Computer Controlled Pulse Counting Photometry

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I wish to present some aspects of a computer controlled pulse counting system for general photoelectric photometry.

The pulse counting technique applied in astronomical photoelectric photometry has yielded significant improvements as to telescope efficiency, especially in connection with the measurement of very faint light sources. This is achieved through the advantages inherent in the pulse counting technique over the conventional charge technique, that is:

(i) ability to discriminate effectively against several of the sources contributing to the dark current (or dark pulses, if you prefer to say that);

(ii) perfect linear integration over unlimited time intervals in counting fundamental events;

(iii) optimizing the procedure of collecting information facilitated by applying statistical control of the data;

(iv) perfect (time-) gating or manipulation of the signal which is a train of pulses. This is of the utmost importance for chopping or scanning photometers (*e.g.* area scanners) or for any kind of photometer dealing with a quickly varying light signal.

At the Copenhagen University Observatory we have acquired pulse amplifiers and discriminators from Solid State Radiations Inc. in California. So far they have performed completely satisfactorily.

In addition to a pulse amplifier and discriminator, a pulse counting system usually incorporates an electronic counter, a special purpose programming unit and timer, besides a complete digital data acquisition system.

We found that the total cost of such a system would be comparable with that of a small on-line computer equipped with a proper interface (for handling the information from a binary counter etc.). And I stress that when talking about a small on-line computer I mean one having 4K memory of 12 bits. The on-line computer, besides being very useful for the data acquisition task, enables the full utilization of the advantages of the pulse counting technique, especially with reference to the enhanced telescope efficiency due to an optimum data collection procedure as mentioned earlier.

It may be worth while to outline the basic philosophy behind the concept of "optimizing the data collecting task".

Pulse counting photometry is concerned with the determination of a time average of the repetition frequency of fundamental events, the events being the arrival of photons which have succeeded in causing charge pulses above a given magnitude at the anode of the photomultiplier.

This time average of the pulse repetition frequency, $\bar{f}$, is given by

$$\bar{f} = \lim_{T\to\infty} \frac{N}{T}$$

where N is the total number of pulses counted during the counting (or integration) time, T.

For reasonably high values of N, $\sigma_N = \sqrt{N}$, *i.e.* the relative standard deviation is

$$\frac{\sigma_N}{N} = \frac{1}{\sqrt{N}}$$

which is therefore controlled by N itself.

Consequently by proper programming of the computer, the computer itself may:

(i) compare the actual spread in repeated measurements with the statistical spread just derived, so that the quality of the observation can be evaluated;

(ii) carry out integration to a certain total count which is preset from the computer, so that a constant statistical spread and optimum integration time is obtained;

(iii) carry out multiple short integrations of given durations or of given total counts, in which case the results and the spreads of the individual integrations may be compared and if desired "bad measurements" could be rejected.

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One very considerable advantage of the on-line computer is that semi-reductions of the observations may be carried out instantaneously. Hence astronomically relevant data can be presented for the observer. Thereby the photoelectric observations will no longer be a tedious data taking job, but a task where you right away have a good feeling with your observations and you may take important decisions at the telescope as to whether to repeat a measurement, stop observing a variable star, or any other decisions concerning the continuation of the observations. Also this fact will increase the efficiency of the telescope considerably, since with traditional methods after days of reduction work it might be concluded that one should just have carried on taking a few more points of the light curve of a variable star, or that one has spent useless observing time because the weather or the equipment had caused the observations to be of too low quality.

Figure 1 shows a block-diagram of the computer controlled pulse counting system.

The main units are:

Pulse amplifier and pulse height discriminator. These are the commercial SSR units. Between the amplifier and discriminator a variable attenuator is inserted, since the threshold level of the discriminator is preset by the manufacturer and not easily changeable.

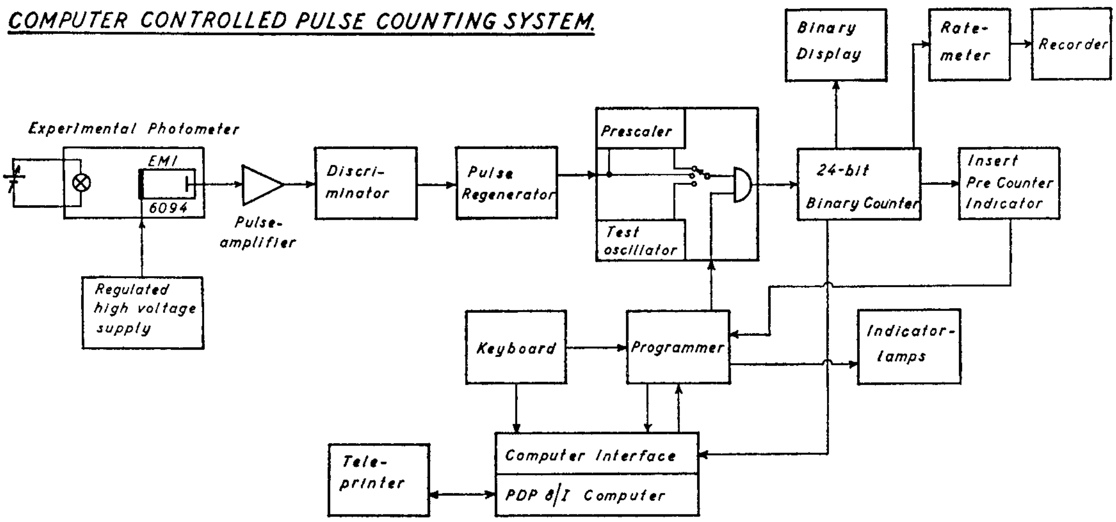

Fig. 1

The pulse regenerator receives the pulses transmitted from the discriminator which is located at the telescope via a rather long 50 ohm coaxial cable, and it transforms the pulses to TTL logic levels.

A 50 MHz prescaler is normally bypassed, but in case of very high pulse rates it is inserted under computer control.

The main counter is a 24-bit binary counter having a binary display unit.

A ratemeter generates an analogue signal for a normal strip chart recorder. Thereby the observer will not lose his feeling of contact with the observations, as he has the analogue display exactly as for the d.c. amplifier method. It is of the utmost importance that the observer should have confidence in his measurement and his equipment.

All logic functions for the programmer etc. are issued by the computer interface. This unit also takes care of the timing and data taking and finally also of the observer-computer communication.

At present the computer controlled pulse counting system is used in conjunction with an experimental photometer. The experiments so far have been very successful.

Soon, when the programming of the computer is complete, photoelectric observations will be initiated on one of the observatory's photoelectric telescopes in Denmark. Later we may wish to utilize the equipment at a telescope at the ESO observatory in Chile.

DISCUSSION

J. Tinbergen: I am puzzled by your cost estimates. We built a five-channel system for the price of just your PDP8 without peripherals. The computer system is much more flexible, I agree; but I would estimate the capital outlay as two or three times higher for the computer controlled system.

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R. F. NIELSEN: The costs were comparable, for the pulse-counting equipment together with the data-acquisition system required for the pulse-counting set-up. I agree with you that analogue systems can be built cheaper, but still I don't think there is such a large difference in cost that it would be worth while saving perhaps 30 per cent of the price and having the hard-wired, inflexible system.

J. TINBERGEN: I still think it would be more like a factor of two or three.

G. J. CARPENTER: What is the bandwidth of the discriminator and pulse-counting circuits?

R. F. NIELSEN: It is 40 or 50 MHz.

G. B. WELLGATE: I should like to stress the importance of a monitor on which one can see what is actually happening at the time. I should also like to point out that usually you would have one more knob to twiddle in order to get the gain of the monitor right. It's important to make this automatic if at all possible. My first photometer, which had just ordinary analogue recording, had an extra knob; with the exception of Dr. Stoy and myself, nobody ever used it!

E. W. DENNISON: Would you describe the sidereal clock?

R. F. NIELSEN: It works from the observatory system. We rely on the external 50 Hz sidereal signal which we convert into 10 pulses per sidereal second, and then we are actually using a software clock. This is only for the time of day; for determining the integration time there is an internal crystal-controlled clock, not having such good accuracy as the one on the observatory time-line.

W. LILLER: In these days of tight budgets, I should note that a circuit diagram has been published (S. A. Miller, *Rev. scient. Instrum.*, **39,** 1923, 1968) for a pulse counting unit that can be built for \$50. Employing integrated circuits, the unit amplifies, discriminates, and supplies uniform pulses to a standard \$500 counter. You can really make quite inexpensive pulse-counters, which I have found far better, particularly for faint sources, than current integrators.

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