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Three-Channel General-Purpose Astrophotometer

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Abstract

The high-speed three-channel photometer suitable for the time-series observations of the "Whole Earth Telescope" (WET) project as well as for multicolor photometry is described. The photometer, designed for the Capodimonte Astronomical Observatory, Italy, is the latest version of the WET photometers developed by the WET group of Vilnius University since 1992. The main optical and mechanical layouts of the optico-mechanical module as well as the block-diagram of electronics are presented. The main specifications of the photometer expected after its completion are given.

1. Introduction

The "Whole Earth Telescope" project is a cooperative optical observing network for time-series photometry of rapid variable stars [1]. It acts as a multimirror ground-based telescope which uses a sequence of existing telescopes, distributed in longitude and coordinated from a single control center, to measure designated target stars by turns so long as they are in darkness for each site. This instrument is the first to provide data continuity and quality that permit true high-resolution power spectroscopy of pulsating white dwarf stars and other rapid variable stars. It is clear that the observing technique and instrumentation at all sites of the WET have to be as uniform as possible. The instrumental team of the Astronomical Observatory of Vilnius University, Lithuania, joined the WET in 1992. Our colleagues from the WET recognized this team to be useful in

developing of the photometric equipment for the WET. The technical experience and skill of our team in designing and manufacturing photometers was acquired during the last two decades, when we worked for the Soviet military and space industry. The main field of our activity in the WET is design and development of the photometric equipment for this project. In this work the attention is constantly given to the cost, size and reliability of the equipment, together with its technical specifications satisfying the WET requirements. We try to build the instrumentation which could be considered as a standard [2] for the WET, the worldwide astronomical observing network, and could be useful for any group of this network. Our first attempt within this field was to build a small amplifier-discriminator suitable for the WET photometers [3]. Only the tenth version of the amplifier-discriminator, named F 316, was accepted in 1995 as a standard component of the WET photometer [4]. Afterwards, our high voltage divider D 303 and computer interface CCLA were approved by the WET leaders. During the last three years, several components of the photometric instrumentation as well as complete photometers for the WET and other projects have been developed by the Vilnius team [5-7]. After a successful attempt in 1996-1997 to build three photometric channels for the existing two-channel photometer of the Suhora Astronomical Observatory, Poland, we started the designing and fabrication of the Vilnius type standard WET photometer, i.e. the one of our own design, but satisfying the strict requirements of the WET authorities [2]. The first copy of the latest version of the WET standard three-channel photometer is designed for the Capodimonte Astronomical Observatory in Italy. Bellow we will refer to it as TTCP (Toppo Three-Channel Photometer). The first copy of the photometer is intended to be built this year. Next year several copies of this type photometer should be built for the existing WET groups as well as for the new ones. We hope that it would be the last high-speed three-channel photometer of the classic type (using the photomultiplier as a detector) designed by our team. Actually CCDs are marching victoriously throughout the observatories, and we should pay attention to this device in our future designs of modern high-speed photometers. Despite that, we are sure that the classic photometers will still serve faithfully the astronomers the whole next decade or maybe longer. Such photometers are indispensable for investigation of rapid phenomena, especially in variable stars. On the other hand, it is too expensive to have three-channel high-speed photometer and to use it only for one or two WET observational runs, i.e. during ten or thirty days per year. Thus one of the purposes of the TTCP design was to make it as a general-purpose photometer (suitable not only for the WET). That is why the possibility to use the TTCP photometer for classical *UBVR* and multicolor intermediate-band photometry, such as *Stromgren*, *Vilnius* and *StromVil* [8], were considered during the course of designing.

2. Mechanical Construction and Optical Layout

In figures 1 and 2, two main cross sections of the TTCP optico-mechanical module are presented. As seen from the figures, all three channels of the photometer coincide with the telescope's main axis. The main measuring channel (first channel) is designed for

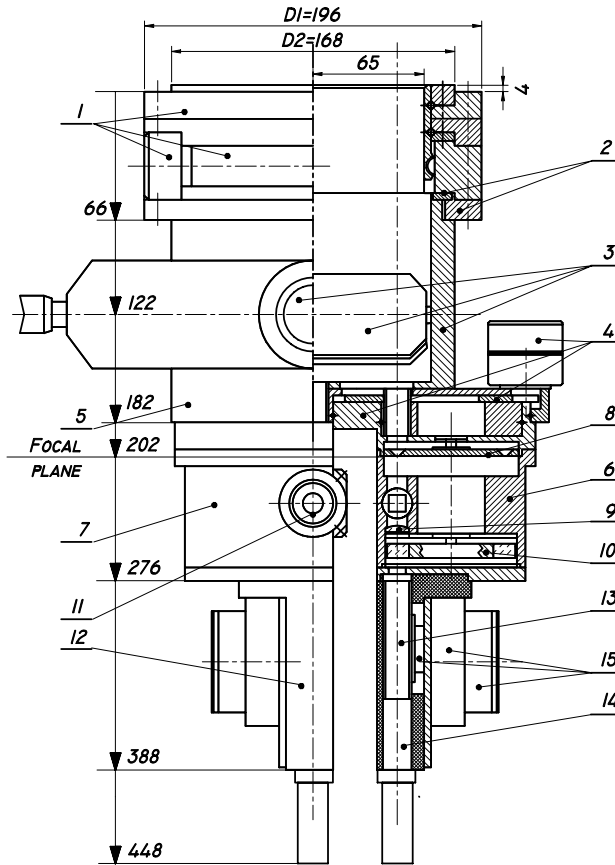


Figure 1. The longitudinal cross-section of the TTCP photometer

the light measurement of a target star, and the second one for the measurement of a comparison star. The latter can be moved and positioned in the ring field around the first channel (Fig.2). 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 optico-mechanical module of the TTCP consists of the following main units (fig.1): rotational bearing (1), centering unit (2), movable field eyepiece unit (3), second-channel movement unit (4), third-channel movement unit (5), one-beam (6) and two-beam (7) miniphotometers (miniphots) including aperture wheels (8), Fabry lenses (9), filter wheels (10) and microscopes (11), and photoelectrical head (12) including photomultiplier (PMT) (13), high voltage (HV) divider (14) and PMT cooler (15).

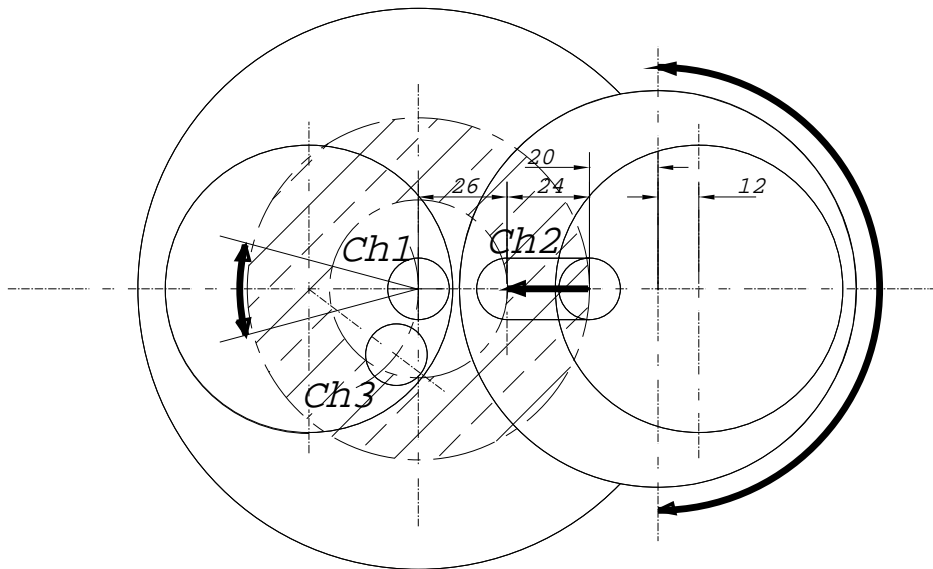


Figure 2. The transverse cross-section of the TTCP photometer

The rotational bearing is designed to rotate the whole photometer around the main axis of the telescope (target star). It enables to search out a comparison star, in combination with the radial movement of the second channel. The centering unit is necessary for adjustment purposes only. The unit of movable field eyepiece allows to survey the field around the target star as well as to search the comparison star by moving the field eyepiece in radial direction. The second-channel moving unit enables us to move it to intercept the light of a comparison star according to the field eyepiece position 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 to move the third channel to the 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, filter wheels, Fabri lenses and microscopes. 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 miniphot should contain the filters placed in pairs because the measurement of the target star and the sky is accomplished simultaneously through neighboring holes of the same filter wheel. Both photoelectric heads of the type FEG 310 [7] consist of PMTs, HV dividers and thermoelectric PMT coolers. The only difference is that one of them has two measuring

channels (first and third), while the second has only one (the second) channel. As one can see in Fig.1, the main feature of the TTCP, distinguishing it from the standard WET photometer [2] as well as from the "Pancake" photometer [9], is that all three channels are parallel to the main axis of the telescope. Another specific feature is the way how the 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 in making the photometer less bulky and more convenient for the observer. Fig.2 represents the schematic cross section perpendicular to that shown in Fig.1. In the Fig.2 the positions of all three channels as well as the directions and boundaries of possible channel movements are shown. The allowance field around the target star, where the comparison star could be searched, is shown in Fig.2 as the hatched ring shape zone.

3. Electronics of the Photometer

In Fig.3 the block-diagram of the photometer electronics is presented. The electronics is divided into two main parts: the computer interface with amplifier-discriminators, counters and step-motor drivers, and the unit of power supply. We suggest to use +24 V DC for the supply of the whole electronics. All necessary voltages will be generated in the power supply unit by DC-DC converters-stabilizers. We designed the unit of motor driver as a separate module with the possibility of further extension of the number of motors. The computer interface consists of CPU unit, timing circuit and three-channel counter circuit. The CPU unit includes two types of memories: FLASH and RAM. The use of a separate RAM chip is related with the data buffering necessity due to a comparatively large amount of data to be handled in short time. Timing circuit is designed for making use of exact time signals from the GPS (Global Positioning System) time source. We suggest to use a continuous correction for the frequency of the internal oscillator using a 1 Hz signal from GPS. As an internal oscillator, the OCXO type oscillator of 0,5 ppm thermal stability is used. 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 a large amount of interrupts and to get a higher speed of data acquisition and shorter integration times. Another difference of the interface designed by us from the one used till now in the WET [10] is the use of different type and different size messages in communication between the computer and interface. Also, all measurements will have the marks of the accurate time. To achieve a higher speed of communication between the computer and interface we use the combined communication interface. We use the RS232 port of a computer, and the same port is implemented in the interface card. However, the cable contains two communication interface converters: from RS232 to RS485/422 and the reverse one. It allows us to achieve the data transfer speed 115,2 kbps at the length of a twisted pair cable of 100 m and more. In this way we save the standard communication interface RS232 for the case of lower transfer rate or shorter distances.

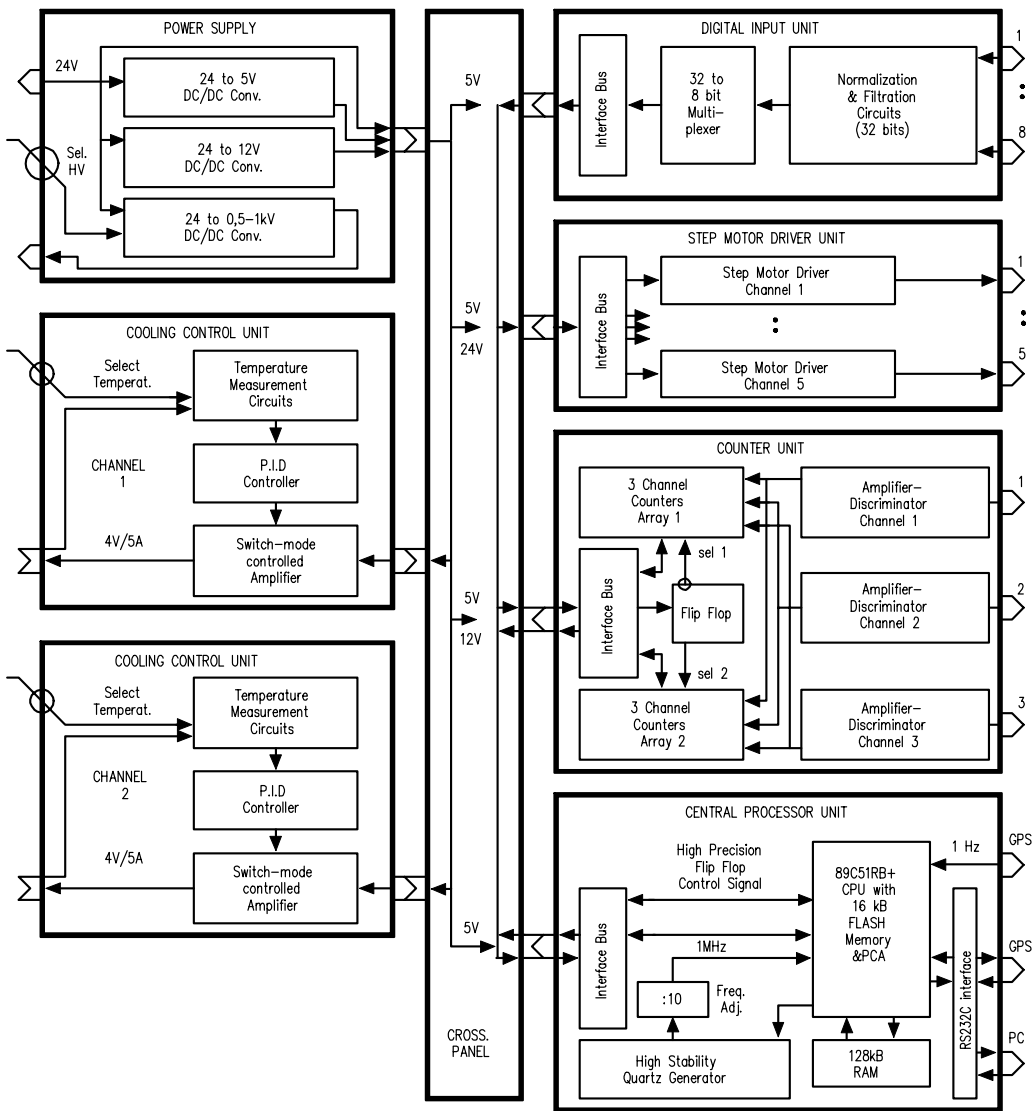


Figure 3. Block-diagram of the TTCP electronics

4. Main Specifications

The main specifications of the TTCP are the following:

-number of channels (CH1, CH2 and CH3)	3
-distance between the channels	
CH1 and CH2	26 mm to 50 mm (7 arcmin to 13 arcmin for F=13 m)
CH1 and CH3	20 mm (5,3 arcmin for F=13 m)
-possible deviation of CH3	± 2 mm (31 arcs for F=13 m)
-number of filter wheels	2 (for CH2 and for CH1+CH2)
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	0,3 to 8,0 mm (5 arcs to 2 arcmin for F=13m)
-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 aperture microscopes	25^X
diameter of the field of microscopes	8 mm (2 arcmin)
-number of Fabri lenses	3
diameter of Fabri lenses	14 mm
focus length of Fabri lenses	30 mm
diameter of outgoing pupil	2,5 mm
-spectral range	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 temperature
-system of the PMT cooling	one stage thermoelectric cooler with actively ventilated heat absorber
-dimensions of the photometer	
height	410 ± 5 mm
max diameter (including microscopes)	210 ± 5 mm
max diameter of the main frame	140 ± 5 mm

5. Photometric Systems of the TTCP

Two sets of the filters are designed for the TTCP photometer one for the realization of intermediate-band *Strom Vil* [8] and the other for wide-band *UBVR* photometry. For the *Vilnius* system the following filters will be used [11] (Table 1):

Table 1. Filters for the *Vilnius* system

	U_V	P	X	Y	Z	V_V	S
λ_0 , nm	350	374	405	466	516	544	656
$\Delta\lambda$, nm	30	26	22	26	21	26	20

Additional filters for the realization of the *Stromgren wby- β* photometric system (u , b , y correspond to U_V , Y , V_V , respectively) will be added to the set of the *Vilnius* system filters (Table 2):

Table 2. Additional filters to the *Vilnius* system for the realization of the *Stromgren wby- β* system

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

For the WET observations, the bialkali (S11) photomultipliers Hamamatsu R647, in combination with *UBV* filters (or without any filters), are usually used. It is evident that for *UBVR* and *StromVil* photometry the multialkali (S20) PMTs should be used. For this purpose the Hamamatsu R1463 PMTs are foreseen in the TTCP. Thus, two different sets of filters as well as two different types of PMTs will be used, combining them in dependence on the astronomical task chosen. The following filter wheels are foreseen in the TTCP (Table 3):

Table 3. The types of the TTCP filter wheels

	1	2	3	4	5	6	7	8	9	10	Channel	Set
1.	U	U	B	B	V	V	R	R	0	0	CH1,3	WET,
	U	B	V	R	0	0	0	0	0	0	CH2	<i>UBVR</i>
2.	$U_V = u$	P	X	$Y = b$	Z	$V_V = y$	S	ν	β_w	β_n	CH1,3	<i>Strom-</i>
	$U_V = u$	P	X	$Y = b$	Z	$V_V = y$	S	ν	β_w	β_n	CH2	<i>Vil</i>

For the WET observations the bialkali PMTs R647 and the set of *UBVR* filters will be used. For *UBVR* photometry (or only for the R band) the same set of *UBVR* filters with the multialkali PMTs R1463 would be necessary. For *Stromgren*, *Vilnius* or *StromVil* photometry, the set of *StromVil* filters and multialkali PMTs should be chosen.

6. Acknowledgments

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