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PROCEEDINGS OF THE
IVth INTERNATIONAL SEMINAR

MANUFACTURING OF SCIENTIFIC SPACE INSTRUMENTATION

USSR, Frunze, September 18–24, 1989

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НАУЧНОЕ КОСМИЧЕСКОЕ ПРИБОРОСТРОЕНИЕ

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IVth INTERNATIONAL SEMINAR

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INSTRUMENTS FOR STUDYING SPACE PLASMA AND COSMIC RAYS

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V МЕЖДУНАРОДНОГО СЕМИНАРА

НАУЧНОЕ КОСМИЧЕСКОЕ ПРИБОРОСТРОЕНИЕ

ПРИБОРЫ ДЛЯ ИССЛЕДОВАНИЯ КОСМИЧЕСКОЙ ПЛАЗМЫ И КОСМИЧЕСКИХ ЛУЧЕЙ

СССР, Фрунзе, 18–24 сентября 1989

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Под редакцией В.М.Балебанова

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The IVth International seminar on scientific space instrumentation manufacturing was held in Frunze in September 1989. The Seminar was initiated by the Space Research Institute, USSR Academy of Sciences, and by the INTERCOSMOS Council, USSR Academy of Sciences.

More than 200 specialists from the USSR and other countries (including - for the first time - capitalist countries) participated in the Seminar.

These Proceedings include papers submitted to the Program Committee by the time the preparation of seminar materials for publication began.

IV Международный семинар по научному космическому приборостроению состоялся в сентябре 1989 г. в г. Фрунзе. Семинар был организован по инициативе Института космических исследований АН СССР и Совета "Интеркосмос" при АН СССР.

В работе семинара приняли участие более двухсот советских и зарубежных специалистов, в том числе впервые из капиталистических стран.

В настоящий сборник вошли доклады, представленные авторами в программный комитет к моменту начала подготовки материалов семинара к публикации.

ON BOARD DATA PREPROCESSING FOR THE PARTICLE ANALYZER TAUS

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INTRODUCTION

The Martian plasma complex consists of two sensors, SOWICOMS and TAUS, and two dedicated preprocessing units located in a common electronic box. The TAUS-sensor is a novel electrostatic-magnetostatic particle analyzer, performing three dimensional measurements separately for H^+ and He^{++} particles. An additional channel accumulates heavy-ions $(M/Q \geqslant 3)$ without angular resolution. The instrument operates with an acceptance angle of $40^\circ \times 40^\circ$ divided into 8 x 8 angular channels. The energy range is 30 eV to 6 keV, particles are classified to 32 logarithmic steps. The dedicated TAUS-preprocessor controls four measurement modes for the solar wind phase and the Martian environment.

The TAUS preprocessor hardware

The data processing unit was developed around the 80C86 micro-faster.

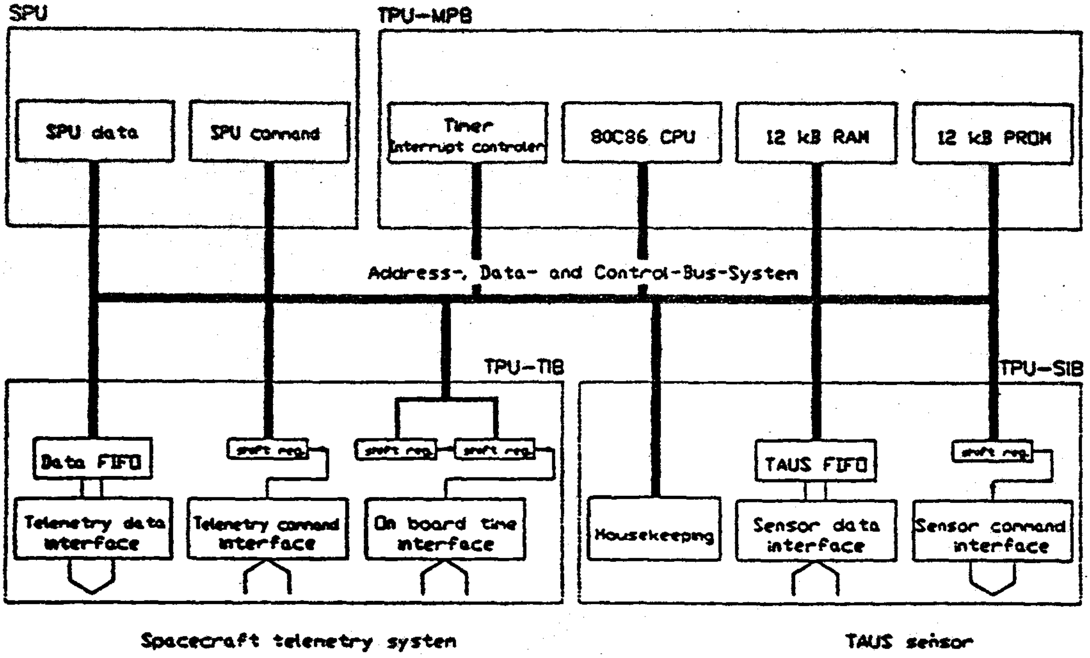

Figure 1

The logic components for the processor area are selected from the 54HCxx series, which guarantees working speed of more than 10 MHz. The logic for peripheral interfaces is built around components out of the CD40xx series. In Figure 1 an overview to the hardware design is given.

Software structure

The TAUS preprocessing unit is designed to do three independent tasks at the same time. The control and the data reduction for the TAUS-sensor, the communication with the spacecraft telemetry system and the transfer of data-frames, generated by the SOWICOMS processing unit, to the telemetry system. To avoid problems with timing and priority, all tasks are executed in a time slot configuration with a turn around time of 100 ms (Figure 2). A central schedule program is responsible for controlling and managing tasks. This reduces the maximum available computation power, but, on the other hand, it is more reliable and it makes the test-phase shorter and easier. It is necessary to run in parallel, periodic tasks and tasks taking an execution time larger than an available time slot. Therefore a foreground and background system is installed separate for each

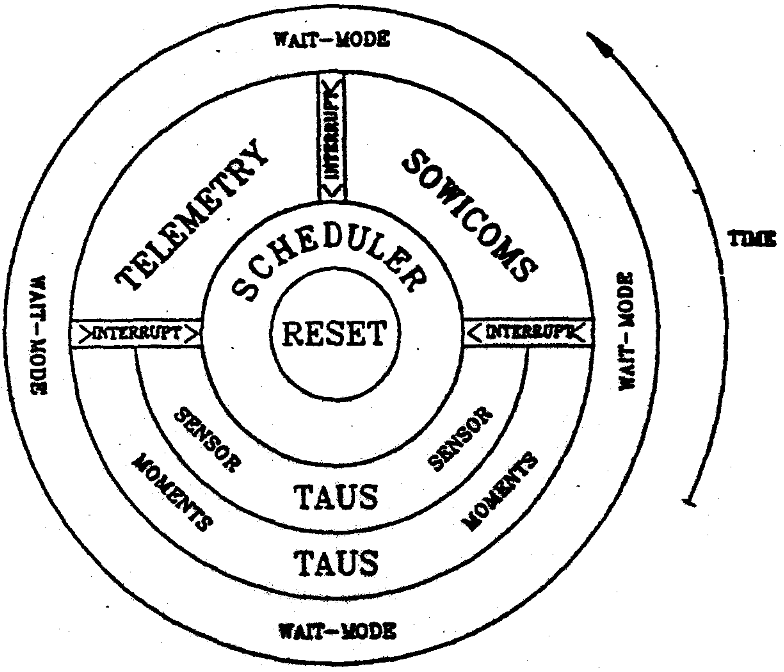

Figure 2

time-slot. For a maximum of independences and a minimal interaction of all tasks in case of failures, a dedicated stack and data area for each time slot is reserved. In cases when the execution time is shorter than an available time slot, the processor is switched to a sleep mode until next interrupt occurs to switch over to another task. This method reduces the average power consumption by about 20%.

Data compression

The set of measurement data created by the sensor is like a cube of eight by eight by thirty-two boxes, each box contains the corresponding count-rate (Figure 3). The dynamic range of the count-rates is equivalent to 16 bit data. The sensor works, in principle, in two modes, one for H^+ and one for processor family. This type of microprocessor, well known from personal computer systems was the first 16 bit processor available in CMOS technology. The 80C86 performs all integer arithmetic including 16bit multiplication and division. Using additional components out of this processor family as interrupt controller 82C59, timer 82C54 and the clock driver 82C84, gives a powerful system.

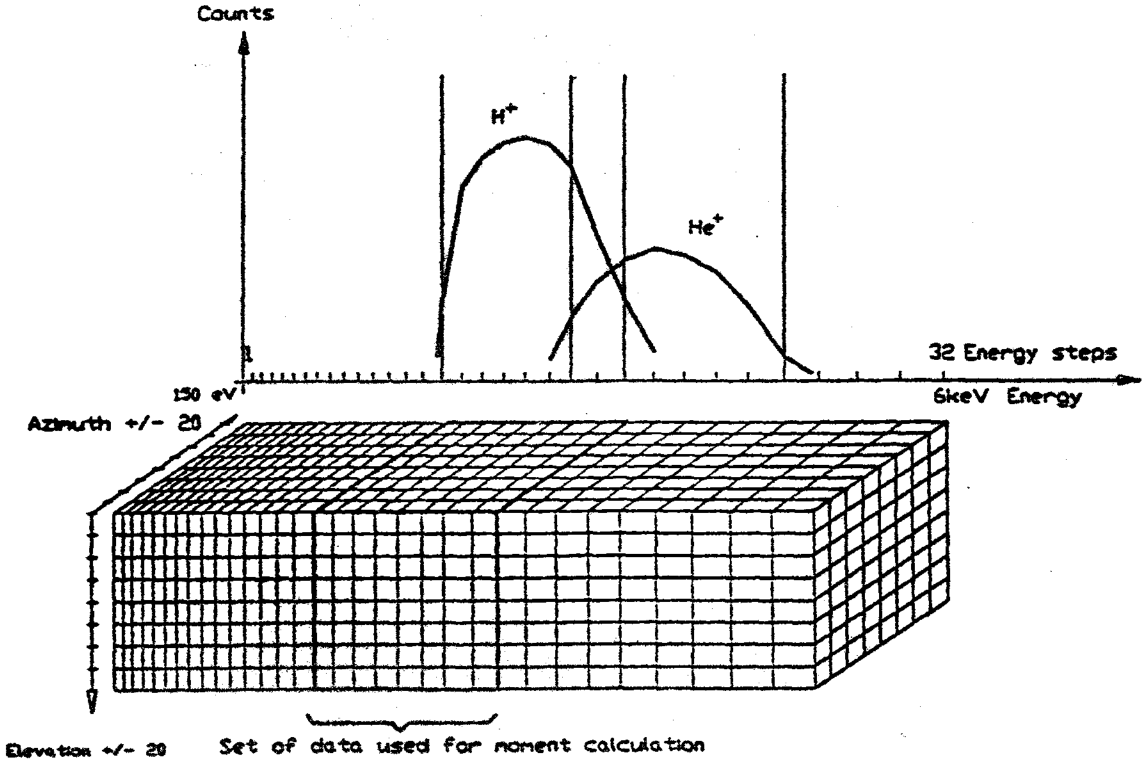

Figure 3

The program memory with a capacity of 12 kbyte is built from 2 kbyte chips, the type is HM-6617. Using this type restricts the maximum memory capacity, on the other hand, this type of PROM is the only one CMOS-type which is available in 'fusible link' technology. The operation memory is constructed by using the 2 kbyte HM-6516 type, the total capacity is 12 kbyte.

The TAUS processing unit communicates with the sensor and the spacecraft telemetry system via serial lines. The data interchange with the second preprocessor (SOWICOMS processing unit) is done in parallel format. All communication channels are buffered with FIFO memories. This reduces the number of interrupts, the software structure is simpler and the CPU works

He^{++} particles. The accumulation of heavy-ions is done simultaneously. In case of H^{+} particles a complete energy sweep is done in eight seconds. For He^{++} particles the accumulation time is enlarged by a factor of four. At the same time the energy sweep is reduced to ±4 steps around the precalculated maximum. One measurement in eight seconds gives a data rate of about 512 bytes/s from the sensor interface. The telemetry data rate in comparison is rather small with 10 bits/s. The preprocessing modes are designed to combine sets of unprocessed raw data in low time resolution with the results of preprocessing algorithm which give a maximum time resolution by loosing basic information. The maximum in data reduction is achieved by use of the statistical method of moment calculation.

In general the scientific output data contain raw data (around the maximum), single- and multidimensional spectra and results of the moment calculation. All count-rates are compressed to eight bit values, using quasilogarithmic compression. As usual, sets of housekeeping data for the preprocessor and the sensor and time information are add to the telemetry frames.

Moment calculation

Starting with a three dimensional distribution function a set of statistical parameters are calculated. Using these parameters allow the recalculation of typical physical values for the distribution function as density, velocity vector, temperature and heat-flux tensors. In case of TAUS the simulations showed numerical problems for the results of the heat-flux, so this part was canceled and replaced by additional basic information.

The sensor results have to be corrected before the data set is processed to moments. The formula (1) shows the compensation of dead-time of channeltrons and amplifiers. Formulas (2) and (3) take in account the difference of the detector effects caused by the geometry. The ratio $\frac{\Delta E}{E}$ is not constant over the energy range, formula (4) takes this in consideration. The symbol α is used for the angle where the channeltrons are located, ε for the perpendicular direction.

$$Z1(E,\varepsilon,\alpha) = \frac{Z0(E,\varepsilon,\alpha)}{1 - Z0(E,\varepsilon,\alpha)\frac{\tau}{T}} \qquad (1)$$

$$Z2(E,\varepsilon,\alpha) = Z1(E,\varepsilon,\alpha)K(\alpha) \qquad (2)$$

$$Z3(E,\varepsilon,\alpha) = Z2(E,\varepsilon,\alpha)K(\varepsilon) \qquad (3)$$

$$N(E,\varepsilon,\alpha) = Z3(E,\varepsilon,\alpha)K(E) \tag{4}$$

$ZO(E,\varepsilon,\alpha)$ ... countrate rawdata T ... accumulation time
$N(E,\varepsilon,\alpha)$ ... corrected countrate τ ... deadtime

The common statistic formulas for the moment calculation are given in (5), (6) and (7). In case of measurements the distribution function is a discrete function and the integrals are replaced by summations.

$$M^{(o)} = \int_E \int_e \int_\alpha N(E,\varepsilon,\alpha) \tag{5}$$

$$M^{(1)} = \int_E \int_e \int_\alpha N(E,\varepsilon,\alpha)\, V(E) \tag{6}$$

$$M^{(2)} = \int_E \int_e \int_\alpha N(E,\varepsilon,\alpha)\, V^2(E) \tag{7}$$

In (8), (9) and (10) the formula for the moments of the x-component are given. Formula (11) is one example for mixed components in case of the second moment. All other components are in principle identical, there is just a change in the trigonometric functions. Base is a rectangular coordinate system x,y,z with x pointing towards the sun, and the y-component in the ecliptic plane.

$$M^{(o)} = \sum_E \sum_e \sum_\alpha N(E,\varepsilon,\alpha) \tag{8}$$

$$M_x^{(1)} = \sum_E \sum_e \sum_\alpha N(E,\varepsilon,\alpha)\, V(E) \cos\varepsilon \cos\alpha \tag{9}$$

$$M_{xx}^{(2)} = \sum_E \sum_e \sum_\alpha N(E,\varepsilon,\alpha)\, V^2(E) \cos^2\varepsilon \cos^2\alpha \tag{10}$$

$$M_{xy}^{(2)} = \sum_E \sum_e \sum_\alpha N(E,\varepsilon,\alpha)\, V^2(E) \cos^2\varepsilon \cos\alpha \sin\alpha \tag{11}$$

The second set of formulas are used to recalculate the physical values. Since the number of parameter's is not changed, this part can be performed at ground. The formulas (12), (13) and (14) are for the x-component, (15) is one example for mixed components. All other components may be generated by changing the summations are done with 16 bit numbers. Instead of truncation the results of multiplications are rounded to minimize the error. All parameters are normalized to values less than one, the decimal point is defined left from the most significant digit. This guarantees that never an overflow will occur. Figure 4 shows the flow chart for a single countrate. A sixteen bit software simulation was used to compare the microprocessor algorithm with standard floating point routines. The programs showed failure rates of approximately 10^{-4}. To minimize the necessary computation time only ±4 energy steps around the maximum, instead of a complete set of raw-data, were used for calculating the moments. This agreement fits well to the typical solar wind conditions. To be able to check later on, if the energy range of the distribution function is less or equal to the energy range of the raw-data, the maximum count-rate in the lowest respectively highest energy step is transmitted.

RESUME

The moment calculation is a powerful data compression algorithm, the amount of data is reduced by a factor of 200 and more. The sixteen bit microprocessor system has enough computation power to control the sensor and compress the measurement data in parallel. Minor changes in the hardware design should be made for future applications. Adding a separate hardware multiplication-accumulation unit would accelerate the moment calculation and/or allows the usage of thirty-two bit algorithms. The size of the calculation memory (RAM) has to be enlarged, to buffer formatted telemetry frames if the instrument works asynchronous to the telemetry cycles. The numerical limitation to sixteen bit does not effect the result to much. More troubles occur when the statistical parameters are compressed for transmission. The problems are located in the formulas for recalculation. In formula (14) two parameters have to be subtracted. Both are in about the same size, the difference is approximately one per mile. The typical exactness of the compressed values is less, therefore it is impossible to recalculate the correct values for the 'plasma temperature'. A solution would be, to include these subtractions to the on board preprocessing algorithm. Changes in the sensor characteristics (efficiency, high voltage, noise, cross talking ...) influence the results quit enormous. A combined software-hardware sensor simulator would be helpful to test all algorithms and to simulate unusual sensor conditions too.