Bull. Astron. Belgrade № 151 (1995), 135 – 139

UDC 520.17
Professional paper

THE CONSTRUCTION PRINCIPLES OF THE CCD CAMERA FOR FUNCTIONING IN THE REAL TIME ON THE BELGRADE LARGE TRANSIT INSTRUMENT

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(Received: January 20, 1995)

SUMMARY: The possibilities of CCD sensors and the accompanying hardware for comparison of the local time t(UTC) with the position of star-image in the pixel matrix of the sensor are analysed. It is shown which data are necessary for this comparison as well as the organization of the necessary hardware.

1. INTRODUCTION

Functioning in the real time during star observations on the Large Transit Instrument (LTI) supposes the establishment of the correspodence between each illuminated pixel of CCD sensor and time t(UTC) obtained from the local T/P standard. The moment of illumination of each individual pixel, the interval of integration time of the illuminated pixel, intensity of the illumination, velocity and direction of star-image motion across matrix of pixels and jitter of the star-image are the basic parameters (excluding LTI instrumental errors) for time determination of meridian passages.

To define the basic conception for functioning in real time t(UTC) it is necessary firstly to analyse the basic structure of the concrete CCD sensor (it is a FT 800P - PHILIPS IMAGING TECHNOLOGY). Simplified structure of this sensor is shown in Fig. 1 (Mackay, 1986).

The number of columns in the image section and in the storage section is the same - k=774. The number of lines in the image section is n_i=290 plus two black reference lines. The number of lines in the storage section is n_s=301. Horizontal shift register K_{hr} has 774 storage sections plus 7 dummy pixels.

A matrix of photo-sensitive picture elements (pixels) in the image section converts projected star-image in the electron image. The image section is controlled by four A electrodes (A_1,...,A_4). At these electrodes a four-phase clock arrives, which for the certain number of clocks shifts a complete electron image to the storage section. For functioning in the real time it is necessary to determine the interval of time which is necessary for shifting the complete image from the image section to the storage section. If the basic frequency of the clock for A electrodes is $f_A=1/T_A$, then the time interval which is necessary for shifting 1 line is $5/4T_A$ (Fig. 2).

The whole time interval which is necessary for shifting the complete image from the image section is $5/4T_A \cdot n_i$.

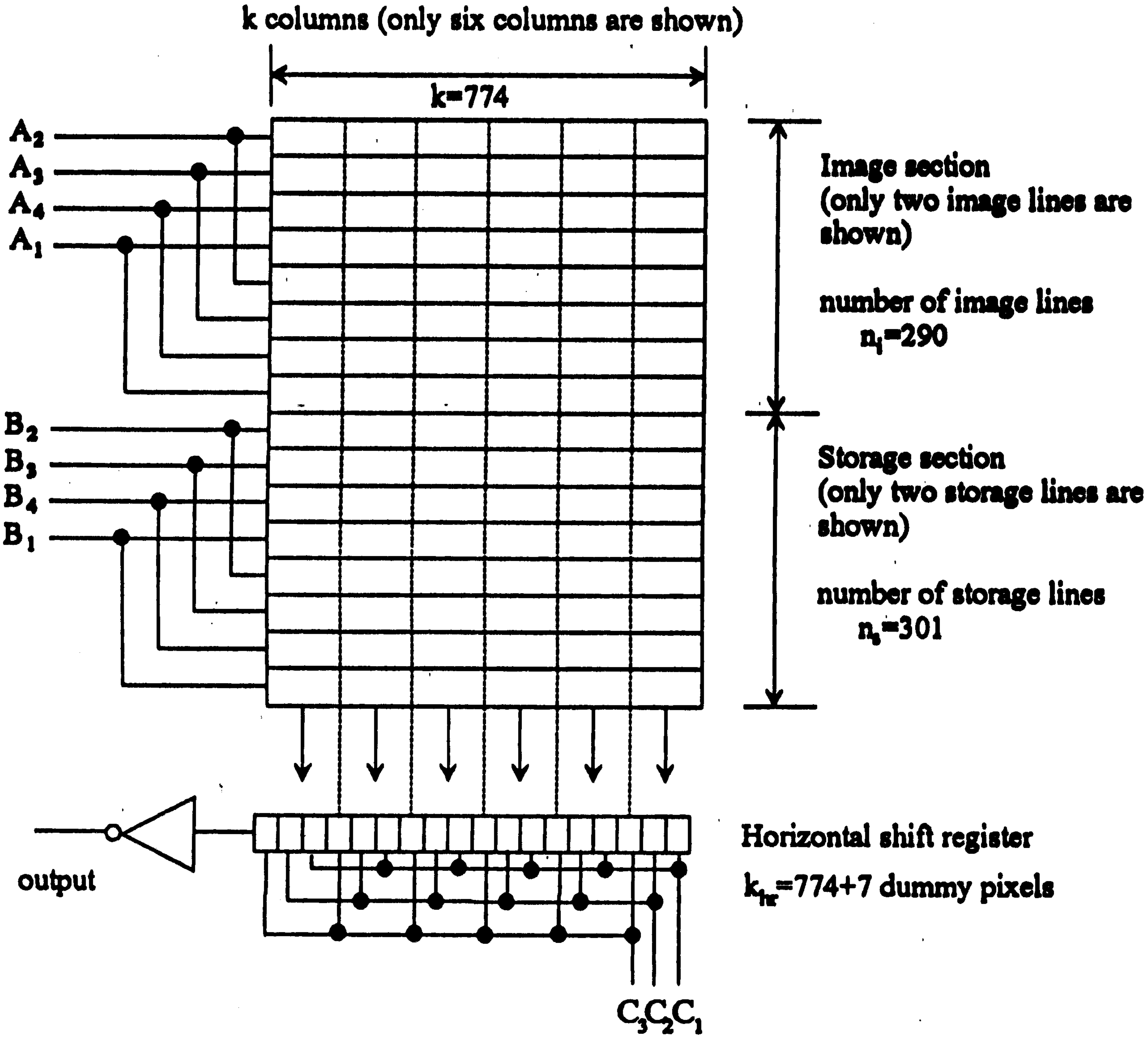

Fig. 1. FT 800P siplified diagram.

In the storage section there is a matrix of storage elements. The storage section is controlled by four B electrodes ($B_1,\ldots,B_4$). During the interval of image shifting from the image section to the storage section, the clock at B electrodes must be the same as one at the A electrodes, so that the reception of data in the storage section needs no extra time interval. After the end of the image section line shift a certain time interval is left necessary for integration time T_s. The 12 storage sections data are being successively shifted into horizontal register. For shifting one line from the storage register into the horizontal register, the necessary time interval is $5/4T_B$ where T_B is the period of clock $f_B = 1/T_B$. As the clock in the horizontal register is three-phased, the time interval which is necessary for shifting each datum for one place to the left (Fig. 1) is $7/6T_C$ (Fig. 2), and the complete time for the serial exit of one line is $7/6T_C \cdot k_{hr}$, where k_{hr} is the complete number of the storage sections in the horizontal register.

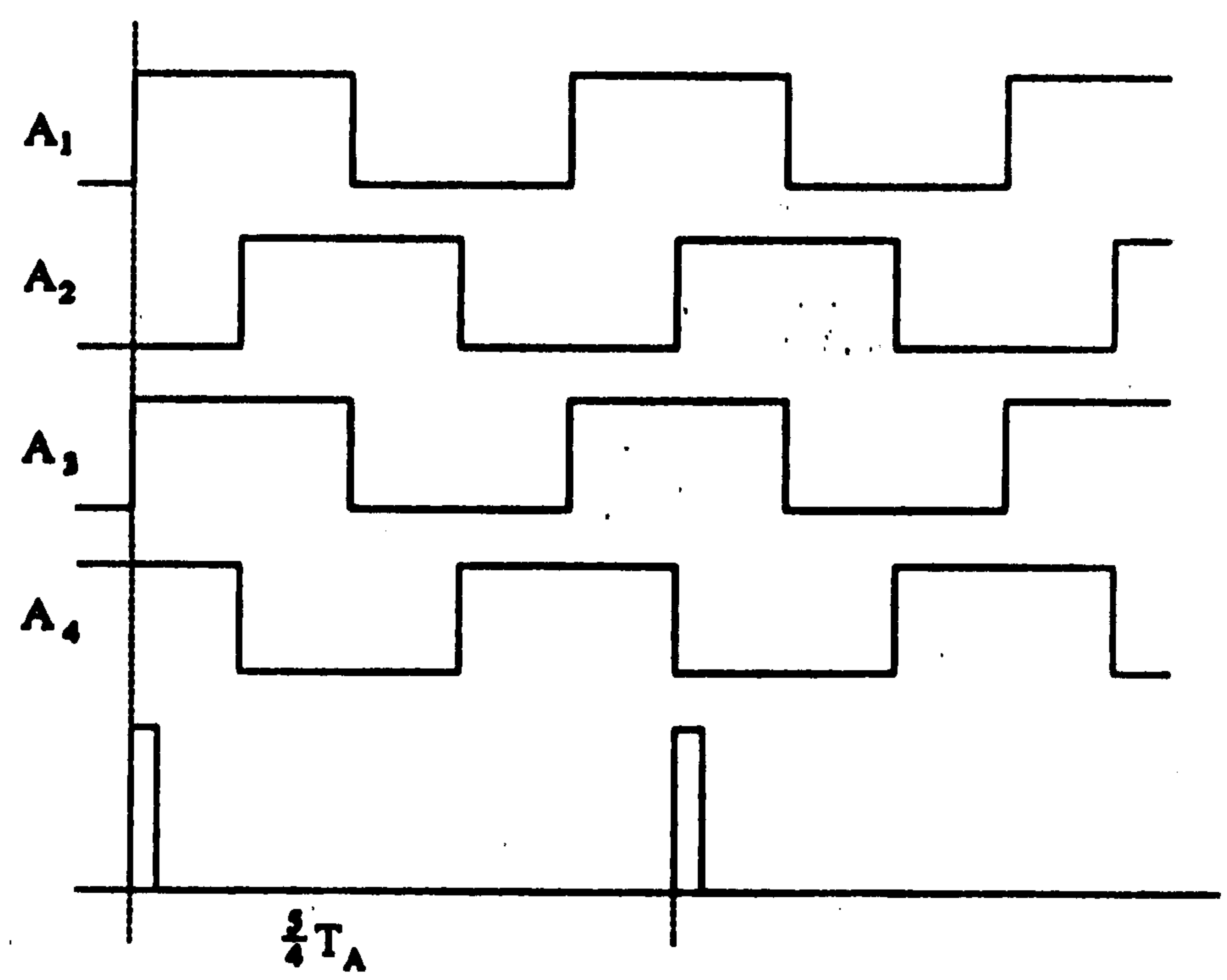

Fig. 2. Control of the storage section.

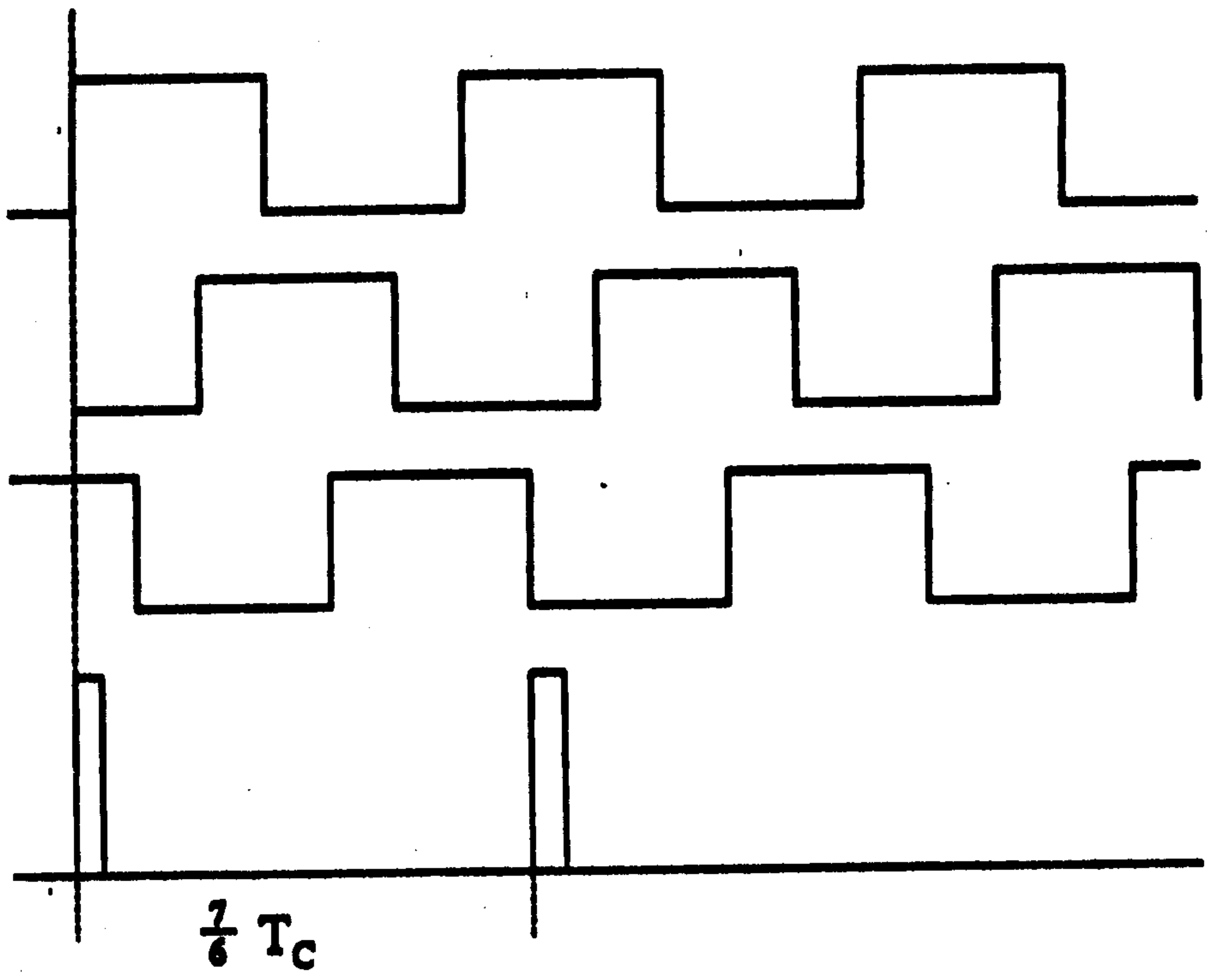

Fig. 3. Control of the horisontal shift register.

2. THE INTERVAL OF INTEGRATION TIME

According to the magnitude of a star, dimension of a star-image and the velocity of a star-image motion across the pixels matrix in the image section, necessary integration time interval of the CCD sensor is determined. It is important to note that, for a certain star (excluding atmospheric conditions), this time interval is fixed and is T_e.

The charging value in each pixel of the image section is proportional to the illumination intensity and to the integration time (Fig. 4).

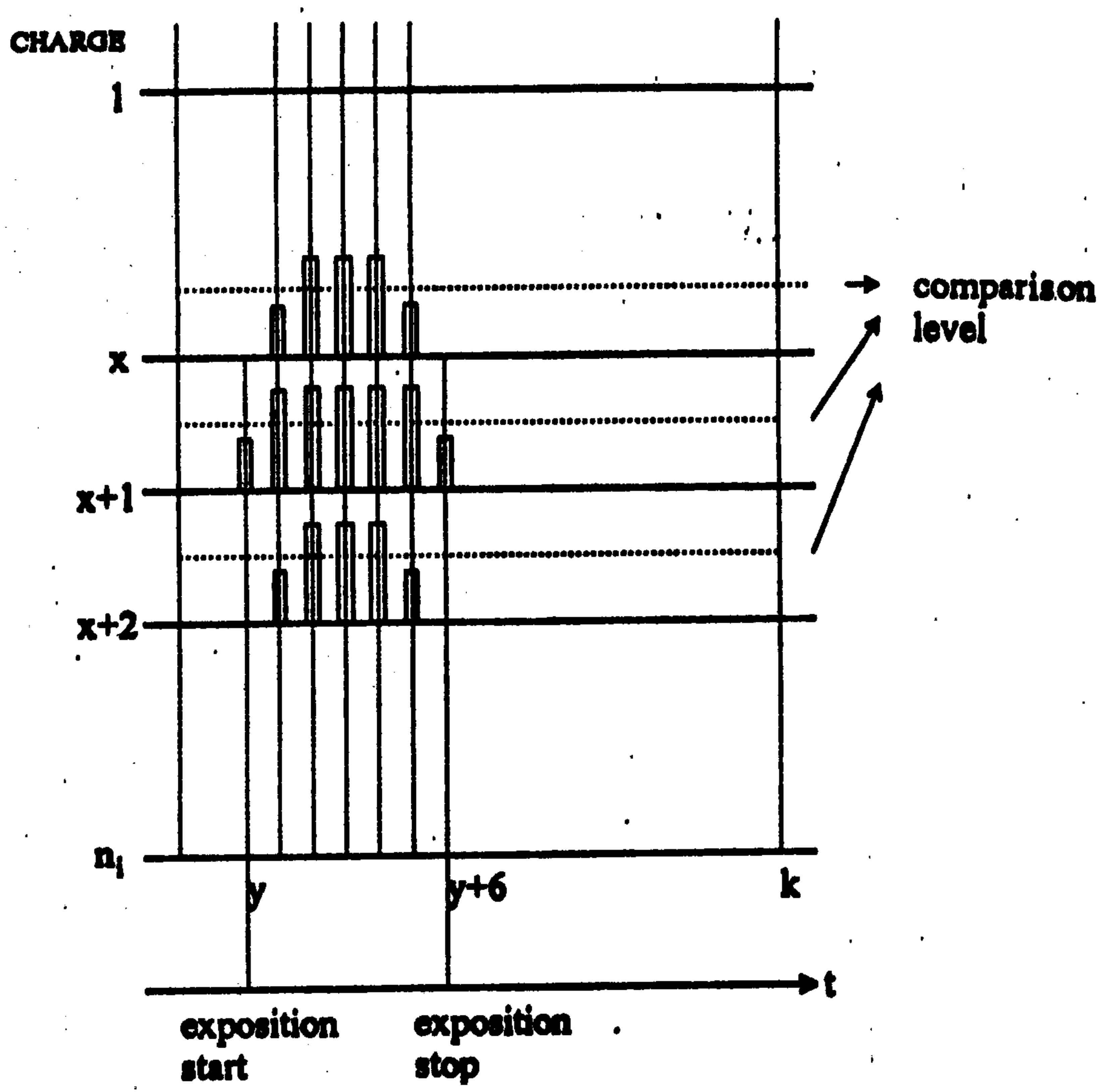

Fig. 4. Charging and illumination.

For functioning in the real time, the one-bit analog digital convertor with determined comparison level for each star is sufficient. In the conditions of ideal positioning of CCD sensor and in the absence of star-image jitter, for the individual measurement, a charging order which is symbolicaly shown in Fig. 4 would be obtained. The correspodence which is necessary to establish is t(UTC) obtained from the local T/C standard and numbers of lines $x, x+1, \ldots, x+\alpha$ and columns $y, y+1, \ldots, y+\beta$ which are charged. x, y, α and β are whole numbers and represent addresses of the illuminated pixels.

In the case of non-ideal positioning of CCD sensor and presence of the star - image jitter or in case of deliberately taken diagonal motion of the star-image in the image section of the CCD sensor, the charging order of the image section pixels would be as in the Fig. 5.

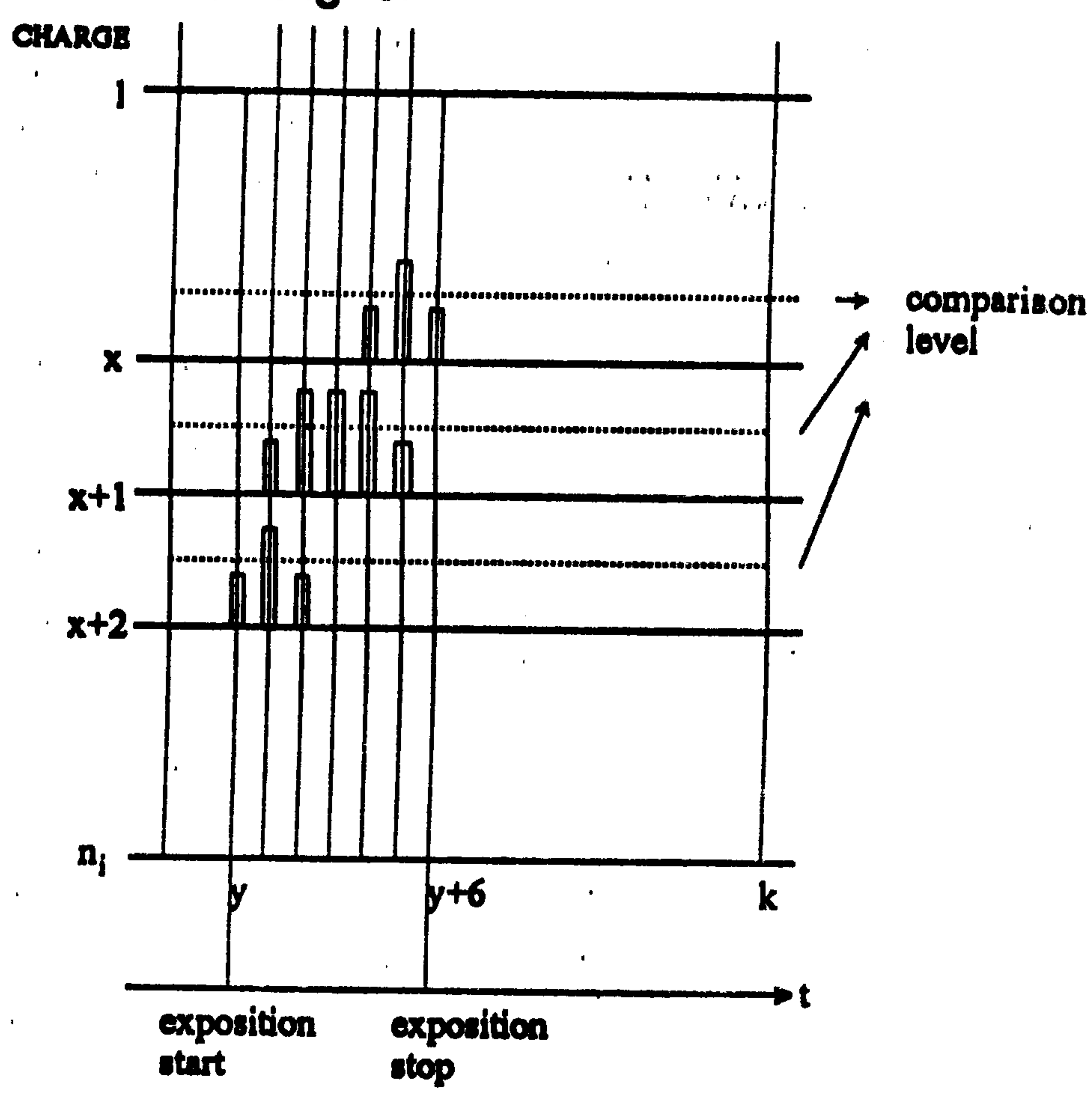

Fig. 5. The charging order of the image section pixels.

Taking in consideration the comparison level it can be seen that for establishment of the correspodence between the charging value of each pixel and time obtained from local T/P standard t(UTC) it is best to take the mean value $t(UTC)+T_e/2$. In both cases (ideal and non-ideal positioning) the correspondence is as follows:

$$t(UTC) \rightarrow [x+\alpha, y]$$

$$t(UTC)+\frac{T_e}{2} \rightarrow [x-\frac{\alpha}{2}, y+\frac{\beta}{2}]$$

$$t(UTC)+T_e \rightarrow [x, y+\frac{\beta}{2}]$$

3. DETERMINATION OF THE COMPLETE DELAY

To obtain the construction principles of the CCD camera for functioning in the real time, it is necessary to take in consideration, exept the integration time T_s, also as follows:

- the time interval of vertical transport of the electronic image from the image section to the storage section T_{ut};
- the time interval of the transport from storage section to horisontal register T_{SH};
- the time interval of the transport of data from the horizontal register to the output T_{HT};

The time interval necessary for electronic devices after the output amplifier to treat the obtained signal is in this analysis neglected.

The time interval of vertical transport from the image section to storage section T_{VT} is always fixed and is as follows:

$$T_{VT} = \frac{5}{4}T_A \cdot n_i$$

The time interval of the image transport from the storage section to the horizontal register depends only on x,x+1,...,x+α

$$T_{SH_1} = \frac{5}{4}T_B \cdot (x+\alpha)$$

$$\vdots$$

$$T_{SH_\alpha} = \frac{5}{4}T_B \cdot x$$

The time interval of the data transport from the horizontal register to the amplifier output depends only on y,y+1,...,y+β, so is

$$T_{HT_1} = \frac{7}{6}T_C \cdot y$$

$$T_{HT_2} = \frac{7}{6}T_C \cdot (y+1)$$

$$\vdots$$

$$T_{HT_\beta} = \frac{7}{6}T_C \cdot (y+\beta)$$

On the basis of this analysis it is clear that the escorting electronic devices of CCD camera must register x,...,x+α and y,...,y+β. However T_s,T_C,T_B and T_H are known constant values.

3. THE BLOCK SCHEME OF CCD CAMERA FOR LTI

The principles of hardware organization of CCD camera for functioning in the real time is based on the analysis in Chapter 1. and 2. of this paper. For determination of the correspondence between local time t(UTC) and the image of observed star, it is necessary to register the address of each illuminated pixel in the CCD matrix and to take into consideration all transport delays.

The principle block scheme of the data preparation for the trearment in the computer is given in Fig. 6

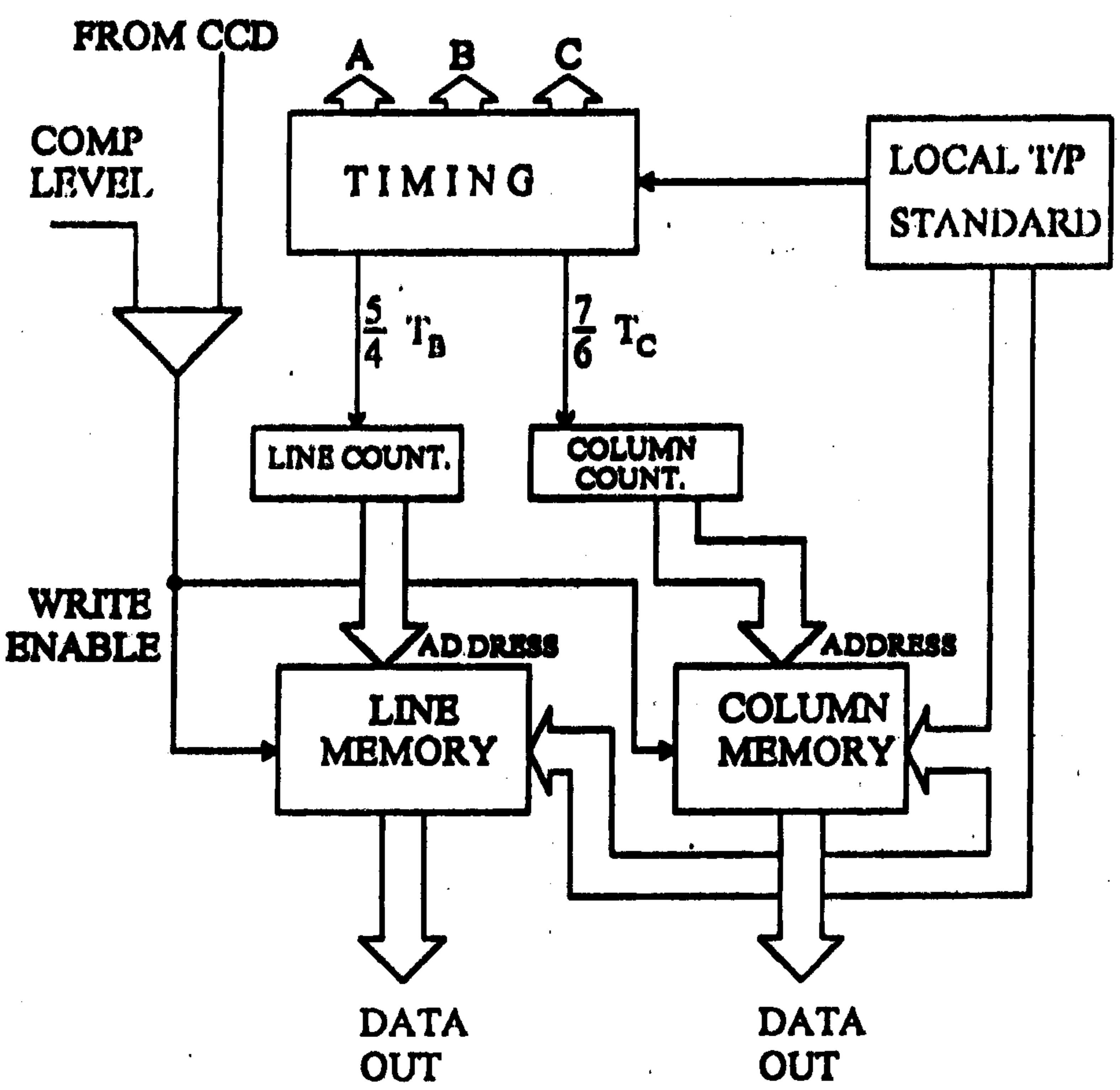

Fig. 6. The block scheme of data preparation.

The device for timing is incited from the local T/P standard and the parallel BCD code, which represents the code of the local time t(UTC), is carried out. This code is in correspondence with the image position in line and column memories so that the data of these memories contain definite functional dependence with t(UTC).

The timing device generates:

- four-phase clock A_1,...,A_4
- four-phase clock B_1,...,B_4
- three-phase clock C_1,...,C_3
- the impuls sequence with periods $5/4T_B$ and $7/6T_C$ which represent the clock for the line address counter and for the column address counter.

The output from the CCD sensor represents write enable signal for line and column memory, so that address represents x,...,x+α and y,...,y+β. At these addresses the value t(UTC) is writen. In such a way in line and column memory all necessary data for determining t(UTC) are existing. The computing algorithm has to take away all delays according the analysis carried out on Chapter 3.

Acknowledgments – This work has been supported by Ministry for Science and Technology of Serbia through the project "Physics and Motions of Celestial Bodies".

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ПРИНЦИПИ КОНСТРУКЦИЈЕ CCD КАМЕРЕ ЗА РАД У РЕАЛНОМ ВРЕМЕНУ НА ВЕЛИКОМ ПАСАЖНОМ ИНСТРУМЕНТУ У БЕОГРАДУ

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УДК 520.17
Стручни рад

Рад третира могућности CCD сензора и пратећег хардвера за поређење локалног времена t(UTC) са положајем лика звезде у матрици пиксела сензора. Показано је који су подаци неопходни за ово поређење као и организација потребног хардвера.