HARDWARE AND SOFTWARE RECORDING COMPLEX FOR USE ONBOARD A LIGHT-WEIGHT AIRPLANES

A.P. Rostov

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
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In this paper I describe the recording complex for measuring atmospheric parameters. The complex has been designed for installation onboard a superlightweight airplanes.

Different kinds of aviation facilities are used for direct measurements of horizontal and vertical profiles of meteorological parameters, atmospheric aerosol parameters, and radiation fluxes in the atmosphere.[1] The motor deltaplane was used for such measurements in the fall of 1996 in the frameworks of the international project Atmospheric Radiation Measurements (ARM).

The automated hardware and software recording complex was specially developed and constructed for collecting, preliminary processing and recording the data from the sensors installed onboard a deltaplane. The requirements imposed on the complex were very tough. It should be lightweight, portable and provide the automatic recording of up to 9 different parameters under the real atmospheric conditions and strong vibrations. One should also take into account the effect of electromagnetic fields from the ignition system and onboard radiostation. Taking into account these requirements, when developing the complex, we decided to refuse from the data storage systems that have mechanical drives while using as recording devices the semiconductor memory and modern ICs of the firms Intel, Mitsubishi, and Integral, which have high level of integration, low energy consumption, wide range of working temperatures, and good internal performance.

FIG. 1. System block of the complex.

The complex includes: the system block (its external view is shown in Fig. 1), nephelometer,[3] optical sensor of the sky irradiance, three standard sensors of the solar radiation (two actinometers and 1 balance meter), and the particle size sensor.[4] To measure pressure, temperature and humidity, the standard airborne meteorological sensors were used. All sensors, except for the nephelometer and the particle size counter, had the constant voltage as an output parameter, and were connected to the analog inputs of the system block. The nephelometer and the particle-size analyzer devices have been supplied with the corresponding software. Such an approach made it possible to achieve high stability of their operation in a wide range of working temperature and vibration.

Let us now consider in a more detail the system block of the complex and the algorithms of its operation. The structure block-diagram is shown in Fig. 2. The main control unit is an Intel[2] single-crystal microcontroller i80196 KB. It has a fast 16-digital processor with a well developed command system, 10-digit 8-channel analog-to-digital converter (ADC), two timers, serial and parallel ports, RAM and the controller of interruptions. The SIM-signal generator makes it possible to obtain slow analog signals. There are special protection tools against bugs – the watch timer, restarting the processor at cycling and instruction for the code reset. We used the variant of this microcontroller capable of working at temperatures from –40 to 85°C.

<u>Specifications of the onboard complex</u>

Processor clock rate, MHz 10
RAM, kbyte 512
ROM, kbyte 8
Number of the parameters recorded 9
Maximum amplitude of the voltage
at the analog inputs, V 4.4
Dynamic range of input signals for:
analog inputs, dB 60
nephelometer, dB 80
particle-size analyzer, dB 90
Time of continuous record, hours 3
Time of continuous operation from the
internal power source, hours 10
Working temperature, °C .... –40...+60
Mass, kg .... not more than 2
Size, mm .... 300×200×40
Construction .... vibration stable,
.... interference-protected

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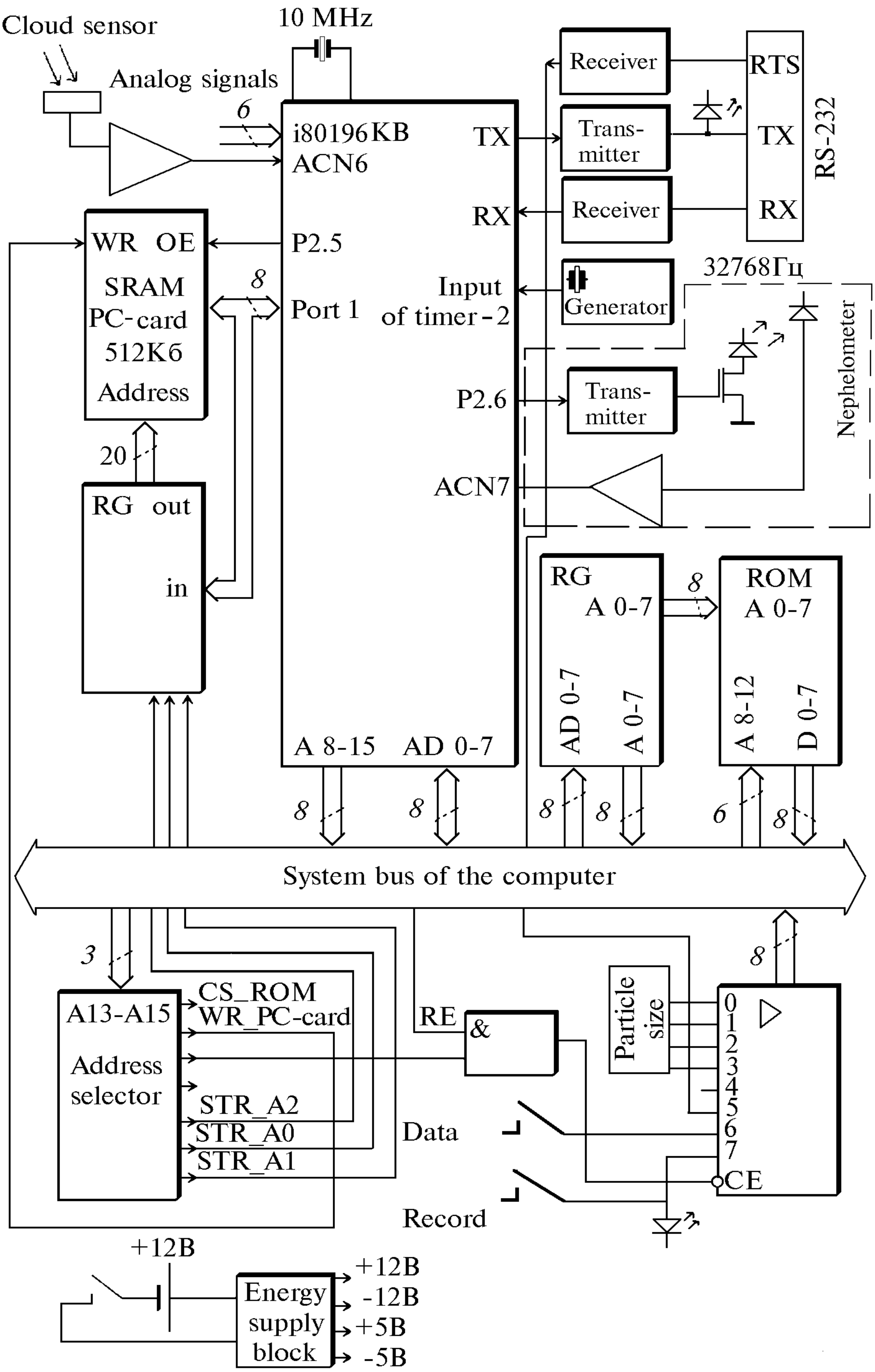

FIG. 2. Block-diagram of the system block of the complex.

The computer of the block has its own system bus. It provides the exchange of data and commands between the parts and devices of the block. The bus involves 16 address digits, 8 data digits and 2 control digits.

The address space of the computer is divided into 8 equal parts of 8 kbytes. The distribution is as follows:

0–1FFFH is for inner registers and input-output ports;

2000H–3FFFH is for RAM containing the code of the controlling program of the computer;

4000H–5FFFH is the window for making records into the PC-card, SRAM–512;

6000H–7FFFH is the address of the register for the number of the particle size and the state of the control switches of the block;

8000H–9FFFH is the reserve;

A000H–BFFFH is the strobe for records to the register of a high-level address of the PC-card;

C000H–DFFFH is the strobe for records to the register of low-level address of the PC-card;

E000H–FFFFH is the strobe for records to the register of medium-level address of the PC-card.

In order to improve the reliability of operation of the microcontroller and to decrease the current consumption, the looping of the microprocessor is made at a frequency of 10 MHz, that is a little bit less than the limit (16 MHz).

The serial port of the microcontroller is used for the program control, adjustment and examination of the system block. It is additionally equipped with the level converters to RS–232 standard. These are the ICs 75SN188 and 75SN189 containing 4 receivers and 4 transmitters respectively.

The exchange is performed at a rate of 57.6 Kbit/sec with 8-bit words without the parity check. One of the converters is also used for forming the control voltage of the field-transistor KP921A that operates as a power key of the nephelometer transformer.

The PC-card (old name is PCMCIA-card) SRAM–512 made by Mitsubishi having 512 Kbyte capacity is applied to data reading and recording. The interface of the PC-card is emulated as a software and hardware by means of 3-digit address (Ic155IR22), quasidoubledirection port R1 of the microcontroller and the address selector (Ic1554ID7).

Such an interface makes it possible to address to 16 Mbyte memory, that allows one to use the PC-cards of a greater capacity. Data recording is performed with at a rate of 1 Hz. Separate generator with the frequency of 32768 Hz is available to obtain exact time interval. The signal of this frequency is entered to the input of the timer-2 of the microcontroller. Timer-2 isolates from this signal a signal at the frequency of 1 Hz. The program of measuring 8 and recording 9 parameters is started in the microcontroller interruptions from the timer-2.

Power supply of all systems of the block is realized by means of the internal power source. The primary power source is the Ni–Mn accumulator providing 12 V voltage and the capacity of 2.5 A/hour. The pulse energy transformer was created for obtaining the necessary working voltages of +5 V, –5 V, +12 V and –12 V. Its working frequency is approximately 1000 kHz. The voltage stabilization is done by stabilizing the primary voltage. Maximum value of the output current at the voltage of 5 V is 500 mA, and 100 mA at other voltages.

The operation programs are run from the block keyboard, or by the program through the serial communication port RS–232. All software is written in assembler. The program size is 676 lines, so we do not present it in this paper. Let us briefly consider the operation algorithms.

After switching on the power supply, processor adjusts all devices of the computer for obtaining the needed configuration by transferring the corresponding comands, then the working registers of variables and constants are initialized. Then the processor starts cycling and tests, the positions of switches on the computer keyboard, the presence of commands or messages at the serial port and the state of the address counter of the PC-card. Corresponding decisions are made based on the results of these tests for executing one or another command for starting the corresponding programs or subroutines.

The main program is started by switching-on the “Record” key on the block panel. This is marked by a light signal on the panel. The processor allows interruptions from timer-2 of the microcontroller and then it starts to test the presence of the data from the particle–size analyzer and the state of the switch “Record” in cycle, with the period of 2.6 μs. When the data containing the code of the particle size number appear, the processor increments one of the 15 corresponding 2-byte variables to 1 and informs the particle size sensor. Then it continues operation in the cyclic mode of the sensor polling again. Fifteen variables of the particle size are in the buffer array of data in RAM of the microcontroller and occupies 50 bytes. The diagram of data arrangement is given in the Table I.

When the request for interruption appears from timer-2 (once a second), the processor starts the subroutine of servicing this interruption. When entering to this subroutine, first all working registers of the processor are stored in the stack, then 7 analog signals coming from the block input are digitized. Then the subroutine of service of the nephelometer is put into operation.

Let us consider in more detail the operation of the nephelometer. Since the internal power supply has the limited energy resource (2.5 A/hour), the pulse-batch mode of operation was realized. The energy needed for the transmitter operation was periodically accumulated in a capacitor (68000 μF) through the current limiting element.

TABLE I. The view of buffer data array

1	Time, s
2	1st ADC chann.
3	2nd ADC chann.
4	3rd ADC chann.
5	4th ADC chann.
6	5th ADC chann.
7	6th ADC chann.
8	Cloud radiance
9	Low order word from nephelometer
10	High order word from nephelometer
11	The number of particles of size No. 01
12	The number of particles of size No. 02
13	The number of particles of size No. 03
14	The number of particles of size No. 04
15	The number of particles of size No. 05
16	The number of particles of size No. 06
17	The number of particles of size No. 07
18	The number of particles of size No. 08
19	The number of particles of size No. 09
20	The number of particles of size No. 10
21	The number of particles of size No. 11
22	The number of particles of size No. 12
23	The number of particles of size No. 13
24	The number of particles of size No. 14
25	Number of particles of size No. 15

Twenty current pulses are delivered to the photodiode of the transmitter by the processor command at a rate of order 1 kHz by a powerful KMOP-key. The current amplitude reaches 1.5 A, radiation wavelength is 0.87 μm. Then a portion of reflected radiation comes to the receiver situated at the angle of 45° with respect to the transmitter axis. The IR-photodiode is used as a detector. The electric signal from it comes to an ac preamplifier with the amplification coefficient about 3000 within the frequency the operation band. Then the signal enters the selective amplifier with the transmission band of about 100 Hz. Its amplification coefficient within the transmission band is about 10, and the end-to-end amplification of is 30000. Taking into account that the total noise level of the photodiode and of the preliminary amplifier noise reduced to its input is about 50 nV/Hz, and we have the noise level of 0.02 V at the output of the entire channel within the operation frequency band, that corresponds to the values of microcontroller ADC code 4–6. In general, the nephelometer sensitivity occurs to be quite high. Accurate calibration measurements were not carried out, but the fact was observed, that the decrease of aerosol amount was recorded in the closed room where people were absent during two days, and the signal level at the end of the second day was two times greater than the dark current of the receiving channel. When the door had been open after two days, the aerosol concentration splash was recorded of 3–4 times greater than before this moment.

The processor has time enough to make 180 readings of the received signal amplitude, to take squares and to sum them during the pulse train transmission. When finishing the measurement, the sum obtained is recorded as a 4-byte variable of the output data array. The time of one measurement cycle of the nephelometer is about 18 ms.

When the nephelometer operation, terminates, the processor rewrites the data from the working buffer to the PC-card and increments the counter of seconds to 1. Then it makes the variables of the working buffer equal to zero, restores all working registers from the stack, and returns to the cycle of measuring the particle size. Exit from this mode is done by switching on the switch "Record".

As was mentioned above, the processor can perform a number of commands coming to the serial port. The first command group launches some operation modes of the onboard computer, the second group makes it possible to obtain the data from separate devices, and the third group serves for testing some devices of the microcontroller.

The following commands are in the first group:

– start of the program of preparing the PC-card for measurements;

– start of the program of output of 512 kbyte of the recorded data to the serial port, taking into account the readiness of the communication port of the PC for receiving;

– start of the main program of measurements.

The second command group:

– start of the nephelometer program with the output of the data to the serial port;

– start of the program of evaluation of the analog channel with output of the result to the serial port.

The third group:

– output of the byte from the noted address;

– write the byte to the address, shown.

The set of these commands is enough to prepare the computer for operation in the experiment, and to test and adjust both separate units of the device, and the complex as a whole.

The complex was installed onboard a motor deltaplane in September-October 1996. There were carried out 10 flights at the altitudes up to 3000 m with the mean duration of 1.3 hours. The data were obtained on vertical and horizontal distribution of temperature, humidity, aerosol scattering coefficient, down and upgoing radiation fluxes, during the fall in the Western Siberia. The plots shown in Fig. 3 show sharp change of the aerosol scattering coefficient, radiation level and other parameters, that is characteristic of flying through the cumulus clouds. Four flights were performed under severe meteorological conditions, such as rain, snow, low temperature, 98% humidity. There occurred strong over loads when flying through the cumulus clouds due to the developed turbulence. There were no failures of the system block of the complex noticed under such conditions. Only separate sensors refused, as a rule due to low mechanical strength.

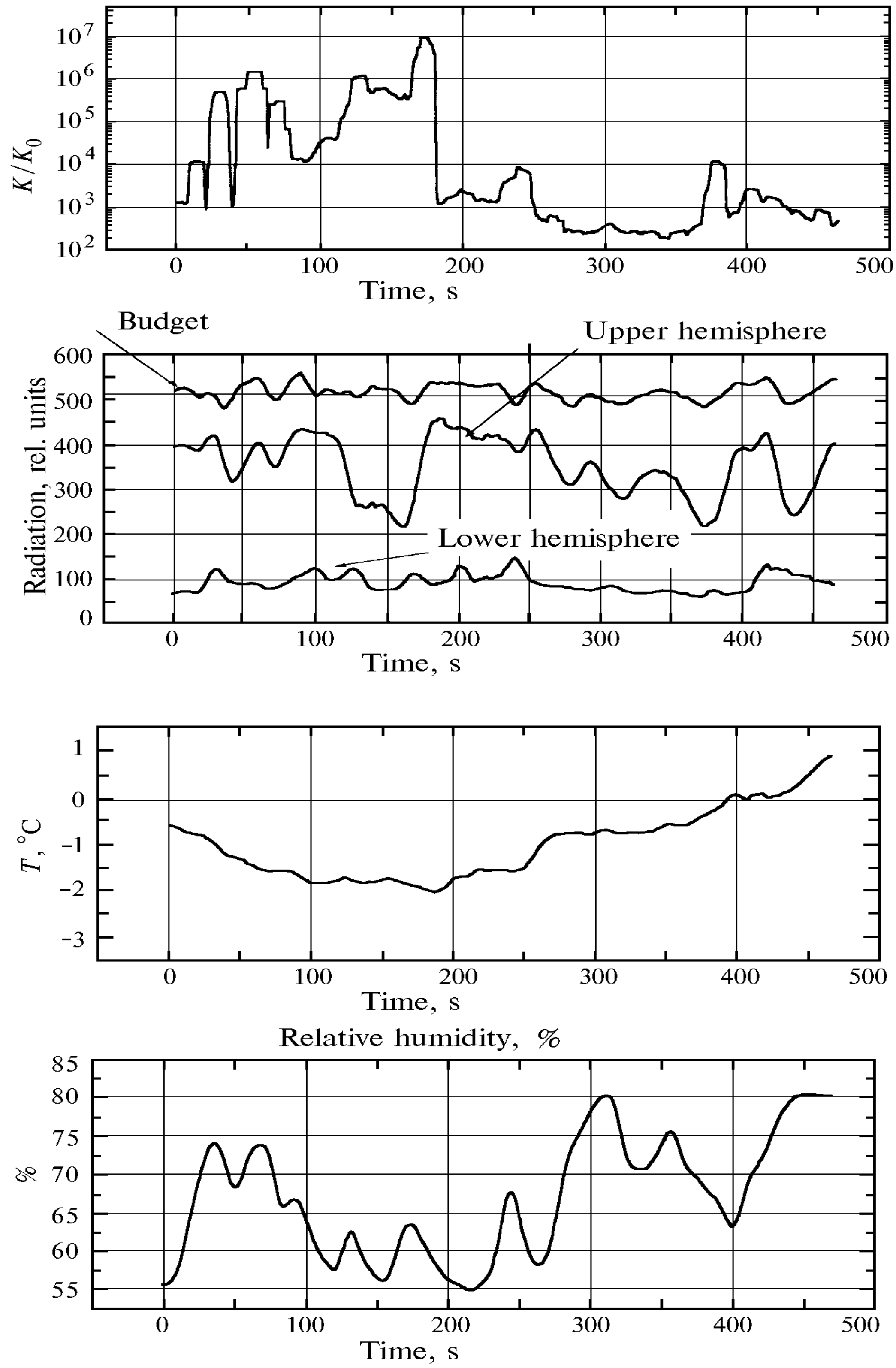

FIG. 3. Fragment of the data recorded by onboard computer when flying through the cumulus clouds in the vicinity of Tomsk. October 6, 1996.

ACKNOWLEDGMENT

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