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TECHNICAL NOTE

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DATA ACQUISITION SYSTEM FOR A PRESSURE SCANNED PHOTOELECTRIC FABRY-PAROT SPECTROMETER

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Abstract:-

The pressure scanned photoelectric Fabry-Perot spectrometer is a high resolution instrument used for spectroscopic observations of astronomical objects. This technical note describes the data acquisition and recording system for this type of Fabry-Perot spectrometer. This instrument was used at the Cassegrain focus of 1 meter telescopes at Kavalur and Nainital, India.

Introduction

A data acquisition system has been developed for a pressure scanned photoelectric Fabry-Perot Spectrometer which can be used at Cassegrain focus of a large telescope for the velocity field and spectral measurements on planetary nebulae. These measurements are made by obtaining line profiles through scanning various emission lines from the sources. A Fabry-Perot spectrometer is used in the pressure scanned mode and both the signal in terms of photon counts and Fabry-Perot Etalon chamber pressure in terms of pressure counts are recorded on digital printer. After reducing these numbers to corresponding intensity and wavelength forms, one can plot the complete line profile for a selected wavelength.

Instrument:

Figure 1 shows schematically the spectrometer together with the data acquisition system. Light flux from an astronomical source falls on the primary mirror of the 1 m telescope and after reflections from primary and secondary mirrors, it gets collected at the Cassegrain focus. This f/13 light beam, after passing through an aperture, a collimating lens and a tunable filter, falls on to the Fabry Perot parallel plates placed inside a Fabry-Perot etalon chamber. Due to the multiple reflections inside the two parallel plates, an interference fringe pattern is generated. The central fringe is passed through an aperture and then focussed by an achromatic lens on to the photocathode of a photomultiplier tube.

The photomultiplier tube used in this system is ITT FW-130 type from M/s Electro-optical Products Division, USA. This is a special purpose 16 stage multiplier phototube having S-20 spectral response and restricted sensitive area of 0.1 inch dia. It has a high photoelectron counting efficiency of greater than 80% and low dark current of 2×10^{-9} A at 5×10^{6} gain and hence more suitable for photon counting applications. Output photoelectron pulses from the photomultiplier are given to the pulse amplifier discriminator circuit as explained later in the electronics system description.

Scanning through a line profile is achieved by changing the pressure inside the Fabry-Perot chamber filled with Freon-12 gas, permitting scanning range of about 4 Å/atm. The Fabry-Perot etalon is placed inside this chamber and the pressure in the chamber is varied in steps (0.7 mm Hg every 2 seconds) by means of a piston-cylinder unit. The step-wise motion of the piston inside the cylinder is achieved with the help of a geneva gear drive coupled to a 1440 RPM continuously driven synchronous motor. A microswitch has been mounted near the piston shaft which is closed at the end of each step movement for a few milliseconds, by a cam mounted on the piston shaft itself. This micro-switch pulse is used to synchronise the complete electronics system operation as explained later.

The pressure inside the F.P. etalon chamber is monitored by means of a pressure transducer type 590 Barocel from M/s Datametrics, Inc., USA. This pressure sensor provides highly accurate, repeatable and reliable pressure measurement over a wide range of 1000 Torr (mm Hg) and converts it into an output signal of 0 to ± 10 Volts DC, floating. It has a transient response of 8 milliseconds and provides an accuracy of about 0.1 Torr with a repeatability of 0.01% of the reading. The D.C. voltage output of the pressure transducer is fed through a differential amplifier to a voltage to frequency converter in order to get pressure readings in terms of digital data as pressure counts.

Electronics System

The complete electronics data acquisition system consists of the following subsystems:

i) Charge Sensitive Pulse Preamplifier Discriminator
ii) Photon Counter
iii) Differential Amplifier
iv) Voltage to Frequency Converter
v) Pressure Counter
vi) Digital Multiplexer
vii) Digital Printer.

The interconnections between these subsystems are as shown in the Fig. 1. The functioning of each subsystem is as described below:

i) Charge Sensitive Pulse Preamplifier Discriminator:

The photoelectron output pulses from the anode of the photomultiplier tube are amplified by a charge sensitive pulse preamplifier and subsequently discriminated against background noise level by a discriminator circuit. For this purpose, an integrated hybrid charge sensitive preamplifier, discriminator and pulse shaper, Model A-101 PAD of M/s Amptek Inc., USA, has been used. This has a nominal threshold referred to the input of 1.6×10^{-13} coulomb, equivalent to 10^{6} electrons, with a RMS noise level less than 0.4% of the threshold. The output is available in the form of TTL level pulses of 220 ns nominal pulse width with a typical rise time of 6 ns and fall time of 20 ns. The maximum count rate can go upto 4×10^{6} counts/second giving pulse pair resolution of 250 ns. A small circular printed circuit board carrying this 12 pin PAD integrated circuit was mounted directly behind the photomultiplier tube in the same housing so as to avoid noise and pick up problems. A 10 turn potentiometer was also mounted inside the same housing in order to set accurately the desired threshold level.

ii) Photon Counter:

The TTL level pulses from the pulse preamplifier discriminator circuit are counted for an integration period of 1 second in a 6 digit Binary Coded Decimal (BCD) counter. This counter employs a piezoelectric crystal of 1 MHz forming a basis for a stable 1 MHz crystal clock generator. The clock frequency has been divided down to 1 pulse per second (1 PPS) with the help of three numbers of dual decade counters type 74390. This 1 PPS with the help of gating circuitry (7402), Flip-Flop (7473) and monoshots (74121 and 74123) forms a gate period of 1 second for integration of photon counts and pressure counts.

Input photon count pulses are passed through input gate (7400) to 6 digit BCD counter using TIL-307 integrated circuits, which have built in BCD counters, latches, decoders, drivers and 7 segment LED displays also. Thus, the photon counts are made available in parallel BCD form for display and recording purpose as shown in Fig. 2.

iii) Differential Amplifier:

The output of the pressure transducer is a floating 0 to $\pm$ 10 V DC voltage corresponding to a differential change of pressure of 1000 Torr (mm Hg). When the pressure inside the Fabry-Perot etalon chamber is increased by the moving piston, the output of the pressure transducer increases, say from 0 volts towards + 10 volts and vice versa. Sometimes while this pressure is coming back to normal chamber pressure, the transducer output may undershoot below 0 volts towards negative side. In order not to loose these pressure readings, a polarity change over switch with an LED indicator has been provided alongwith the differential amplifier. A FET input operational amplifier Type 740 has been used in unity gain differential configuration which gives single ended output of 0 to 10 volts.

iv) Voltage to Frequency Converter:

The analog output of the pressure transducer after passing-through the differential amplifier has been converted into digital form by a voltage to frequency converter type 4705 of M/s Teledyne Philbrick, USA. This low drift V/F converter has a wide operating range of 1 Hz to 1.05 MHz corresponding to 0 to 10 V input voltage, with 0.01% linearity, giving equivalent resolution more than 14 bits. The output of this V to F converter is TTL level pulses which can be directly fed to the pressure counter.

v) Pressure Counter:

The pressure counter circuitry is exactly similar to the photon counter. Here the pulses output from the voltage to frequency converter are passed on through an input gate to a 6 digit BCD counter using integrated circuits TIL 307, similar to photon counter. The input gate is opened for a counting period of 1 second by the same source which controls the input gate of the photon counter. Hence, the counting of photon counts and pressure counts, as well as latching of the counts on the respective BCD latches in TIL 307 integrated circuits, in both the counters is done d simultaneously. Thus, the Fabry-Perot etalon chamber pressure which is converted from analog voltage into corresponding digital values by V to F converter is available in parallel BCD form for display as shown in Fig. 2 and can be further processed for recording purpose.

vi) Digital Multiplexer:

The limitations of the digital printer used in this experiment was that it could not print more than maximum 8 digits in a single line. The lab-testing with this Deltronix printer showed that whenever we tried to print more than 8 digits in parallel columns, it was either not printing at all or misprinting. This is probably due to the load exerted by number of hammers on the drum at a time and thereby on the motor due to which it slows down and looses the synchronization. This restricted the design of the recording system to have 6 digits of photon counts and 6 digits of pressure counts in two separate lines, instead of in a single line of 12 digits, although both the 6 digits data are acquired simultaneously. Thus, to print these two data lines one after another on the digital printer, they were required to be multiplexed and passed on to the printer at different times with the help of separate subsequent print commands. For this multiplexing purpose, 74157, Quadruple 2 line to 1 line data selector/multiplexer integrated circuits are used as shown in the Fig. 4. These data multiplexer chips have two sets, each of 4 line inputs A and B and 4 line outputs, being selected by a single select line. Depending upon the logic level on the select line, inputs A or B will be passed on to the corresponding output lines.

vii) Digital Printer:

The digital printer used in this experiment was of rotating drum type, Model 2002 from M/s Deltronix Ltd., Bombay. This has a printing speed of maximum 3 lines/second and upto 18 columns including 0 to 9 numerals and some special characters. The printer provides timing and reset signals and accepts parallel BCD data, alongwith the print command through an interface, which was developed earlier.

OPERATION

The detail electronics circuit schematic of photon/pressure counters is as shown in Figure 3. The complete electronics system is synchronised by a pulse derived from the microswitch fitted on the piston drive system. This microswitch gives out a pulse on every revolution of the piston shaft, at the interval of 1.5 seconds, both in the forward and reverse motion of the piston. Upon the arrival of this pulse which is fed to the input of 74123 in the "EXT" position, both the photon and pressure counters are resetted and a delay of 0.5 seconds is given by one of the monoshots of 74123 as shown, before integration of photons and pressure counts gets started. This delay is desirable for the stabilization of pressure in the F.P. Etalon chamber, after each step of piston movement.

The photon and pressure counts are counted simultaneously in two separate 6 digit BCD counters for an integration period of 1 second and then they are latched by a latch pulse, at the same time, on to two separate 6 digit latches, as well as displayed in the same integrated circuits viz. TIL 307-7 segment displays alongwith counter, latch and decoder driver functions. This latch pulse has been derived from the other monoshot of the same 74123, which is triggered by the trailing edge at the Q output of J K flip flop 7473. Thus, 6 digits of photon counts and 6 digits of pressure counts are simultaneously available in parallel BCD form for data recording.

Now, to print these 6 digit photon counts and 6 digits pressure counts in subsequent lines on the digital printer, we have to generate two distinct print command pulses, synchronous with the corresponding 6 digit data. This has been achieved with the help of 6 Nos. of 74157 Quadruple 2-line-to-1-line data selectors/multiplexers, a monoshot 74123 and an AND gate 7408, as shown in the circuit schematic of Digital Multiplexer, Fig. No.4. The 'latch' pulse which transfers photon and pressure counts data on the respective latches, has been utilised to trigger one of the monoshot of I. C. 74123. This monoshot gives a delay of 0.5 seconds before triggering the other monoshot of the same I. C. 74123. The $\overline{Q}$ output of this monoshot and the basic 'latch' pulses are passed through an 'AND' gate IC 7408, to generate two distinct 'print commands'.

The 6 digit photon counts A1 B1 C1 D1, A2 B2 C2 D2 ...... and the 6 digit pressure counts P1 Q1 R1 S1, P2 Q2 R2 S2 .... are connected to the respective A and B input lines of the corresponding multiplexer I. Cs. 74157 and the multiplexed 6 digit parallel data outputs, viz: W1 X1 Y1 Z1, W2 X2 Y2 Z2, ... are passed on to the digital printer. The common 'input select' line of these multiplexers is connected to the Q output of the 1st monoshot of I. C. 74123. As shown in the timing diagram of Fig. 5, when the 'latch' pulse arrives, the Q output of the monoshot or the 'select' line of the multiplexers is at logic 'Low' level and hence the photon counts are selected and printed on the digital printer by the same 'latch' pulse serving as the first print command. Now the 'select' line of the multiplexers goes to 'HIGH' level and hence the pressure counts are selected, when the other print command arrives after 0.5 seconds as explained earlier these pressure counts are printed in the next line on the digital printer.

CONCLUSION

The data acquisition and recording system for the Fabry-Perot spectrometer has been developed and used to record photon and pressure counts in two separate lines of 6 digits each, on the digital printer. This limitation of printing two separate lines for a single data point can be avoided, in future, with the help of better printers available recently in the market, e.g. EPSON Model 350, 360 or 720.

ACKNOWLEDGEMENTS

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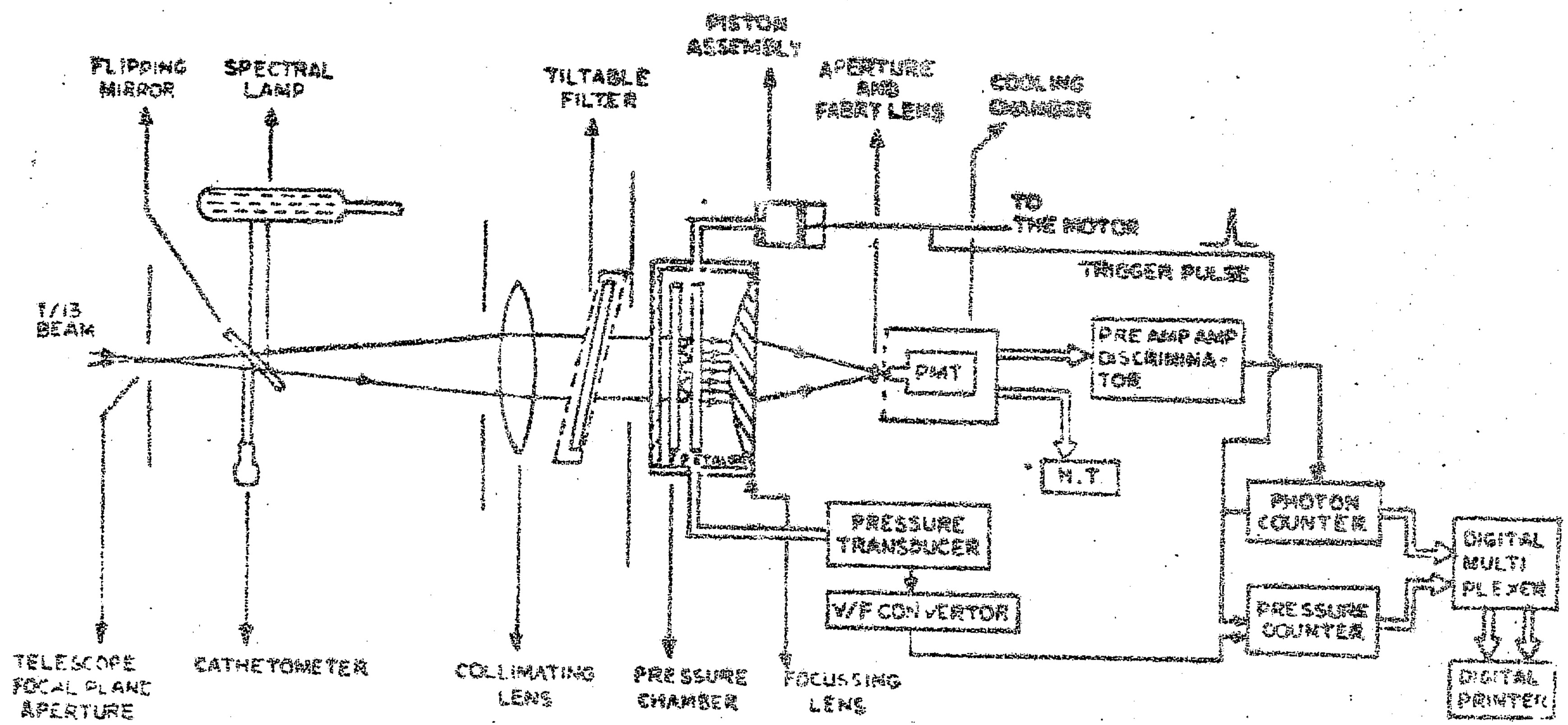


FIG. 1. SCHEMATIC LAYOUT OF THE PHOTOELECTRIC PRESSURE SCANNED FABRY-PEROT SPECTROMETER.

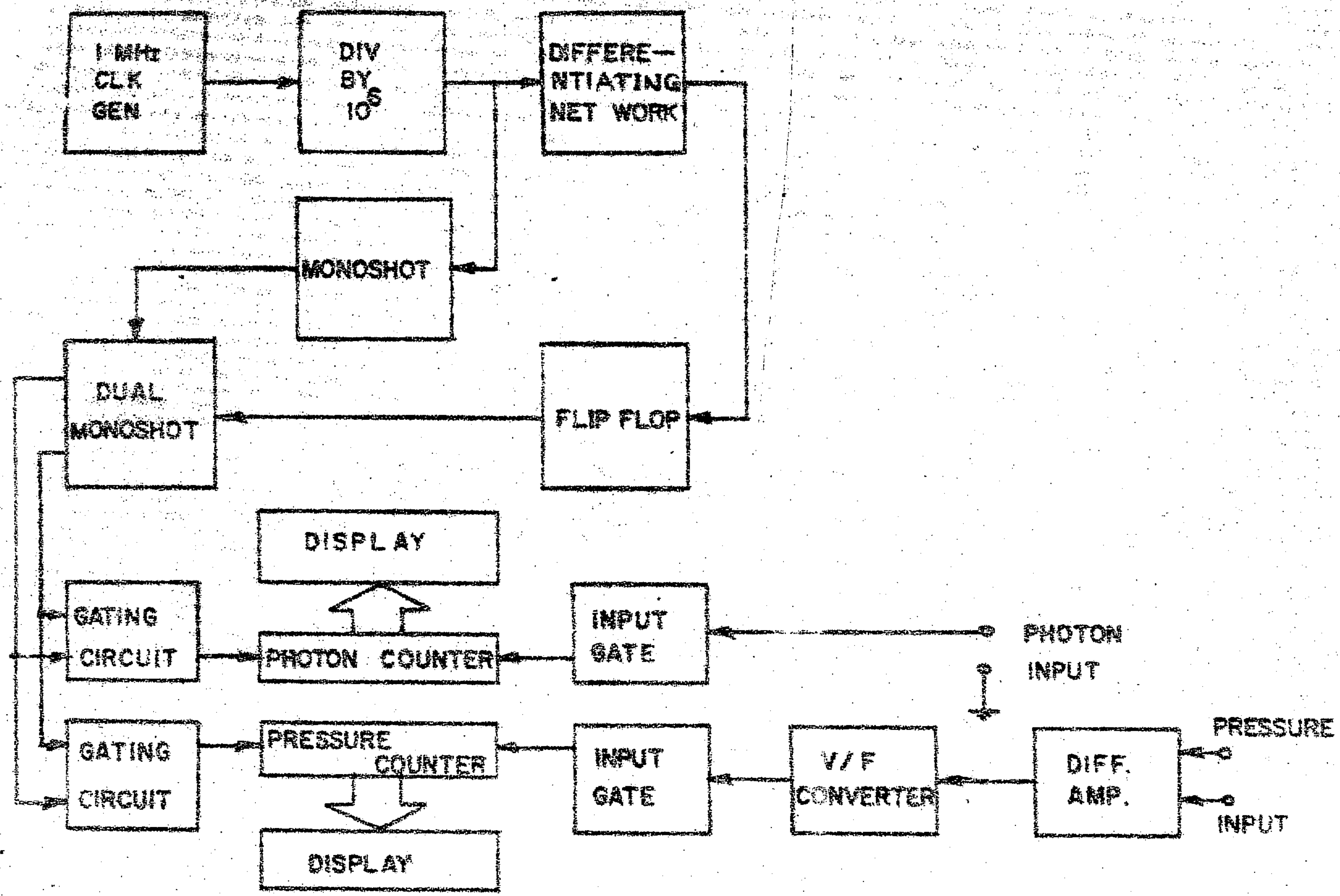
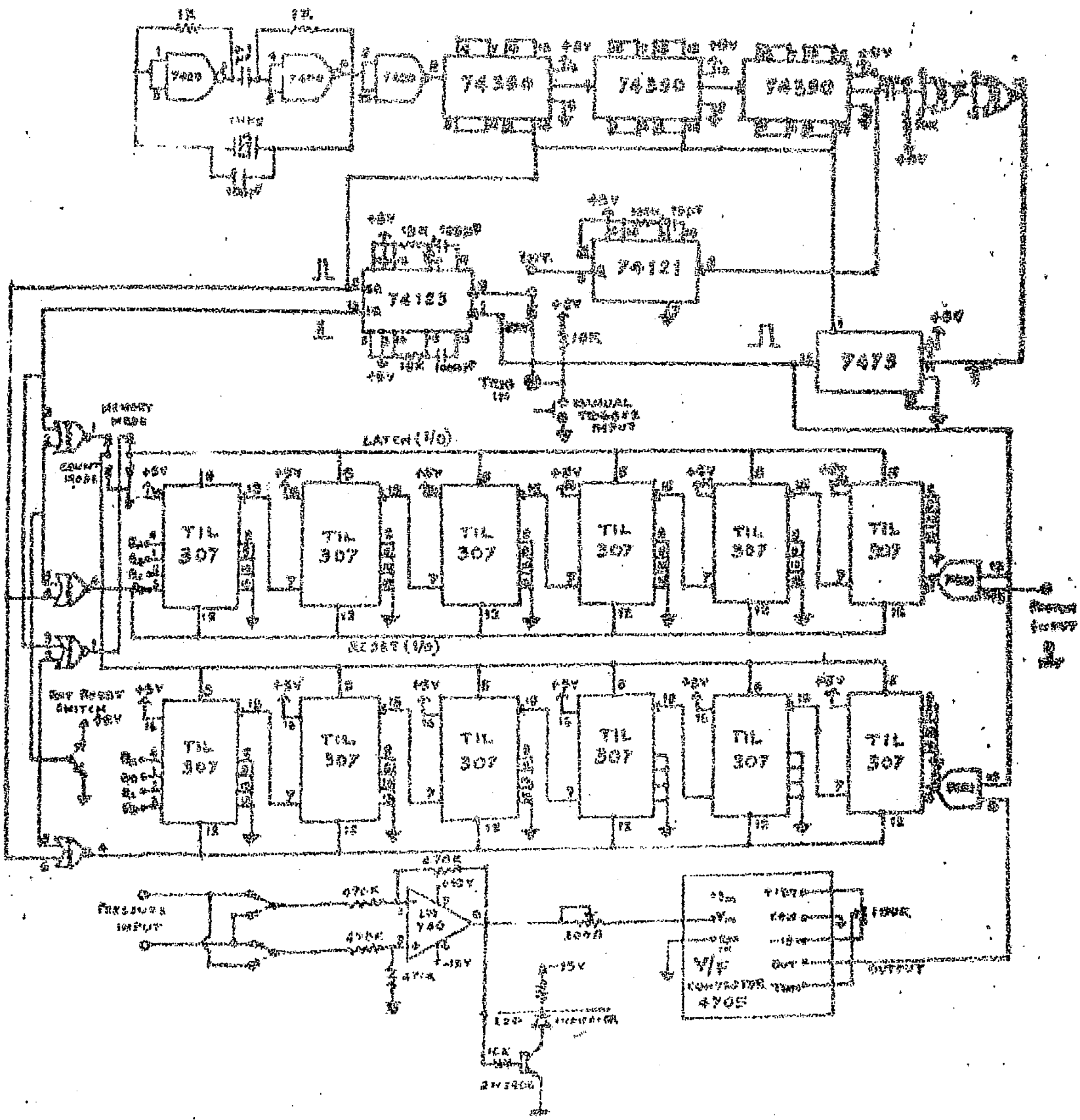


FIG.2. BLOCK DIAGRAM OF PHOTON COUNTER AND PRESSURE COUNTER

FIG. 3. CIRCUIT SCHEMATIC DIAGRAM OF DATA ACQUISITION SYSTEM OF FABRY-PEROT SPECTROMETER



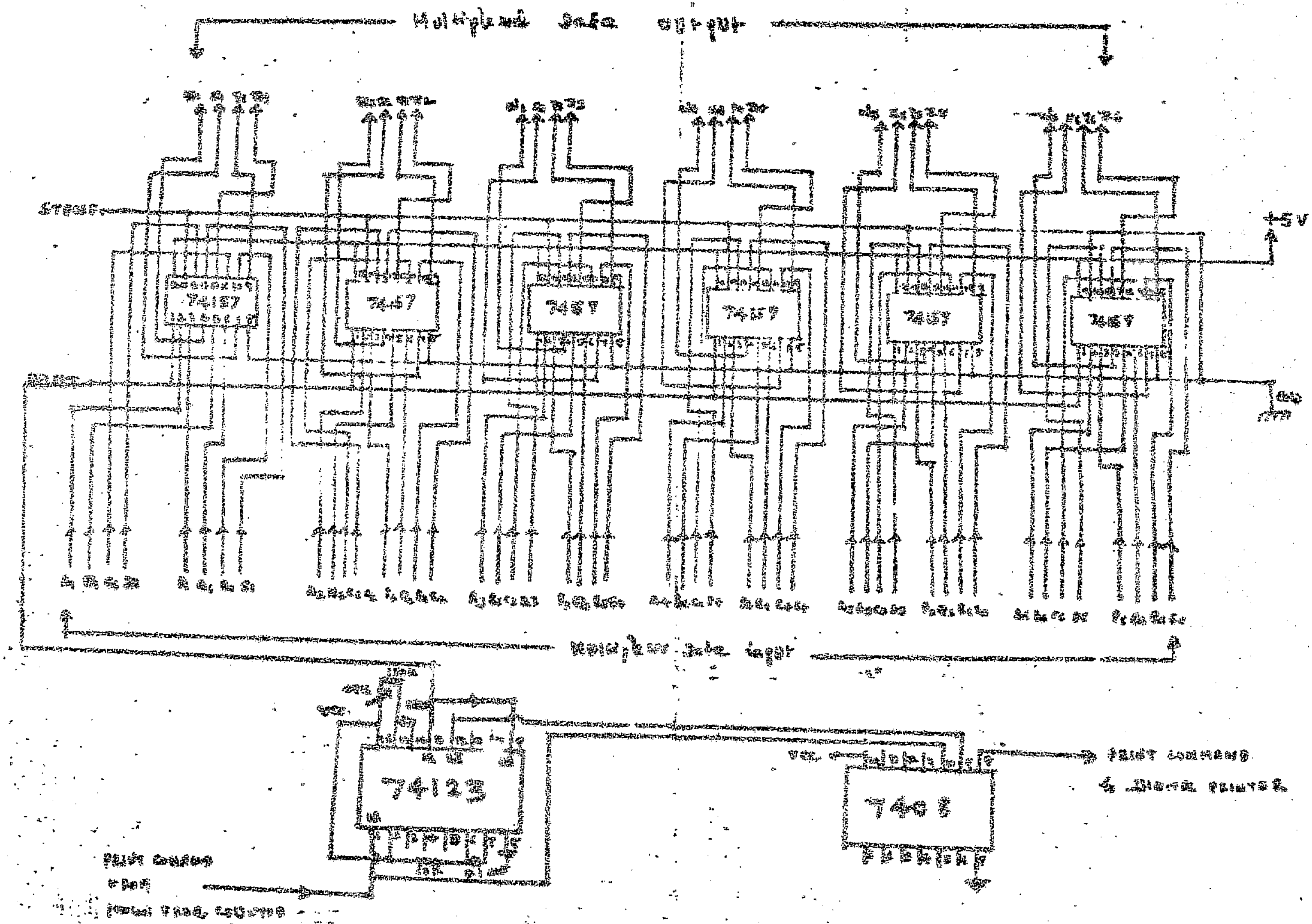


FIG. 4: CIRCUIT SCHEMATIC OF DIGITAL MULTIPLEXER

FIG.5. TIMING WAVEFORMS OF COUNTER-MULTIPLEXER