other devices onboard of the satellite.
Currently this control unit can do the following operations:

- Piezo motor control,
- Rotating of the polarization head to the specified angles,
- Gathering polarimeter photosensor information,
- Gathering thermo sensors information,
- Providing the real-time time and date for data packs timestamps generation,
- Storing some of the data packs in the internal buffer in case of communication issues,
- Communicating with PC through USB interface,
- Providing possibility for firmware update through USB interface without need of the specific hardware programmers,
- Provide fully automatic and manual control remotely.

With the aid of specially developed communication application all transferred data storing in the database, locally deployed on the PC. The remote database also can be used. The data can be accessed with other application for further usage.

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CONTACTS

Yurii Hirniak email: yurii.b.hirniak@lpnu.ua
ORCID: https://orcid.org/0000-0002-4835-230X
Prof. DScTech Orest Ivakhiv email: orest.v.ivakhiv@lpnu.ua
ORCID: https://orcid.org/0000-0003-3299-9798
PhD Petro Nevodovskyi email: nevod@mao.kiev.ua
ORCID: https://orcid.org/0000-0002-7958-2255
Prof. Dr. Phys.-Math. Sc. Anatolyi Vidmachenko email: vida@mao.kiev.ua
ORCID: https://orcid.org/0000-0002-0523-5234
Prof. Dr. PhD Mykhailo Geraimchuk email: geraimchuk@kpi.ua
ORCID: https://orcid.org/0000-0002-8987-0867
Prof. Dr. PhD Olexsandr Zbrutskyi email: zbrutsky@kpi.ua
Scopus Author ID: 6507183267

