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Professional paper

APPLICATION OF ELECTROOPTICAL CCD SENSORS FOR REGISTRATION OF STAR TRANSITS WITH THE BELGRADE LARGE TRANSIT INSTRUMENT

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SUMMARY: A project for installing of electrooptical CCD sensors on the Large Transit Instrument (LTI) of Belgrade Observatory is given. The works are planned to be carried out in 3 phases. The basic task of the first phase is the realization of the hardware and software with the cheapest selection of the CCD sensor and standard personal computer, for the purpose of functional verification of the entire system. The second phase foresees the selection of the optimal sensor, the analysis of system errors and factors affecting its work and the possibility of multiple observations of star transits. Finaly, the third phase foresees the full automatization of the registration of star transits and the automatic treatment of obtained results.

In this paper a detailed review of the planned project of the first phase is given.

1. SELECTION OF THE ELECTROOPTICAL CCD SENSOR

The first phase of the project which is related to the installation of the CCD electrooptical sensor on LTI ought to provide the functional verification of the hardware and software. Having this fact in mind, the basic criteria for the selection of the CCD sensor of the lowest possible price but still functionall and concerning to the basic accuraccy, is to satisfy requirements for meridian observations.

The basic parameters, which the sensor has to satisfy are determined by the characteristics of the LTI (f = 2578 mm, θ = 190 mm). The working observation area is 3 to 4 mm and the illumination at the place of CCD sensor, according to the magnitude of the observed star, is:

m = 0	5 lx
m = 8	3×10^{-3} lx
m = 10	0.5×10^{-3} lx

The diameter of the star image at the sensor place is 0.100 to 0.037 mm.

On the other hand, the minimal number of pixels in the working area needed for time registration is 100.

Comparing the given requirements with the characteristics of the commercial CCD sensors, (see Philips Catalogue, CCD sensors, 1992 and Fairchild Catalogue, CCD, The Solid State Imaging Technology.) one comes to the conclusion that the only problem is the noise level at the ambiental temperatures above the 0°C.

For example, the FT 800P sensor has the entire width of the sensor field 6.579 mm and the height of 5.044mm. As it can be seen, the width is double than required and the height allows a comfortable positioning of the instrument along the meridian.

The effective number of the pixels horizontally is 774 and vertically 580. In the working area there are more than 300 pixels which also exceeds the requirements.

The sensitivity of FT 800P sensor for the spectral region of the brightness which corresponds to the brightness of the observed stars is 30 mV/1x or 30 μV/m1x. That would be completely satifactory for stars up to the 10^{th} magnitude. With certain software averaging the observations of fainter objects would be possible.

The problem is in the thermal noise (non-illuminated sensor) which is at 333 K 5mV considerably exceeds the intensity of the brightness of the 6^{th} magnitude objects.

The aim of this analysis is to show that it is necessary to cool the sensor to a level when it can still work. For the mentioned CCD – FT 800P – the level is -40°C. As the noise level decreases approximatelly exponentally with the temperature, it is easy to show that at -40°C the noise level is of the order of 0.1 μV. This proves that even with this relatively cheap sensor it is possible to register objects fainter than 10^{th} magnitude.

2. ELEMENTS OF THE HARDWARE OF OPTICAL CCD SENSORS

In the first phase of the installation of CCD optical sensors on LTI, the use of standard components is forseen, mostly the existing elements with only a few new most necessary devices. The general block scheme of the proposed system is given in Fig. 1.

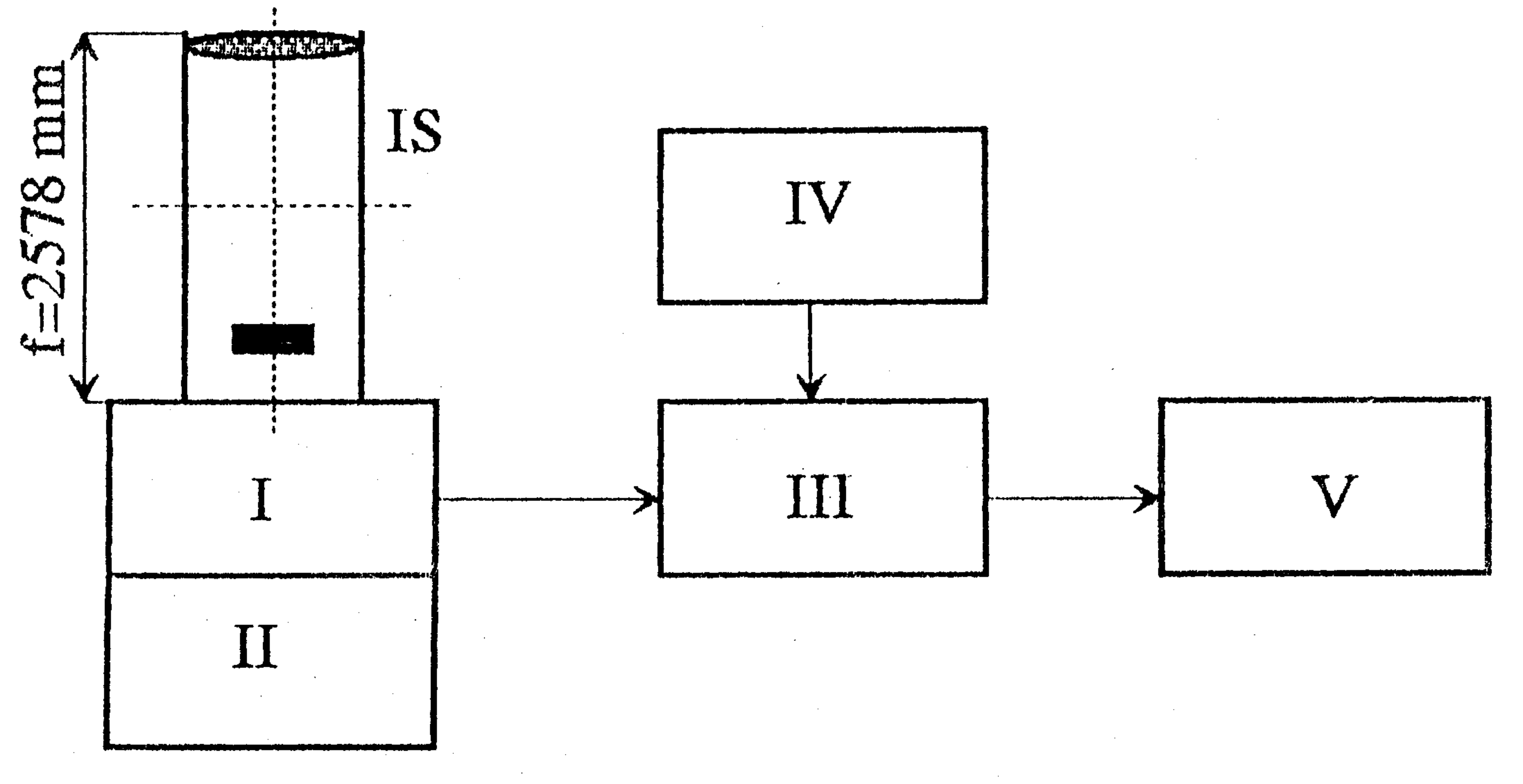

Fig. 1. IS – LTI, I – CCD camera, II – cooling, thermostat, temperature control, device against fogging, III – interface block, IV – main clock, V – personal computer & equipment.

The CCD camera and the cooling device (thermostat, temperature measuring & control of the CCD sensor, the heater against fogging) are installed directly on the eye-piece end of the LTI tube and with the flexible cable (in the second phase the application of fiberoptical cable will be considered) are connected with the interface device.

As the LTI is not provided for photometry nor spectroscopy but only for the registration of star transits, it is logical to apply binary monochromatic system of CCD camera (Fig. 2).

The basic commands which arrive at CCD camera are video clock and comparison level. Video clock determines the CCD scanning regime which depends on the observed object. For the objects nearer to the equator video clock increases and for those nearer to the pole it decreases. The comparison level is determined by the object magnitude.

From the video camera to the interface for time positioning the following signals arrive: binary video signal, command DATA VALID and the information that CCD is saturated, which shows that it is necessary to change automatically the amplification.

At the instrument (LTI) sensor cooling system also exists (details are not given in Fig. 2). In this phase a thermostat with the dry ice (CO_2) which can sufficiently cool CCD sensor is planned. A double optical filter (with a vacuum between the filter planes) and a corresponding heater should eliminate fogging.

From the video camera the signal goes to the time interface device (Fig. 3).

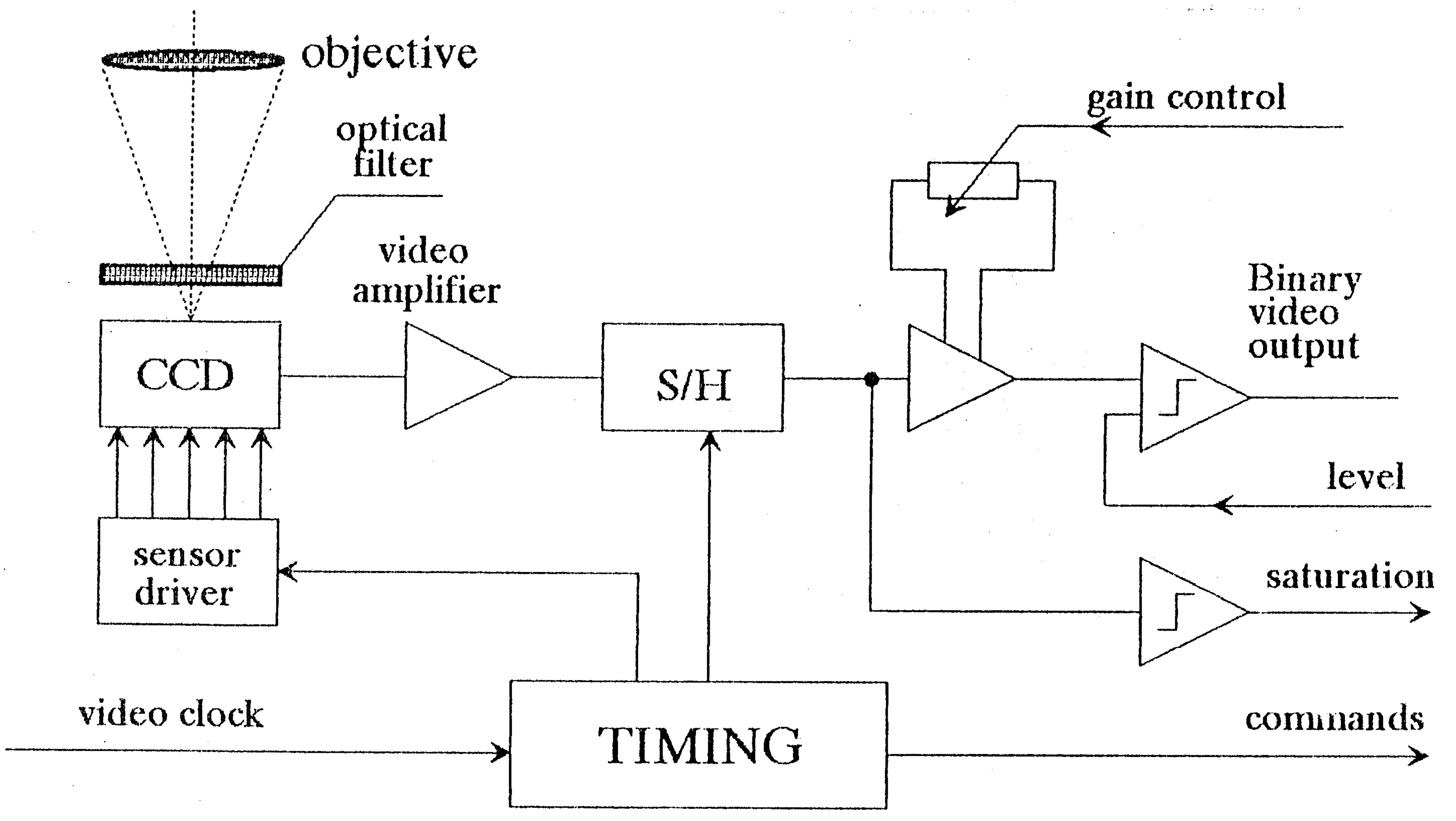
objective
optical filter
video amplifier
CCD
S/H
gain control
Binary video output
level
saturation
sensor driver
video clock
TIMING
commands

Fig. 2.

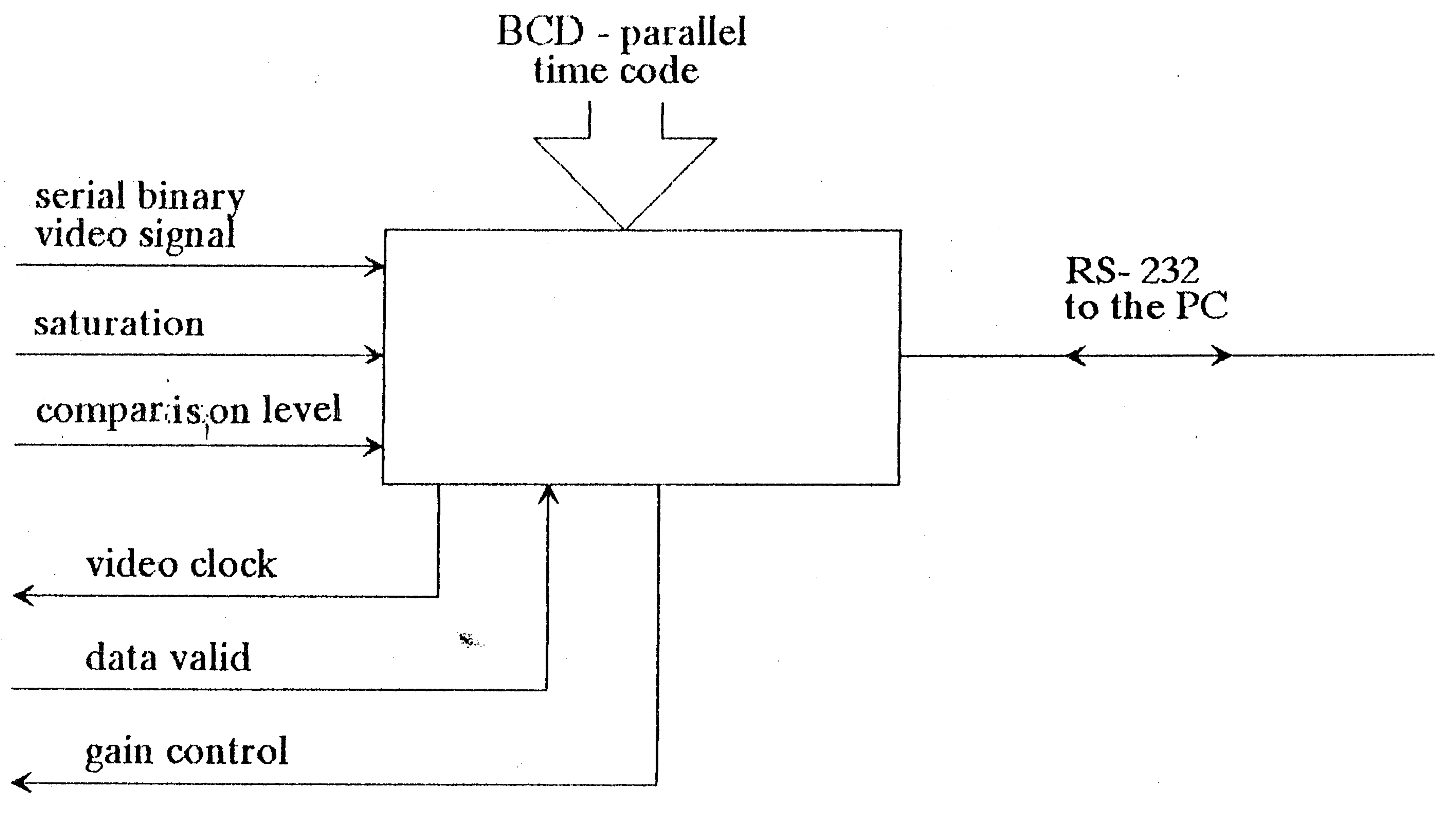
BCD - parallel time code
serial binary video signal
saturation
comparison level
RS- 232 to the PC
video clock
data valid
gain control

Fig. 3.

The basic function of time interface is to determine the binary (BCD) time code to the serial video signal and to send such signal by serial RS-232 connection to PC input.

Other functions of the time interface are:
- determination of the video clock according to the speed of the object under observation;
- determination of the comparison level according to the magnitude of the observed object;

3. SOFTWARE ELEMENTS IN THE FIRST PHASE OF THE INSTALLATION OF CCD SENSOR ON LTI

As the first phase represents only a functional verification of the system, the forseen software is quite simple and contains only two subprograms:
- Data memory and its presentation on the screen and the printer;
- lifting data from the hard disc to the algorithm for data treatment;

At this stage the algorithm can not be defined because the number of necessary averaging depends on many parameters:
- the magnitude of the object;
- the speed of the object;
- night sky light, etc;

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REFERENCES

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ПРИМЕНА CCD ЕЛЕКТРООПТИЧКИХ СЕНЗОРА ЗА РЕГИСТРАЦИЈУ ПРОЛАЗА ЗВЕЗДА НА ВЕЛИКОМ ПАСАЖНОМ ИНСТРУМЕНТУ У БЕОГРАДУ

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Стручни чланак

У раду је дат приказ пројекта за увођење CCD електрооптичких сензора на Велики пасажни инструмент (ВПИ). Радови су планирани да се изврше у три фазе. Основни циљ прве фазе је увођење хардвера и софтвера са најјефтинијом варијантом CCD сензора и стандардним PC рачунаром, а све у циљу функционалне верификације читавог система. Друга фаза предвиђа селекцију оптималног сензора и одговарајуће усавршавање хардвера и софтвера, анализу грешака система и анализу утицајних величина, као и могућност вишеструког посматрања звезда. Коначно, трећа фаза предвиђа потпуну аутоматизацију регистрације пролаза звезда кроз меридијан и аутоматску обраду добијених података.