Baltic Astronomy, vol. 9, 433–445, 2000.

THE NEW SERIES OF THE VILNIUS-DESIGN CLASSICAL WET PHOTOMETER

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Received November 12, 1999

Abstract. The latest version of the WET high-speed three-channel classical photometer series developed by the WET group of Vilnius University is described. The main optical and mechanical layouts, as well as the block-diagram of electronics of the photometer, are presented. Firmware and software of the photometer are shortly described.

Key words: Instrumentation: photometers

1. INTRODUCTION

After approval by the WET authorities of some components of photometric equipment designed in 1993–1996 (Kalytis et al. 1993, 1996, Kalytis & Meištas 1995) the WET group at the Vilnius University started the design and fabrication of the Vilnius-type standard WET photometer, satisfying the main requirements of the WET (Kleinman et al. 1996).

The first copy of this WET standard three-channel photometer is designed for the new 1.5 m telescope of the Capodimonte Astronomical Observatory in Italy. Bellow we will refer to it as TTCP (Toppo Three Channel Photometer). Next several copies of this type photometer will be build for other WET groups. We hope that it should be the last high-speed three-channel photometer of classical type (using a photomultiplier as a detector) designed by our team. Actually the CCD detectors are marching victoriously throughout the observatories, and we are planning turn an attention to this device in our future designs of modern high-speed photometers. Despite this fact we are sure that the classical photometers will still serve to astronomers faithfully the whole next decade or maybe longer. Such photometers are indispensable for investigation of very rapid phenomena, especially in variable stars.

2. THE DESIGN

The idea of construction of this photometer arose when we realized finally the main requirements that the WET photometer should satisfy. We used also in this design all our experience acquired during several years of collaboration with the WET, i.e., when we produced components for some WET photometers as well as when we modernized the "Pancake" travelling photometer many times.

First, we decided that all three channels of the new photometer should be parallel to the main axis of a telescope, i.e., no prisms or mirrors should be used in the path of the light towards to PMT. Second, we tried to design a more lightweight and less bulky photometer than that of the Texas design. However, a large-field eyepiece unit was designed according to the requirements of the WET as well as under request of customer. It forced us to design quite a complicated unit, which makes up, for the most part, the total weight of the whole photometer. For finding a comparison star in TTCP, the idea used in the "Pancake" (Meištas 1993), but significantly developed, was chosen.

We consider that it is too expensive to keep a three-channel high-speed photometer only in one or two WET observational runs, i.e., during ten or thirty days per year. Thus one of the aims at designing the TTCP was to make it as a general-purpose photometer (suitable not only for the WET). Therefore possibilities to use the TTCP photometer for classical *UBV* and multicolor medium-band photometry, in the *Strömgren*, *Vilnius* and *Stromvil* (Straižys et al. 1996) were considered during its design.

The new architecture as well as more modern components and technologies were used in designing the computer interface of the photometer.

The GPS (Global Positioning System) receiver was included in the photometer as an inherent unit of modern high-speed photometer.

3. SYSTEM CONFIGURATION

In Fig. 1 the block-diagram of the photometer is presented.

The whole system of the TTCP photometer consists of: (1) optic- mechanical and mechanical module including detector units (photoelectric heads) and CCD camera for remote centering, (2) electronics including computer interface, power supplies, (3) GPS receiver, (4) firmware, (5) IBM PC and (6) software.

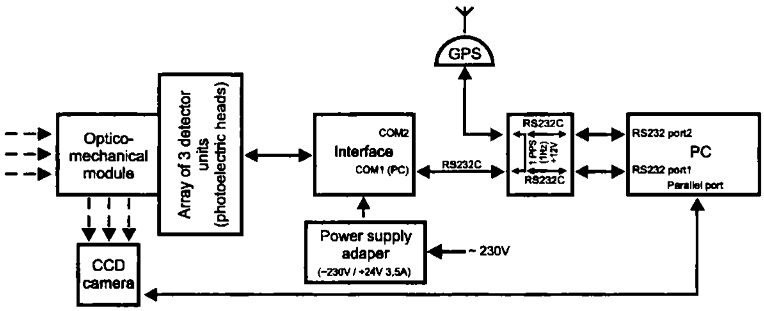

Fig. 1. Block-diagram of the TTCP photometer.

4. OPTICAL-MECHANICAL MODULE

In Figs. 2 and 3, two main cross-sections of the TTCP optical-mechanical module are presented. The optical axes of all three channels of the photometer are parallel to the main axis of the telescope. The main measuring channel (first channel) is designed for the measurement of a target star, the second one is for the measurement of a comparison star. The latter can be moved and positioned in the ring field around the first channel (Fig. 3). The third channel is designed for the light measurement of the sky background and is at the constant distance from the first channel. In this design the possibility is left of a small-amplitude turn of the third channel around the first channel axis.

The optical-mechanical module of the TTCP consists of the following units (Fig. 2):

1. Rotational bearing (1).
2. Centering unit (2).
3. Movable field eyepiece unit (3).
4. Second channel movement unit (4).
5. Third channel movement unit (5).
6. One-beam miniphotometer (miniphot) (6).
7. Two-beam miniphotometer (miniphot) (7).
8. Two-channel photoelectric head (12).
9. One-channel photoelectric head (13–15).

The rotational bearing is designed to rotate whole photometer around a main axis of a telescope (target star). It enables to locate a comparison star (in combination with the radial movement of the second channel).

The centering unit is necessary for adjustment purposes only, i.e., for the coinciding of the rotation axis with the center of a diaphragm.

The unit of movable field eyepiece allows to check the field around the target star as well as to search a comparison star by moving the field eyepiece in radial direction (also using rotation of the whole photometer).

The second-channel moving unit enables us to move it so that the light of a comparišon star is intercepted by second channel according to the position of the field eyepiece when this star is found. This is attained by converting two rotational movements of this unit to the linear movement of the second channel.

The third-channel movement unit is designed for the cases when the configuration of all three channels does not allow to get a pure sky background in the third channel, i.e., when an interfering star is seen in the third channel. This unit allows us to move the third channel to a new position without changing the position of the first two channels.

The miniphots are the main units of the photometer and incorporate its main optical parts: aperture wheels (8), Fabry lenses (9), filter wheels (10) and microscopes (11). As it is seen in Fig. 2, both miniphots have a similar construction. In the two-beam miniphot the first and third channels are joined, while the one-beam miniphot contains only one, the second channel. For this reason the filter wheel of the two-beam minophot should contain the filters placed in pairs because the measurement of the target star and the sky is accomplished through neighboring holes of the same filter wheel.

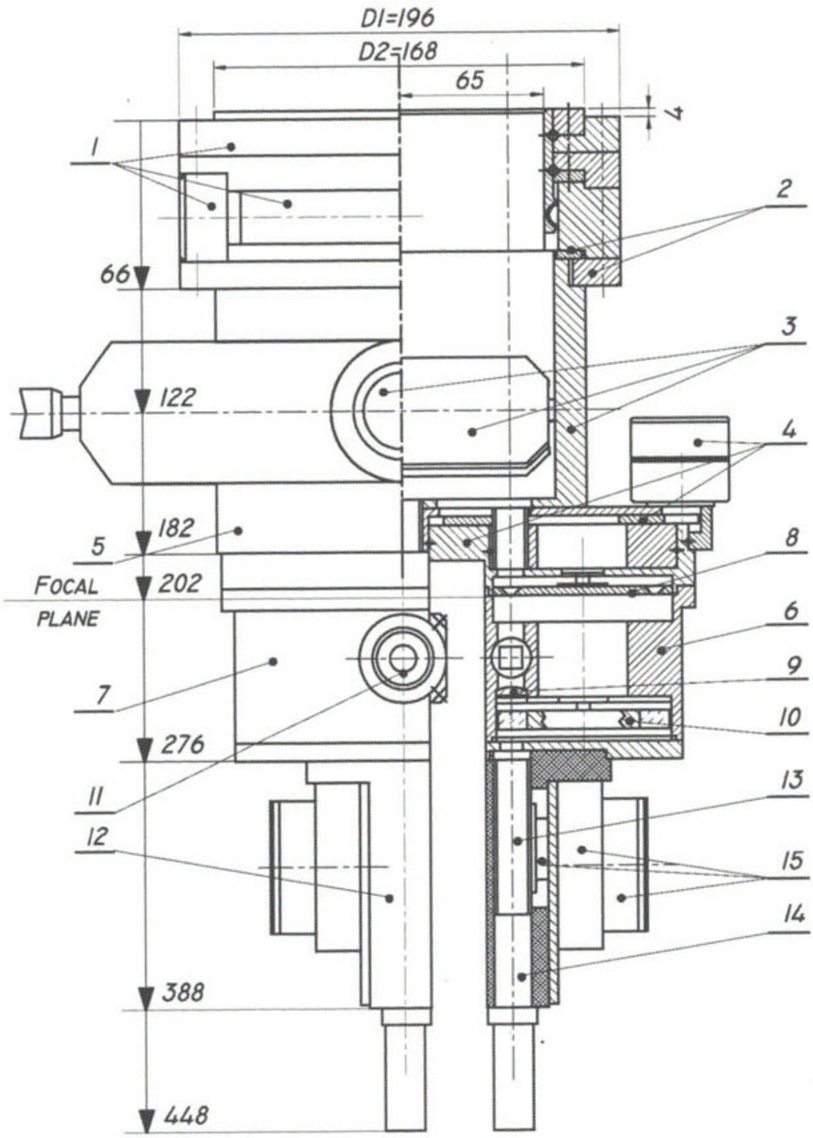

Fig. 2. The longitudinal cross-section of the TTCP photometer.

Both photoelectric heads of the type FEG 310 (Kalytis 1998) consist of high voltage dividers, amplifier-discriminators, photomultipliers (PMTs) (14), thermoelectric coolers, fan and heatsinks (15).

The only difference is that one of them has two measuring channels (first and third), while the second has only one (the second) channel.

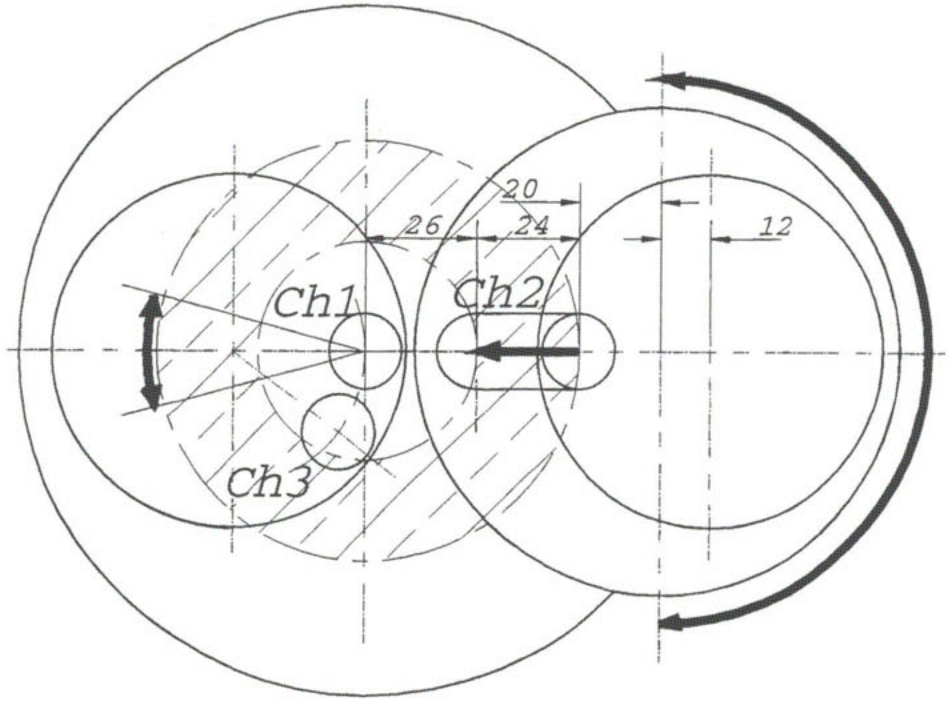

Fig. 3. The transverse-cross section of the TTCP photometer.

The main feature of the TTCP distinguishing it from the standard WET photometer (Kleinman et al. 1996) is that all three channels are parallel to the main axis of a telescope. Another specific feature is the way how a comparison star could be found and how its light could be conveyed to the second channel. Both features make the construction of the photometer rather complicated, but are advantageous by making the photometer less bulky and more convenient for the observer.

Fig. 3 represents the schematic cross-section perpendicular to the optical axis. Positions of all three channels as well as the directions and boundaries of the possible channel movement are shown. The allowance field around the target star, where the comparison star could be searched, is shown in Fig 3 as the hatched ring shaped zone.

5. ELECTRONICS OF THE PHOTOMETER

Fig. 4 shows the block-diagram of the photometer electronics is presented. The electronics is divided in two main parts: (1) the computer interface, counters and step-motor drivers and (2) the unit of power supplies.

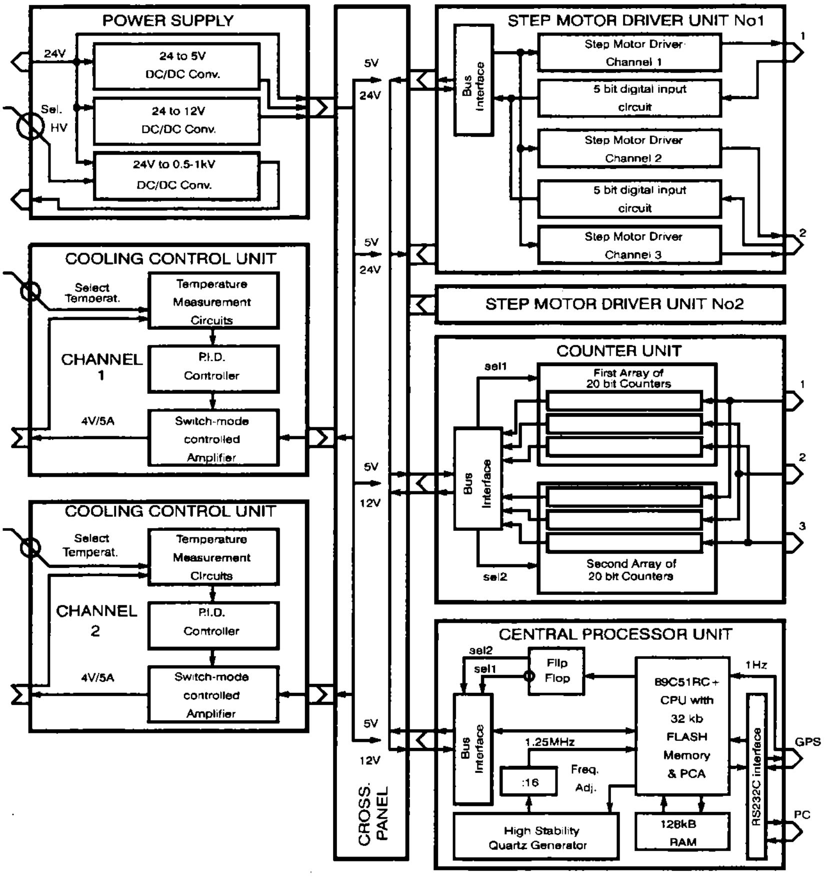

Fig. 4. The block-diagram of the TTCP electronics.

The computer interface consists of CPU unit, step-motor control unit and three-channel counter circuit.

The CPU unit includes the microprocessor of new generation of type P89C51R+ which has In-System Programmable FLASH memory of 32 kB for program and Programmable Counter Array (PCA) for the precise measurement of time. Resources of the microprocessor are extended by external RAM memory of 128 kB.

The CPU unit of the computer interface contains a voltage controlled OCXO type oscillator of 0.5 ppm thermal stability. The frequency of internal oscillator is continually adjusted by a microprocessor using 1 Hz signal from GPS. Thus the start time of every measurement is determined (referring to UTC) not worse than 2 μs, if a 1 Hz signal from GPS is assured.

Firmware is loaded from PC to RAM of the interface where it can be run, stopped and even modified using a monitor written into FLASH memory. The remaining part of RAM is used as a data storage buffer. Such architecture enables us to have in PC several versions of firmware as well as to add quite new firmware when necessary.

We use +24 V DC for the supply of the whole electronics. All other necessary voltages are generated in the power supply unit by DC-DC converters-stabilizers.

6. FIRMWARE

The concept of the interface design and data acquisition program is to use the computer program as a composition of the instructions which are accomplished by the interface at lower level. It allows us to avoid the use of large amount of interrupts and to get a higher speed of data acquisition and shorter integration times. Another difference of the interface from that used till now in the WET (Clemens 1993) is the use of different type and size messages in communication between the computer and interface. A very important feature of the interface, as well as of the firmware and software, is that every measurement is provided with marks of the accurate time.

When the computer interface is switched on, the loader, which is permanently written into CPU FLASH memory, starts to operate. It ensures that firmware is loaded from PC via RS 232 port to RAM of the interface. Firmware starts to work automatically after it is loaded.

After its start the firmware initializes all arrays, sets filter and diaphragm wheels and the prism into their initial positions and sends the report to PC about the interface and firmware readiness to execute a PC program.

After that the PC program communicating with firmware loads instructions indicating in what sequence the filter settings and what integration times should be executed.

The following step is to put a zero time value to the inner clock of the interface. This is achieved by synchronizing this zero time moment with the first 1 Hz pulse coming from GPS after this command.

Then the measurement can be started according to the command from PC. Starting from this moment, all processes of measurement are controlled by firmware. The firmware turns filter wheels, reads the content of counters and writes this content to the buffer, together with the information about the filter number and time when the measurement has started. The records can be sent to PC under request of the PC program.

All processes in the interface go parallelly, independently from one another. It is ensured by using the interrupts and estimating the priorities of each process.

The processes, which need minimal delay in their execution, such as the inner clocking and the commutation of counters, are executed by means of hardware means, using possibilities of PCA. Other processes are executed according to interrupts (starting from the one having the highest priority): (1) rotation of step-motors, (2) service of RS232C interface and (3) program service of PCA.

The processes which do not need a prompt reaction are executed in a background program operating when there are no interrupts: (1) adjustment of the inner oscillator if necessary, (2) interpretation and execution of the commands coming from PC, (3) rotation of the filter and diaphragm wheels in the process of adjustment.

7. SOFTWARE FACILITIES

The computer program for the data acquisition and for the control of the photometer AURIGA working in the WET observation mode is written in DOS Protected Mode environment. SI compiler DJGPP is used for this program.

The screen of the AURIGA's users interface is divided into widows. The main windows are as follows:

- window of the control panel,
- data window,
- CCD window and
- window of the data graphical display.

The graphical user's interface works in the SVGA mode. The program is controlled by a mouse or from a keyboard. The control of the photometer is executed by clicking the cursor on the necessary icon.

The observing parameters can be defined by a set menu called from the control panel. The observer can set parameters describing the run as well as the observing ones: numbers of channels, integration times at each filter and numbers of diaphragms.

The data window shows ten lines of current data: filter name, time elapsed from the start of the run and counting rates in the three channels.

The CCD window is used in the multicolor photometry mode for centering of a star in the diaphragm of the first channel. The program allows to edit CCD image of star and diaphragm and to center the star image into the diaphragm image by moving the telescope.

The size of the window for graphical display of light curves is 600×256 dots. Light curves of all channels and filters can be displayed using the symbols of different shape and color. The symbols for the each curve can be set in set menu. The light curves can be edited from the control panel.

The use of the DOS Protected Mode allows us to utilize all free space of the PC's HDD for the data storage. Data of each run are written in binary files and is converted into text file when program stops or is stopped. Data files have headers containing all information describing given run. Each measurement is provided with time marks.

8. PHOTOMETRIC SYSTEMS

Two sets of filters are designed for the TTCP photometer: one for the realization one of three medium-band photometric systems (*Vilnius*, *Strömgren* or *Strömvil*) (Straižys et al. 1996) and for the broad-band *UBVR* photometry. For the *Vilnius* system the following filters are used:

	U_V	P	X	Y	Z	V_V	S
λ_0, nm	345	374	405	466	516	544	656
$\Delta\lambda$, nm	30	26	22	26	21	26	20

Additional filters for the realization of the Strömgren *uvby*- β or Strömvil photometric systems are added to the set of the *Vilnius* system filters:

	v	β_w	β_n
λ_0, nm	411	487	486
$\Delta\lambda$, nm	19	18	3

The three filters are common for all three photometric systems $u = U_V, b = Y$ and $y = V_V$. Each filter wheel contains 10 positions. The filter wheels with the following filter sets can be used in the TTCP:

No.	1	2	3	4	5	6	7	8	9	10	Channel	System
1.	U	U	B	B	V	V			V^1	R	Ch1,3	*UBVR*
2.	U		B		V				V^1	R	Ch2	
3.	$U_V=u$	v	$Y=b$	$V_V=y$	β_w	β_n	P	X	Z	S	Ch1,3	*Vilnius, Strömgren, Strömvil*

For the WET observations, the bialkali (S11) photomultipliers Hamamatsu R647 in combination with *UBV* filters (or without filters) are used. For *UBVR, Vilnius, Strömgren* and *Strömvil* photometry, the multialkali (S20) PMTs of the Hamamatsu R1463 type should be used. Different *V* filters should be used for the work with bialkali and multialkali PMTs.

9. SPECIFICATIONS

The main specifications of the TTCP are as follows:

- number of channels (CH1, CH2 and CH3)	3
- distance between channels:	
CH1 and CH3	26 mm to 48 mm (7 arcs to 13 arcs for F = 13 m)
CH1 and CH2	20 mm (5.3 arcs for F = 13 m)
- possible deviation of the CH2	± 2 mm (0.5 arcs for F = 13 m)
- number of filter wheels	2 (for CH2 and for CH1+CH3)
number of filters in each filter wheel	10 in CH1(5 pairs in CH1+CH3)
diameter of filters	13 mm
- number of aperture wheels	2 (for CH2 and for CH1+CH3)
number of apertures in each wheel	10 in CH1 (5 pairs for CH1+CH3)
diameter of apertures	0.3 to 8.0 mm (5 arcs to 2 arcmin for F = 13 m)
- diameter of field eyepiece	40 mm (10.2 arcmin for F = 13 m)
- number of aperture microscopes	2 (for CH2 and for CH1+CH3)
magnification of microscopes	$25^{\times}$
diameter of the field of microscopes	8 mm (2 arcmin)
- number of Fabry lenses	3
diameter of Fabry lenses	14 mm
focus length of Fabry lenses	30 mm
diameter of outcoming pupil	2.5 mm
- time of the filter wheel turn to the	
to the neighboring position	0.08 s
over 5 positions	0.20 s
- spectral range and detectors	300 to 650 nm (PMT - R647P); 185 to 850 nm (PMT - R1463P)
- temperature of the PMTs	two stabilized temperatures: −5°C and −15°C which can be set depending on the environmental temperarture
- system of the PMT cooling	one stage thermoelectric cooler with actively ventilated heat absorber
- photometric systems	*UBVR*, *Strömgren*, *Vilnius* and *Ström Vil*
- detector operation mode	photon counting
dead time of photon counters	22 ± 2 ns
- accuracy of absolute timing	
using GPS	± 2 μs
using inner oscillator	± 25 ms per 12 hours
- communication between PC and interface	via RS232 port
data transfer rate	4.8 to 115.2 kbd
- power supply requirements:	
voltage	24 ± 1 V
consumption current	≤ 3.5 A
ripple	≤ 0.5 V, p-p
- dimensions of the photometer :	
height	410 ± 5 mm
max diameter (including microscopes)	210 ± 5 mm
max diameter of the main frame	140 ± 5 mm
- weight	31 kg

ACKNOWLEDGMENTS. This work would have not been possible without the contract No. 2457 between Vilnius University and Osservatorio Astronomico di Napoli Astronomical Observatory of Naples which have initiated this project. We are also thankful to Observatoire Midi Pyrenees and NATO Division of Scientific and Environmental Affairs for financial support which enabled us to take part in this workshop.

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