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Evaluation of effectiveness of the Photometer in Nightglow at Firuzkuh

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Abstract

This work was carried out at the Global Atmospheric Watch Station Mountain 20 km away from Tehran. A photometer designed to change a filter on a short time scale is described. This device is simple, compact and has proved to be very reliable. Evaluation of the photometer indicates that photometric data can be obtained on many nights ordinarily considered unsuitable for photometry due to broken cloud.

Keywords: *Instrumentation, Photometry, Rapid filter change, Polarizer.*

1. Introduction

Popular science Magazines 2005 & Fernie 1972 have pointed out that a rapid filter change photometer may be used in eastern North American observatory sites which typically have weather conditions only just adequate for carrying out a program of photoelectric photometry. The high thin cirrus or broken cloud cover gives a moderate but highly variable atmospheric extinction which make accurate photometry impossible by conventional means, J. Min, 1988. A technique which would make nights with such conditions useful for at least some forms of photometry would clearly be welcome.

A multipurpose instrument capable of filter changes on a short time scale has been described by National and International Science 2005. An obvious first step is to restrict photometric programs to intermediate or narrowband systems and especially to zero baseline color indices such as HB. For zero baseline indices the only atmospheric component of the photometric error is transparency variation at the effective wave length of the filters. This variation occurs at all frequencies, but is most apparent on a timescale of several tens of seconds. Since this is the same time scale on which filters are changed in conventional photometry, this component of the transparency variation has a great effect. An obvious way to lessen this effect is to shorten the period of filter changing by a factor of ten. A multipurpose instrument capable of filter changes was used by chandras 2005 in a sun tracker device.

2. Instrumentation

The rapid filter change photometer is a single-channel photon-counting photometer, ***Figure 1***. It was designed to do simultaneous measurement of two zero baseline colors, but it would be suitable for uvby photometry as well. The work has been carried out at Firuzkuh mountain (52°342, 45°342) at a height of 3000m above mean sea level, 20 km away from Tehran city. Associated with each one of four filters is one channel in a four-channel scaler used to record the pulses due to photons arriving through the filter. The four filters are mounted in a filter wheel so that the filter can be changed every few seconds.

Figure 1 shows the operation of the RFC photometer. Pulses from the photo lube are pre-amplified, divided by two and gated into the control unit. This unit controls the position of the filter wheel & sends the pulses to the appropriate scaler channel. Approximately every three seconds the control unit inhibits counting for about 0.25 sec., advances the counting address, and initiates a train of pulses which drives the stepping motor, bringing the next filter into place. The dead time of about 8% could be reduced to less than 3% by building an acceleration circuit for the pulse-train generator, but at a change time of three seconds such additional complexity does not seem justified. For efficient operation at one second, however, such a circuit would be necessary. The scaler provides five columns of BCD storage. This provides sufficient accuracy as long as the range in counting rates through the four filters is less than about a factor of 100

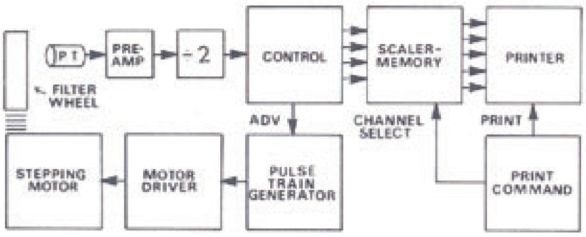

Figure 1. Block diagram of the photometer electronics.

After each filter has been in place ten times, the control unit goes into the off state. A print sequence which steps through the memory channels and activates the printer is manually started. To avoid possible data loss due to a printer malfunction the memory is manually erased.

Instead of using longer integration times for fainter stars, a larger number of standard length integrations are used. Although this reduces operating efficiency somewhat, it avoids the possibility of a chance disturbance destroying a large amount of data. Pre amplification is don with the circuit described by Taylor,1972 Masheshwari, 2006 and Crecraft, 2000. The circuit was chosen because it needs only a t15 volt power supply, a voltage which is also used by the STM 1800. Pulse resolution is as good as or better than that obtained by Taylor, while the output pulses are slightly less than +3 volts.

Extensive use is made of an integrated circuit, 74121, which is a mono-stable oscillator. The operation of this circuit is symbolically depicted in ***Figure 2***, A is assumed high & B is assumed low, the symbol t represents the duration of the Q pulse. This device will trigger on either a positive-going or negative-going edge if the other trigger input is in the appropriate state. The pulse width is adjusted by means of a timing capacitor and resistor. The width shows a slight variation with the operating temperature but is stable otherwise.

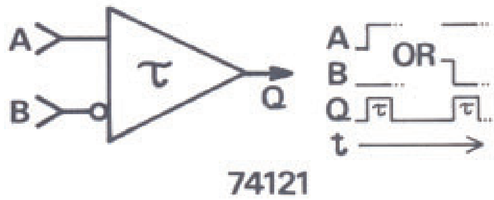

Figure 2. Operation of mono stable oscillator.

Operation of control unit is shown in ***Figure 3***, SW allows the photometer to be used on a conventional time scale; it is shown in the RFC position. The incoming START pulse sets the ON signal to the high state; the rising edge of the ON signal start the loop of three 74121 oscillating with a period of three seconds. The output pulses of the third 74121 are used to advance the channel address and step the motor. The channel is selected by a pair of J-K flip-flops used in the toggle mode. When the ON signal at the flip-flops is low, Q is held low; when the ON signal is high, each negative going edge at the CP input causes Q and Q to invert

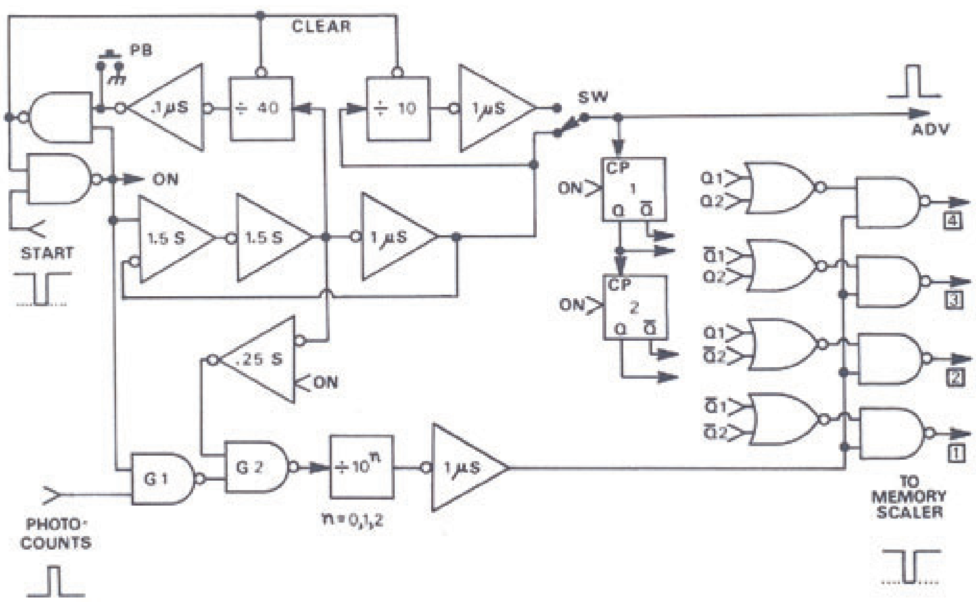

Figure 3. The control unit.

states. The outputs of the two flip-flop are read by four NOR gates which in turn activate one of the NAND gates, allowing the photo counts to pass on to the appropriate channel.(Brimicombe 2000).

When the ON signal is high, the photo counts can pass through G1 to G2. Since the other input to G2 is normally high the photo counts can continue through ˜ 10n circuit and pass out through the appropriate NAND gate. The same negative edge which triggers ADV also triggers a 0.25-second low input at G2, thereby inhibiting counting while the filter wheel is moving. The divided 40 scaler counts the oscillations and shuts the unit off after 40 ADV pulses have been produced. when power is initially turned on, the unit will be stuck in the ON state with the oscillator off. This condition is remedied by activating PB, which puts the unit in the OFF state. The two 1.5-second 74121s cannot be replaced by a single three-second 74121 because this integrated circuit will not perform properly at the virtually 100% duty cycle that would result.

Figure 4 shows the scaler memory. Each vertical sequence of five 7490s counts & holds a five-digit number. Manually produced positive pulses clear the array of 7490s. Each horizontal sequence of four 7454s reads the outputs of the 7490s for the selected channel, producing a four-line BCD output for the printer.(Pittet 2005)

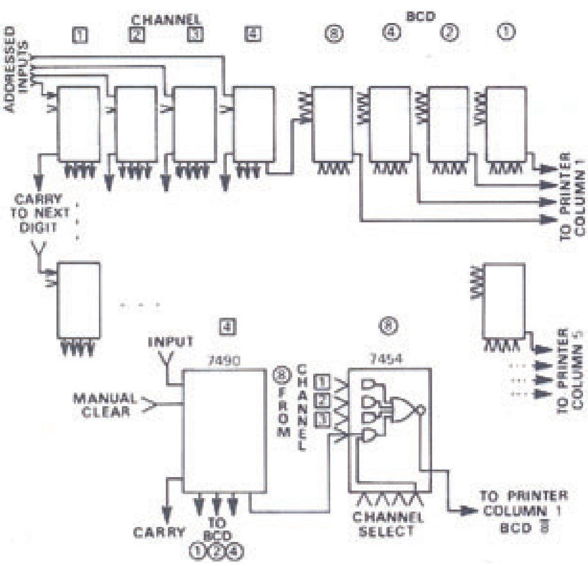

Figure 4. The scaler memory.

The printout control is shown in ***Figure 5***; the second set of NAND gates are 7437 buffers needed because of the large fan-out in the scaler memory. A manually produced start pulse initiates a sequence of four PRINT

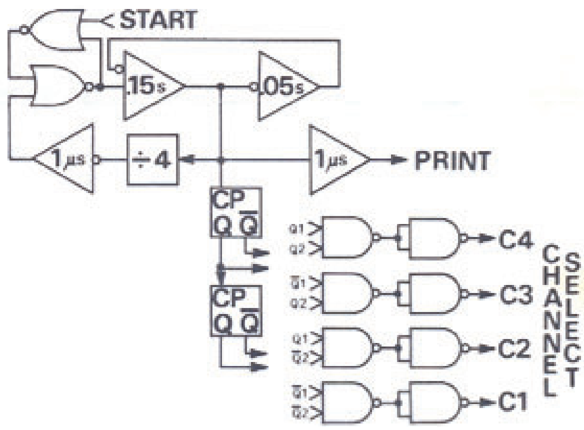

Figure 5. *The printout command unit.*

commands while a pair of toggle flip-flops steps through the four channels. ***Figure 6*** shows the simple pulse-train generator. SI offers a choice of steps commanded by the ADV signal or manually; S2 allows the step motor to be incremented by 1.8° manually, S3 allows the stepping to be suppressed; all switches are shown in their normal operating positions; M.P is a manually activated single pulse. Several switches are included to allow the various modes of operation needed to initially align the filters on the optical axis. Normally the ADV signal initiates a string of 50 pulses which trigger the STM 1800. Probably the simplest acceleration circuit would be obtained by shortening the pulse width of the 74121s from 2.5ms to 0.75ms, changing the ÷50 to ÷60 and using the bit outputs and a set of gates to suppress pulses 1, 2, 4, 5, 7, 54, 56, 57, 59, and 60 Electronic book 2004.The mechanical photometer, showed in ***Figure 7a*** & ***b*** (Payamara 2010), was built in Shahed University. The body of the photometer is cylindrical, facilitating construction by minimizing the number of joints to be machined. A pair of power resistors is mounted on the thick plate to warm the filters; the temperature is monitored by means of the resistor. This work was carried out at the Global Atmospheric Watch Station Mountain, 20 km away from Tehran. An f/15 beam is about 1.5cm in diameter at the filters.

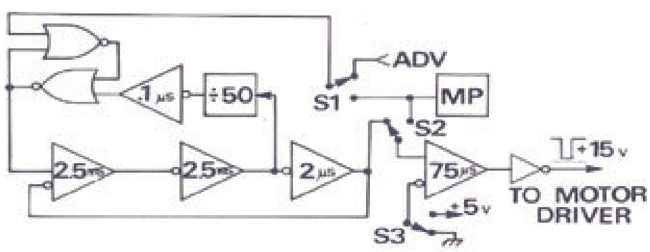

Figure 6. *The simple pulse-train generator.*

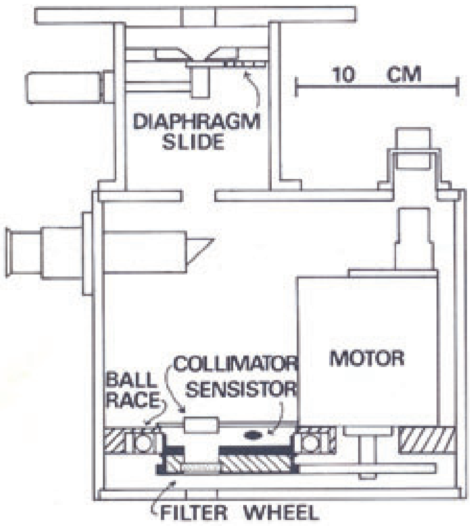

Figure 7a. *The RFC photometer.*

Figure 7b. *Experimental arrangement.*

All electronic logic and power supplies are mounted on one 13.208cm and one 17.79cm standard rack panel; the preamplifier is mounted on the cold box. The advantages of the compact and simple design are well demonstrated by the device. The device has been used on the 61cm telescope. (National & International Patent Databases 2005 and J.Payamara 2010)

3. Mathematical Method

The most straightforward method of evaluating the effectiveness of the RFC photometer in reducing the effect of atmospheric transparency variations is to make both conventional & RFC photometric measurements of the same star in a zero baseline color index. This method was used to evaluate the photometry on two nights having greatly different conditions.

On the first night, which appeared to be cloudless, γ lyrae was measured through two filters of about 20 °A and 160°A half width centered on the G-band. An index I≡2.5 log [count (WIDE) / count (NARROW)] + k was found with the constant chosen to make (I) near zero for γ Lyr. The star was measured 16 times alternating conventional and RFC photometry, and the standard deviation, σ, calculated for each set of eight measurements. The result for the conventional measurements was σ=0.004 and for the RFC measurements the value was σ=0.003.

4. Results

The results serve to reinforce the visual impression that the first night was of photometric quality and also demonstrate that the RFC equipment introduces no new source of noise into the photometry.

An obviously poor night was chosen for the second evaluation of the RFC photometer. As above, conventional photometry was altemated with RFC photometry. After twelve of these measurements had been made, the sky clouded over heavily and observation had to be suspended. About an hour later the sky cleared sufficiently for observation to be resumed and 16 more measurement were made. During the time in which observations were made, the extinction was estimated to be varying between about one and two magnitudes. The counting rate varies by about 10%-20% between measurements taken about five minutes apart.

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The results of all measurements are summarized in ***Table 1***. No account has been taken of shot noise, which was in fact less than 0.001 for all measurements. Because of the arbitrary zero point comparison of value of I from the first night to those obtained on the second is not meaningful; comparison within each night is, however, significant. The reduction of σ is RFC as compared to conventional photometry is about a factor of six. More to the point, the second night was entirely unsuitable for conventional photometry but gave quite usable results with RFC photometry.

TABLE 1. Comparison of photometric results obtained using conventional and RFC Photometry.

	Conventional		RFC	
Night	I	σ	I	σ
1	-0.001	0.004	-0.002	0.003
2 (a)	+0.010	0.021	-0.001	0.003
2 (b)	-0.029	0.013	-0.001	0.008

The RFC photometer was also used to obtain uνby photometry of the variable star. Estimates of the fluctuation in y, (u-ν), and (b-y) were obtained by comparing successive measurements (two minutes apart) of these quantities. Any variations in the star during this time should be negligible. The shot noise is not negligible, however, so the ratio of the fluctuation to the calculated shot noise was taken, considering as significant only ratio of 1.5 or greater. These values are given in ***Table 2***.

TABLE 2. The ratio of fluctuation to shot noise in uνby-photometry.

Color	Night 1	Night 1	Night 1
Y	1.07	4.0	2.6
u - ν.	1.08	-	2.0
ν - b	-	1.5	-
b - y	-	-	-

Conclusion

Although all three nights appeared to be of good quality, the count rates on the second night were about 25% lower than those on the first & third nights. It thus appears that although the second night was of significantly poorer quality, based on lower count rates and larger fluctuations in y, the measurements of (u-ν), (ν-b) and (b-y) were not significantly degraded. The actual value of the fluctuation in (ν-b) on the second night, i.e., the mean error of a single observation, was 0.010. The calculated shot noise for (ν-b) was 0.0065.

The number of additional nights that would be usable through use of RFC photometry depends, of course, on local weather patterns.

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