Observatório Astronómico da Universidade do Porto
Monte da Virgem — Vila Nova de Gaia
PORTUGAL

Digital Recording of the Circle at the Oporto University Mirror Transit Circle

BY
R. S. DE SOUSA NUNES
AND
D. APPELT

PORTO
Imprensa Portuguesa
1968

Digital Recording of the Circle at the Oporto University Mirror Transit Circle

Observatório Astronómico da Universidade do Porto
Monte da Virgem — Vila Nova de Gaia
PORTUGAL

Digital Recording of the Circle at the Oporto University Mirror Transit Circle

BY
R. S. DE SOUSA NUNES
AND
D. APPELT

PORTO
Imprensa Portuguesa
1968

PUBLICAÇÕES DO
OBSERVATÓRIO ASTRONÓMICO
DA FACULDADE DE CIÊNCIAS DO PORTO

N.º 23

Extracto do fasc. 3.º do Volume LI
dos
«Anais da Faculdade de Ciências do Porto»

DIGITAL RECORDING OF THE CIRCLE AT THE OPORTO UNIVERSITY MIRROR TRANSIT CIRCLE

BY

R. S. DE SOUSA NUNES (*)

AND

D. APPELT

1. Introduction

The Mirror Transit Circle at Oporto was designed in 1953 (1) and since its installation it is being continuously improved (2), both in its mechanical and data readout aspects.

As far as latter is concerned, the most recent improvement consisted in the digitizing of the four micrometers (3) (one right ascension and one declination micrometer on each of the two collimators). The corresponding equipment, that was built by Hilger & Watts, London, was installed on late 1967.

Each micrometer digitizer consists of a mechanical digitizer, which accounts for the complete revolutions done by the micrometer, and an optical digitizer that enables a resolution of one thousandth of revolution. With a clock pulse occurring every 2 seconds a strobe of the micrometer position is taken, and the information coming from the chosen digitizer is fed into a central unit where it is amplified and properly decoded into a 5-digit decimal number giving the micrometer position. This decoded information is presented on an in-line display and simultaneously recorded on either a paper punch (8-channel) or a parallel printer.

(*) This work was carried out while the author held a schoolarship of the Instituto de Alta Cultura.

Together with this data, time information (seconds only) is also presented on each these output devices. A means is provided to record also a conventional star number containing as much as three digits.

Now a system is being developped to perform the automatic digital readout of the circle position. This paper gives a brief description of this new system and its operating.

2. Circle digitizing

As far as it is known to the authors, two methods for circle digitizing are being used. At the Copenhagen Observatory a photoelectric scanning of the circle divisions, together with some fixed reticle, is made (4). With this method, the circle position can be determined with a mean error less than 0.″03. Besides this high accuracy a high working capacity — at Copenhagen a circle reading can be performed in 16 seconds — is attainable (5).

At the U. S. Naval Observatory, Washington, an entirely new technique is used: the traditional graduated limb is substituted by an «inductosyn» (6). The inductosyn is an electromagnetical device which operates in a way similar to an electrical resolver (7). An accuracy of about 0.″04 is expected with this technique, which is about as twice as good as the photographic recording of the circles, which is still in use at this Observatory (8).

At the Oporto University Transit Circle a technique similar to that used at the Copenhagen Observatory will be used. As there are already installed two graduated circles, this solution is less expensive and in any case, taking the results obtained at Copenhagen as a base for previsions, the expected accuracy seems to be high enough.

The system will provide a convenient punched tape data recording in such a manner that this information carrier can be directly off-line fed into the Oporto University's NCR-Elliott 4100 computer, as it is already being done with data coming from the digitized micrometers.

3. The circles

The transit circle is provided with two 18 carat gold alloy graduated limbs, 660 mm in diameter, whose smallest divisions correspond to 5 minutes of arc. Only the East side circle will initially be digitized.

The circle observation is done by means of a set of four microscopes, mounted at 90° angles around the circle. On the ocular focal plane of each microscope there is a fixed vertical

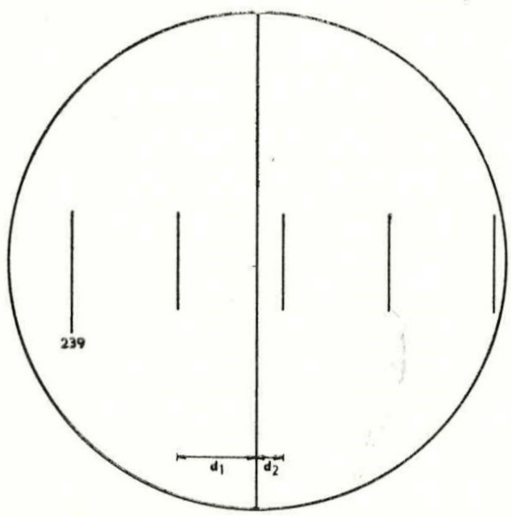

Fig. 1 — Schematic of microscope ocular field.

reticle wire. On looking through the microscope the image of this wire will be seen superimposed on the graduated circle's image (Fig. 1).

The circle is pointed (with an accuracy of about 2′) by means of a servo-system which is operated by a control-box installed at the end of either north and south collimator. A means will by provided by the servo-system in order to achieve that the reticle wire will always lay between the images of the circle divisions, i. e., never overlapping such an image.

With the equipment to be built, distances d_1 and d_2 (Fig. 1) will be measured in a digital way. Ignoring, for a moment, division errors, it should obviously be

$$d = d_1 + d_2 = 5'$$

The correspondent linear distance, on the circle plane, is

$$d = \frac{2\pi}{360} \times \frac{5}{60} \times \frac{660}{2} \times 10^3 = 480 \mu m$$

On the ocular focal plane this distance is about 1.5 mm. On this same plane the common trace width is about 1 mm.

Measurement of distances d_1 and d_2 will be achieved by counting the steps, done by a stepping motor, necessary to move an index from the trace next left to the reticle, up to the reticle wire (d_1) and from this one to its next right trace (d_2). This index will be realized by a .1 mm wide slit on a plate driven by the stepping motor. The circle will be illuminated by an illuminating system providing a high short time stability; the light passing through the slit will be received by a photomultiplier mounted behind the slit and rigidly coupled to the slit plate.

Every time this photomultiplier-slit plate assembly (PMSPA) passes over a trace on the microscope's ocular focal plane, there will be a decrease in light intensity through the slit, thence a decrease in photomultiplier output.

A begin travel and end travel switch will limit to 3.3 mm the total trip for the PMSPA. Each one of the four microscopes around the circle will be provided with such a photoelectric measuring assembly.

A measuring accuracy of at least .1″ will be required. Hence, between two successive circle divisions the stepping motor will have to perform at least

$$\frac{5' \times 60''}{.1''} = 3000 \text{ steps.}$$

Actually, as an interpolation on the number of steps will be done to find the minimum light intensity (thus corresponding to the trace center), the accuracy is expected to be better than .1″.

4. Basic operation

At the beginning of every measurement all PMSPAs will be at their extreme left position. Measurement begins by starting stepping motor movement.

Up to the moment when the slit reaches the beginning of the first trace, photomultiplier output will be high. On a plot of light intensity I versus stepping motor position N (Fig. 2), the corres-

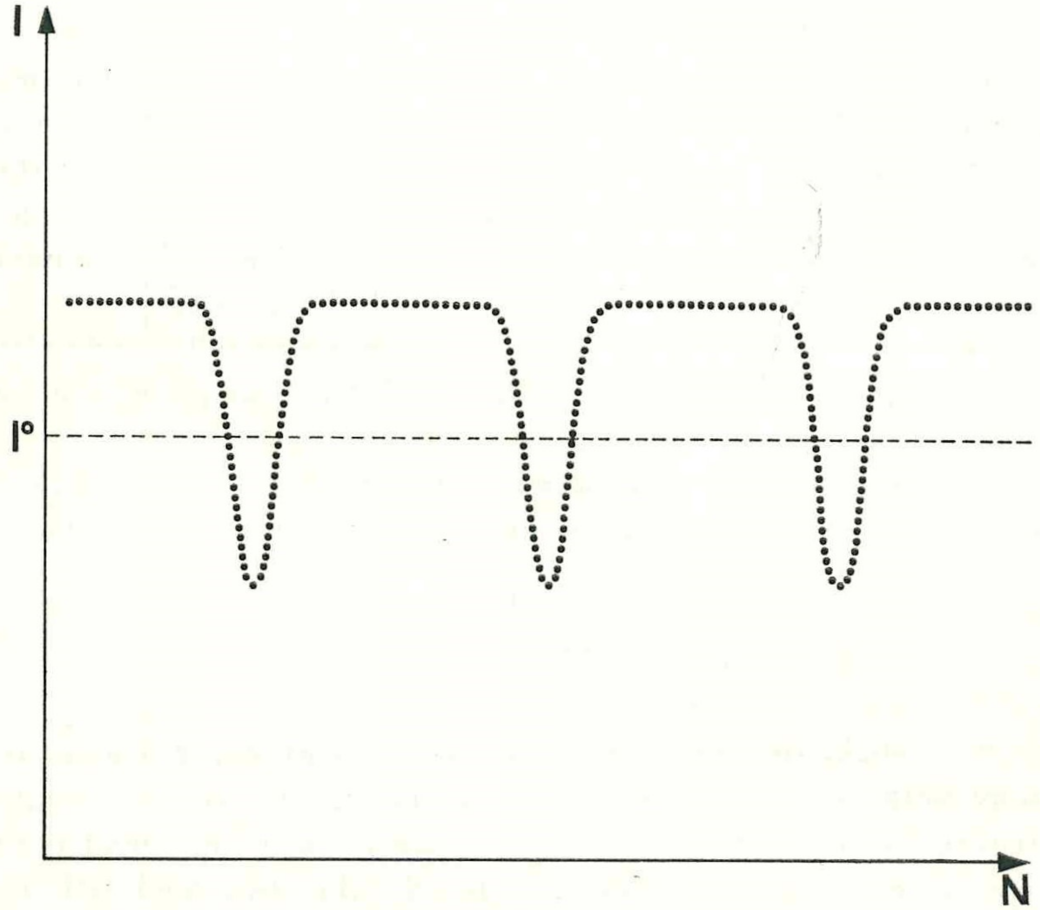

Fig. 2 — Photomultiplier output versus stepping motor position (schematic).

ponding points lay over a preset threshold I° and corresponding data will not be recorded. During all this time the stepping motor advances at full speed.

When in any of the four photomultipliers output for the first time becomes less or equal I°, data recording will begin. At this moment, a counter which accumulates the number of steps N done by any of the four steppinng motors from now on, is set to a given position (1000 for reasons of convenience) and will count all the following steps up to the end of the whole measuring procedure. On a paper tape punch, counter position N and the corresponding photomultiplier outputs I (for all the four photomultipliers, in the sequence 1-2-3-4) will be recorded, regardless of the output of the other three photomultipliers with respect to their I° thresholds.

Stepping motor movement will now be conveniently slowed down to allow full data recording.

From now on only photomultiplier outputs will be recorded (always in the same previously referred sequence) for every succeeding counter position N, up to the moment where for the first time on all four photomultipliers outputs become greater than the respective I° thresholds. For this situation only counter position will be recorded, for further control purposes.

Now the stepping motor will again advance at full speed up to the next trace, for which a similar recording procedure will be performed, as well as for the third trace.

Assuming a .1 mm trace width and that the 1.5 mm distance is covered by 3000 steps, full scanning of one trace will involve

$$\frac{.1}{1.5} \times 3000 = 200 \text{ steps.}$$

It is obviously useless to record such an excessive amount of points with the only purpose to interpolate the minimum light intensity. That is the reason why a means will be provided to preset a recording threshold I°. Usually this threshold will be expected to be set at a level that will give recording of 10 to 40 points.

For subsequent data handling, a convenient separation between recorded data will be provided by some additional characters, such as «carriage return», (R), and «line feed», (L).

5. Brief system description

Fig. 3 shows a simplified block diagram of the whole equipment. The logic unit controls the operating of the entire system. It receives information from the photomultipliers, deciding whether their outputs are higher or not than the I° thresholds, thus

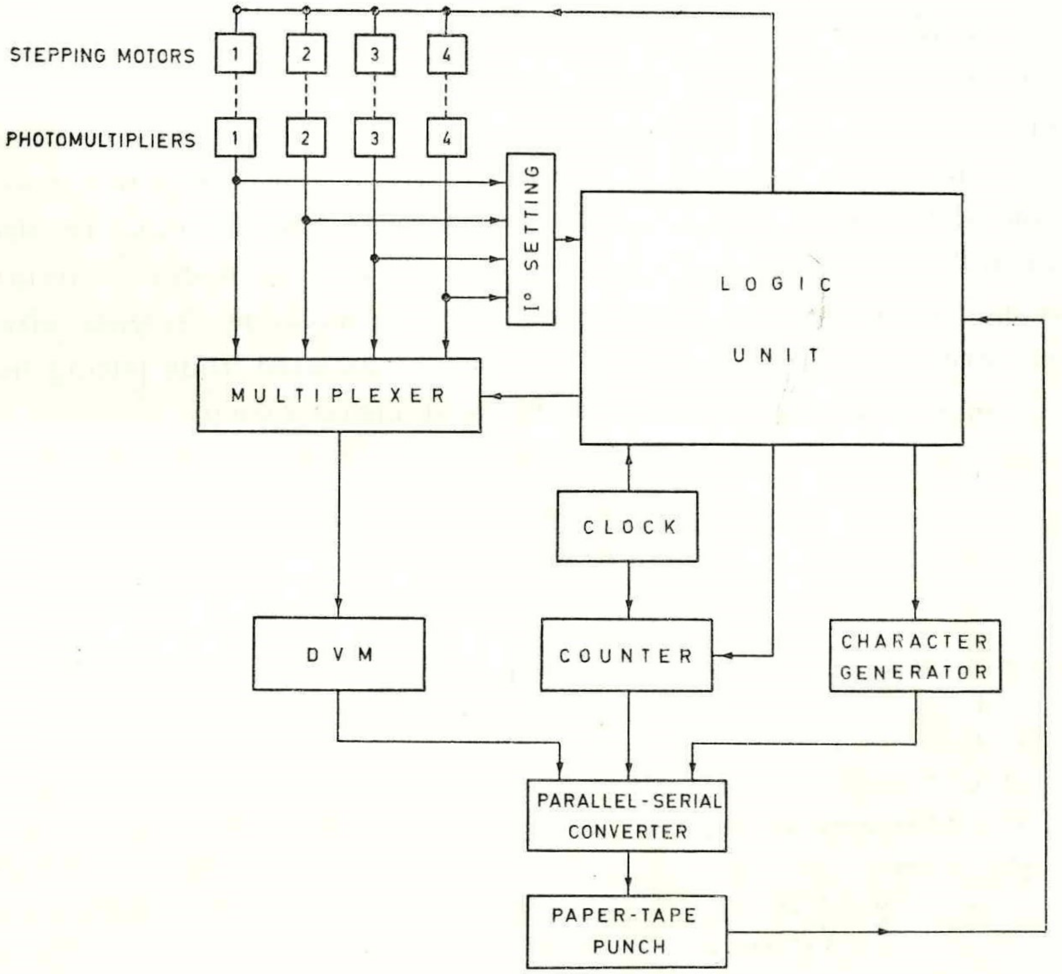

Fig. 3 — System block diagram.

deciding which kind of information shall be recorded: photomultiplier outputs only, counter position only, or both. It also receives a ready signal from the tape punch, thus providing a proper stepping motor speed during recording operation.

The outputs of the four photomultipliers, after amplification, are fed into a multiplexer unit, also controlled by the logic unit. The multiplexer chooses one of four photomultipliers, in the 1-2-3-4 sequence. The analog proportional signal from the multiplexer is fed into a digital voltmeter where analog-digital conversion takes place. The resulting digital information, together with the counter contents and any additional characters from a character generator, is brought into a parallel-serial converter that controls the paper tape punch.

As already stated, when data is not being recorded, the stepping motors move at full speed, the corresponding driving pulse repetition rate being determined by a clock. During data recording, stepping motor advance is controlled by a ready signal coming from the tape punch unit. These fast and slow motions are also controlled by the logic unit. This unit also provides a return of the four PMSPAs, by inverting stepping motor movements, after the entire measuring procedure has been completed, thus setting the system in a position ready for the next measurement.

REFERENCES

1 M. G. Pereira de Barros — O Circulo Meridiano da Faculdade de Ciências do Porto, *Publicações do Observatório Astronómico da Faculdade de Ciências do Porto,* n.º 7, Porto, 1957.

2 M. G. Pereira de Barros — The Mirror Transit Circle of Porto, *Publicações do Observatório Astronómico da Faculdade de Ciências do Porto,* n.º 16, Porto, 1964.

3 R. S. de Sousa Nunes — Digitização do Circulo Meridiano de Espelho do Observatório Astronómico da Faculdade de Ciências do Porto, *Publicações do Observatório Astronómico da Faculdade de Ciências do Porto,* n.º 21, Porto, 1966.

4 S. Laustsen — Development of Impersonal Transit Circle Methods, *Mat. Fys. Skr. Dan Vid. Selsk.,* **3**, n.° 3, 3, (1967).

5 S. Laustsen — Instrumental Developments and Results Obtained with the Copenhagen Transit Circle at Brorfelde, *Copenhagen University Observatory,* August 1967.

6 B. L. Klock — Instrumentation Program for an Improved Transit Circle at the U. S. Naval Observatory, *Astronomical Journal,* **72**, n.° 5, 559 (June 1967). Presented at the *Star Catalogues Conference,* held at the University of Maryland, 3-5 October 1966.

7 Inductosyn — Principles and Applications, *Farrand Controls Inc.,* Valhala, N. Y., U. S. A.

8 C. B. Watts — Description of the Six-Inch Transit Circle, *Publications of the U. S. Naval Observatory,* Second Series, vol. XVI, part II, Washington, 1950.

PUBLICAÇÕES DO

OBSERVATÓRIO ASTRONÓMICO DA FACULDADE DE CIÊNCIAS DO PORTO

1 — *As Coordenadas do Observatório da Serra do Pilar*, por M. G. Pereira de Barros, 1944, 14 págs.

2 — *Dispositivos para Movimento Mecânico dum Micrómetro Impessoal*, por M. G. Pereira de Barros, 1944, 14 págs.

3 — *Um Aparelho para Determinação da Equação Pessoal nas Observações Meridianas de Hora*, por M. G. Pereira de Barros, 1944, 10 págs.

4 — *Sobre o Projecto do Observatório Astronómico da Faculdade de Ciências do Porto*, por M. G. Pereira de Barros, 8 págs.

5 — *Registo Fotográfico das Observações Meridianas*, por M. G. Pereira de Barros, 1944, 62 págs.

6 — *Micro-Indicador Eléctrico*, por R. S. de Sousa Nunes, 1957, 4 págs.

7 — *O Círculo Meridiano da Faculdade de Ciências do Porto*, por M. G. Pereira de Barros, 1957, 94 págs.

8 — *A Conservação da Hora no Observatório da Faculdade de Ciências da Universidade do Porto*, por R. S. de Sousa Nunes, 1958, 220 págs.

9 — *Unidade Visual para Recepção de Sinais Horários*, por R. S. de Sousa Nunes, 1959, 12 págs.

10 — *Cronógrafo Magneto-Digital*, por R. S. de Sousa Nunes, 1959, 16 págs.

11 — *Small Transit Instrument Without Pivot Errors*, por M. G. Pereira de Barros, 1959, 4 págs.

12 — *Estudo da Variação da Colimação num Instrumento de Passagens*, por Maria José Couto Galhano, 1960, 8 págs.

13 — *A Teoria do Instrumento de Passagens*, por M. G. Pereira de Barros, 1960, 124 págs.

14 — *On the Flexure of a Transit Instrument*, por M. G. Pereira de Barros, 1960, 4 págs.

15 — *Estudo dos Erros dos Passos dos Parafusos dos Micrómetros do Círculo Meridiano*, por M. F. Soares Barbosa, 1964, 12 págs.

16 — *The Mirror Transit Circle of Porto*, por M. G. Pereira de Barros, 1964, 8 págs.

17 — *Os Satélites Artificiais em Geodesia*, por José Pereira Osório, 1964, 98 págs.

18 — *Transit Instrument Without Pivot Errors*, por M. G. Pereira de Barros, 1965, 8 págs.

19 — *The Evaluation of the Geopotential*, por José Pereira Osório, 1965, 18 págs.

20 — *Sectorial Harmonics of the Earth's Gravitational Potential*, por José Pereira Osório, 1965, 3 págs.

21 — *Digitização do Círculo Meridiano de Espelho do Observatório Faculdade de Ciências do Porto*, por Rogério S. S. Nunes, 196

22 — *Results of observations of latitude at Monte da Virgem*, por M. e R. A. Vieira, 1968, 28 págs.

23 — *Digital Recording of the Circle at the Oporto University Mirro* por R. S. de Sousa Nunes e D. Appelt, 1968 9 págs.