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FAST PRE-AMPLIFIER DESIGNED FOR SEMIAUTOMATIC TWILIGHT PHOTOMETER

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ABSTRACT
Fast Pre-amplifier is designed for Semiautomatic twilight photometer, used for aerosol measurements over Kolhapur (16°42′N, 74°14′E). This amplifier is designed and developed by connecting 10 single IC amplifiers in parallel. The efficiency of the system is increased by adopting multiple pre-amplifier configuration which improves signal to noise ratio by factor of 10 and this fact is responsible for measuring low level intensity by photometer. Therefore the duration of operation of the system has been increased to 90 min as compared to 45 min obtained by earlier system. As a result the system now can yield a reasonable qualitative picture of the vertical distribution of aerosols from about 6 km to a maximum of 350 km. Some noticeable features of the Fast Pre-amplifier are high speed, high gain, high slew tare and low noise etc. Thus the sensitivity of the system is improved a lot.

KEY WORDS: Fast Pre-amplifier**,** high gain, low noise, sensitivity

INTRODUCTION

The output signal (current) of the PMT (9658B), used for detecting the light intensity during the twilight period, is very low. It is of the order of nano to microamperes. The amplitude or strength of this low signal is amplified by using newly designed **fast pre-amplifier** during this study. The amplification is so high that the amplified signal can be easily recorded with a digital multlimeter. A single IC amplifier is used in the earlier setup of photometer used by earlier workers (Patil *et al.,* 2003, Shah (1969, 1970), Jadhav and Londhe (1992), Nigut *et.al.* (1999). However, during the course of this study the system is suitably modified to improve the sensitivity of the system.

In case of single-IC amplifier the dark current of the PMT and over all internal noise of the system also gets amplified along with the signal. For series combination of amplifiers the gain is increased but the white noise also gets increases. Hence to keep the noise at a minimum level and to improve the Signal to Noise ratio, an attempt is made to modify the Fast Pre-amplifier. The amplifier is designed and developed by connecting 10 single IC amplifiers in parallel. In this system the noise at the output signal of each amplifier not being in phase with the other amplifier signal, a random noise is generated. Therefore total sum of internal noise of produced by all IC's approaches nearer to zero. Thus keeping noise at minimum level (near about zero) we get amplified signal.

The fast pre-amplifier circuit

In this amplifier 10 single-IC amplifiers are connected in parallel. Each amplifier is built by using IC-356. It is a FET input type IC. The FET has high input impedance and low noise level. Off-set current of this IC is 10pA, which is very small than the output single of PMT (which is of the order of 1nA to 1μA). Output from PMT is given to positive Input (pin no.-3) of the IC. Thus positive configuration is used. For very small input current, the output can goes to saturation. To avoid this high resistance of the order of 1MΩ is connected in between the Input and ground. Negative output of this IC is connected to ground. The outputs of all these amplifiers are added by using the summer circuit. The summer circuit is built by using IC OP-07. The offset voltage of this IC is about 10 to 20μV. The signal to noise rato of the system is 100 compare to other similar systems due to random property of noise. After adding ten times, noise is reduced by 10 tines however the signal is added ten times. The amplifier output recorded varies from 1V to 10V depending upon the twilight intensity.

While selecting and designing the Fast Pre-amplifier the following characteristics are considered.

i. Infinite open loop gain and infinite bandwidth.
ii. Infinite differential and common mode input impedance.
iii. Zero output impedance.
iv. Infinite common mode rejection ratio.
v. Zero input offset voltage and bias current.

The circuit schematic of the Fast Pre-amplifier is shown in the figure-1and its photograph in figure-2. In this circuit the non-inverting amplifiers are connected in parallel at first stage. This stage is a current to voltage converter. The second stage is voltage amplification, which is summing inverting amplifier. The third stage is an inverting amplifier.

Circuit Analysis

The direction of PMT output current is in opposite to electron flow. The output current of the PMT is of the order of 1nA to 1μA. So the first stage of the Fast Pre-amplifier is current to voltage converter and second stage is voltage amplifier.

The equation of current to voltage converter is derived as follows:

$$V_{o1} = \left(1 + \frac{RF_1}{R_1}\right) I_{in}$$

$$V_{o1} = \frac{I_{in}}{R_1} (R_1 + RF_1) \quad \ldots\ldots (1)$$

Here V_{o1} is output voltage of single stage amplifier. Ten such single stage amplifiers are connected in parallel. The outputs of all these amplifiers are added further by summing inverting amplifier. Thus output of summing amplifier is given by,

$$V_o = -\frac{RF_2}{R_2} (V_{o1} + V_{o2} + V_{03} + \cdots + V_{010}) \quad \ldots\ldots (2)$$

Thus, $V_o = -10 V_{o1} \frac{RF_2}{R_2}$ ..... (3)

Therefore $V_o = -10 (\frac{RF_2}{R_2})[\frac{I_{in}}{R_1} (R_1 + RF_1)]$

$$V_o = 10\, I_{in} \frac{RF_2}{R_2} (RF_1 + R_1) \quad \ldots\ldots (4)$$

'I_{in}' is in the range of 1nA to 1μA and if we want V_o is in the range 1V to 10V, then we can calculate the resistor values. Suppose RF1 = RF_2 = 10KΩ and if R_1 = 1KΩ, then R_2 = 1.1KΩ.

At the input of the amplifier 30pF capacitor is internally connected.

By connecting 10MΩ resistance, from input to ground the RC time constant is reduced to,

$Rc\ time\ constant = external\ resistance \times input\ capacitance$

$= 10M\Omega \times \times 30pF$

$= 10 \times 10^6 \times 30 \times 10^{-12}$

$= 300 \times 10^{-6}$

$= 300\, \mu\, sec.$ ..... (5)

In this way low noise amplification is possible.

RESULTS AND DISCUSSION

All the earlier workers reported the vertical distribution of aerosols from about 6 km to a maximum of 120 km. In the present work, newly designed Fast-Preamplifier is used in the Semiautomatic twilight photometer, used for aerosol measurements over Kolhapur (16.41°N 74.13°E). The efficiency of the system is increased by adopting multiple pre-amplifier configuration which improves signal to noise ratio by factor of 10 and this fact is responsible for measuring low level intensity by photometer. Therefore the duration of operation of the system has been increased to 90 min as compared to 45 min obtained by earlier system. As a result the system now can yield a reasonable qualitative picture of the vertical distribution of aerosols from about 6 km to a maximum of 350 km. This gives an opportunity to monitor the aerosols not only up to stratospheric levels but also at the mesospheric and thermospheric levels. Thus the sensitivity of the system is improved a lot.

One of the main advantages of the semiautomatic twilight photometer is improvement in height resolution. This is achieved due to high rate of sampling, as data is stored for every 10secs, as compared to 30secs in earlier system. The height resolution is .03Km, 0.15Km, 0.29, 0.51Km, 0.76Km, and 0.91 Km for 6Km, 10Km, 20Km, 50Km, 100KLm, 150Km respectively. Due to this improvement in height resolution, the small fine-scale features, which are not visible in the profiles derived by earlier workers, are visible in the profiles derived in the present study.

SUMMARY AND CONCLUSIONS

Some noticeable features of the Fast Pre-amplifier are,

I. Augmented efficiency of the system
II. Improvement in height resolution
III. Increased duration of operation of the system
IV. Visibility of the small fine-scale features in the profiles derived by this system
V. A lot of upgrading in the sensitivity of the system
VI. Amplified Signal to noise ratio
VII. Drastically reduction in the white noise of the system

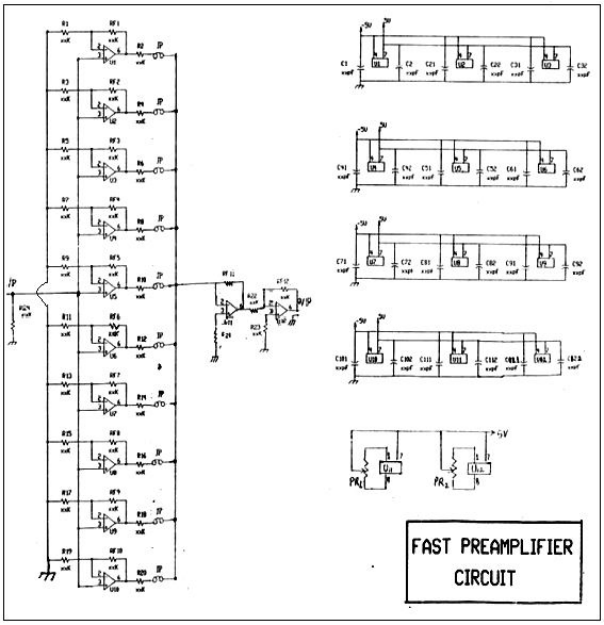

Figure 1. The circuit schematic of the Fast Pre-amplifier

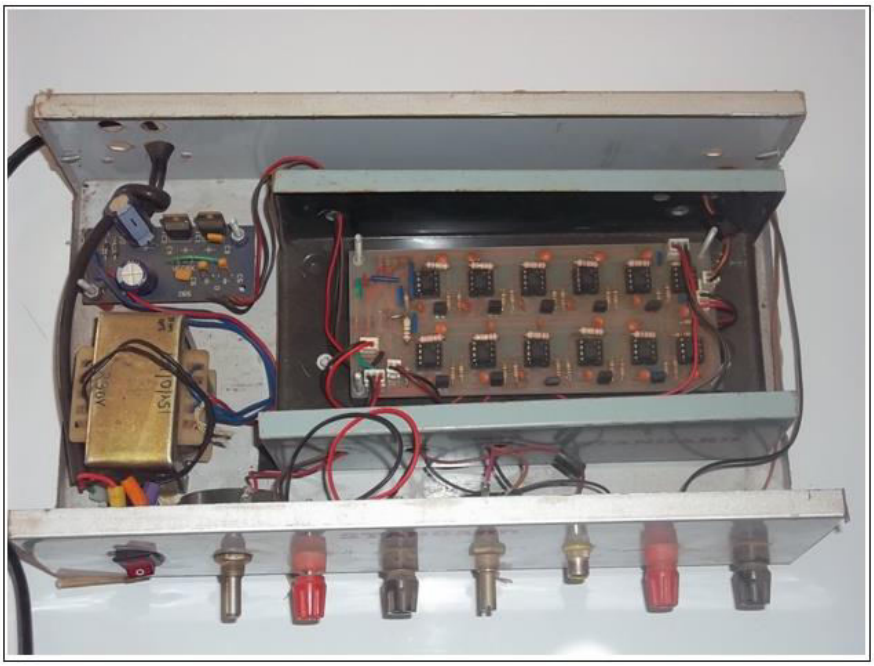

Figure 2. Photograph of the Fast Pre-amplifier

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