Personal computer based spectrum scanner

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The advent of personal computers (PC) has resulted in a flexible and low-cost solution for the control and acquisition of data from spectrum scanner used with optical telescopes. The PC enables user-friendly dialogue for instrument set-up, provides flexibility in modes of operation (sequential or random scans), on-line display of spectrum build-up and storage of data as files in secondary storage media. This paper describes the hardware and software interfaces of an IBM compatible PC to a spectrum scanner developed for the 1 metre telescope at the Vainu Bappu Observatory, Kavalur. The performance of the instrument is also discussed with examples.

1 Introduction

In a spectrum scanner, the star light is dispersed by a grating into its different spectral components, which are recorded by suitable electronic devices. Several spectrum scanners have been reported in literature[1,2]. These were based on the state of art computers available at those times. Minicomputers like HP 2114 B (8K, 16 bit, 2μs) were employed with limitation on primary memory; the application programs were written in assembly code making it difficult to modify programs when necessary. Data-dumps were provided on not so dependent paper tape medium. The advent of personal computers (PC) has provided a flexible and a
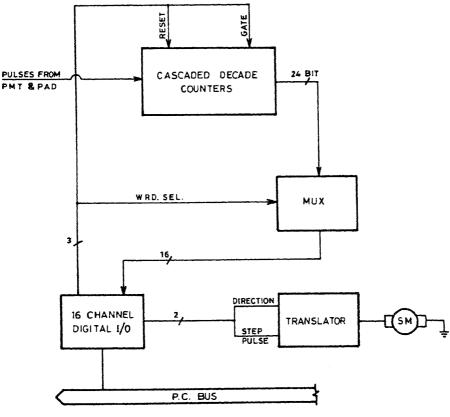

Fig. 1—The interface arrangement

low-cost solution for such applications. In this paper, we describe an IBM compatible PC interface for control and data acquisition for the spectrum scanner[3] in use with the 1 metre telescope.

2 Hardware Description

A PC-XT (640KB RAM, 20MB disk) is used for the scanner control. The following three interface cards are employed for the operation of the scanner.
1. A digital Input/Output card
2. A gated pulse counter card with multiplexer
3. A translator card for stepper motor drive

The spectrum scanner is implemented using these three interface cards and Fig. 1, shows the interconnection between these components.

2.1 Digital I/O card

The digital input/output (I/O) card supports up to 16 digital inputs and 16 digital outputs. It is known as Digiana card and is available from M/s Keonics Magnavision Ltd. The digital inputs and outputs are each addressed as two bytes. The input port reads the pulse counter information and the address assignment corresponds to locations 300 and 301 in Hexadecimal. The output port address resides at location 300 in Hexadecimal. The bit allocations are as follows. D0 and D1 provide the 'reset' and 'gate' signals to the pulse counter card. D2 forms the 'word select' signal to select the high/low (8/16 bit) word from the 24-bit pulse counter. D3 and D4 bits provide respectively the direction control and the step pulses to the stepper-motor. The assignment of various signals related to the I/O registers is shown in Fig. 2.

2.2 Pulse counter interface card

The incoming star light is split into its wavelengths by the grating (600 lines/mm) and routed to the photo multiplier tube (PMT). The PMT is operated in pulse counting mode using a conventional pulse amplifier circuitry. The pulse counter comprises of six 4-bit synchronous binary counters (74LS 193's), cascaded to provide 24-bit counting. It can be reset to zero under program control and then gated for the desired integration time to count the pulses. The resulting count values are transferred to the computer using the
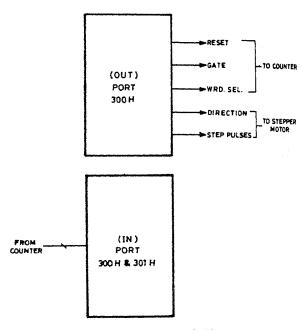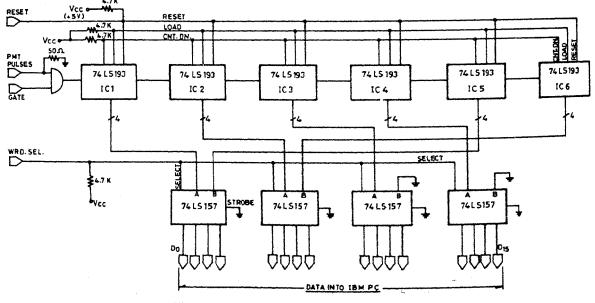

Fig. 2—Assignment of I/O ports

Fig. 3—The schematic diagram of the pulse counter

Programmed Data Transfer technique. Since the input instruction can only read a word of 16 bit at a time, a multiplexing arrangement is used to read the 24-bit counter value. The 'word select bit selects either the 'high word' or 'low byte' to read at a time. The pulse counter interface arrangement is shown in Fig. 3.

2.3 Translator card

The computer provides pulses that cause the stepper motor to move the grating which scans a series of wavelengths. The program specifies the number of steps to move and the direction (D3 and D4 bits of word register 300H). The translator card provides the necessary power level boosting through power transistors to drive the stepper motor coils.

3 Data Acquisition and Display

The spectrum is obtained in increments of 10A by moving the grating in steps. A maximum of 400 points on the spectrum can be measured. The entire scanning operation is under the control of the computer program. The various parameters of scans such as integration time, range of scan and the total number of scans to be made can be specified for each object via keyboard. Other pertinent data like the object identification, filter used, start time, end time are also stored as a file in the computer. After every scan the spectrum is displayed on a monitor screen for visual inspection. One salient feature in scanning is the optional random-mode, in which randomly separated channels of wavelengths can be scanned.

4 Software Description

The instrument control and data acquisition is written in Turbo-Pascal. Due to its structure, the program is modular and provides easy readability and amenability to make changes to suit different application requirements. The various standard procedures and functions available from the language are widely used in the scanner programs.

The program is implemented using the following procedures:

1. Channel adjustment routine
2. Gate generation routine
3. Data acquisition routine
4. Display routine
5. Print routine
6. Hold routine
7. Data storage routine

4.1 Channel adjustment routine

Spectrum range is divisible into 400 channels and any portion of the whole range can be selected initially for the study. This initial adjustment of channel is made through user commands. The number of pulses routed to stepper motor and the direction of movement is specified in the command. The form of the call for the stepper motor movement is

movestepmotor (n: Integer; direction: char);

where

'n' specifies the number of steps to be moved and 'direction' specifies the movement direction. If it is 'f', the stepper motor moves in clockwise direction and if it is 'b', counterclockwise movement is selected. The command is terminated when number 'zero' is entered.

4.2 Gate generation

The PC generates the 'gate' pulse using a delay routine, the duration of which is specified by the user. Delay is provided as one of the standard procedures in Turbo-Pascal and the syntax is as below.

Delay (Time)

This procedure creates a loop which runs for as many milliseconds as defined by its argument 'Time', which must be an integer. The gating interval corresponds to the integration time for which the PMT pulses are counted.

4.3 Data acquisition routine

'Channel-list' contains an array of up to 400 data giving channel addresses to be scanned. The corresponding 'count-interval' array holds the integer values of the integration time units, while the 'time-units' array holds the corresponding time informatiorras millisecond (character 'm') or second (character 's') units. The scan program moves the stepper motor from the first channel to the last channel by selecting the addresses from the channel list array. At each address a gate-signal corresponding to the integration time unit is generated, before moving the stepper motor to the next address. A reset signal is applied preceding the gate-signal to ensure that the pulse counters are initialized to zero values before any counting. At the end of the gate-signal, the pulse counter values are read. The 24-bit counter values are read into the PC in two steps. First the 'word select' signal selects the low word (16 low bits) and then reads the high byte (8 bits). These count values are stored in a data array of up to 400 point real numbers. The display routine presents the count values versus channel number to the graphic display. During the successive scans, the count values are accumulated to the respective channels and the spectra presented in the display
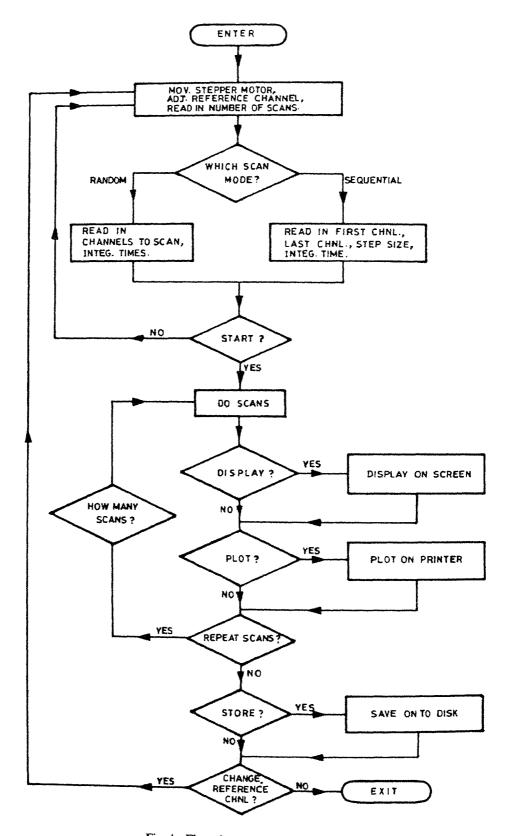
Fig. 4—Flow-chart for the scanner operation

build up. This build-up of spectra proceeds till the programmed number of scans are completed. The complete program flow-chart is shown in Fig. 4.

4.4 Display routine

(a) Graphic display

The PC displays the spectrum obtained on the monitor screen, as a graph of intensity (counts) against wavelength (channel numbers). High resolution graphics gives a resolution of 640 pixels (X-axis) by 200 pixels (Y-axis) on the monitor screen. Each pixel can display a single 'dot'. Therefore, 400 channels are easily accommodated on the X-axis, the maximum permissible being 640.

(b) Normalization

Up to 200 pixels are available on the Y-axis to accommodate the count values. But the actual range of count values may be rather high. To accommodate the actual count values, a normalization procedure is needed. The Y-coordinate (in pixels, with respect to the origin) will be a function:

Round [(count value − minimum value)
(maximum value − minimum value)] ×
(Y-axis length)

To this procedure, the data array of count values and the maximum normalized value (*n*) are submitted. A normalized data array is generated as output from this procedure.

(c) Display procedure

The two function calls used for graphics from Turbo-Pascal are:

(i) Draw (*x1, y1, x2, y2*):

draws a straight line between the points given by coordinates (*x1, y1*) and (*x2, y2*)
(ii) Plot (*x, y*):

plots a single point on the screen.
Pixel coordinates are given by *x* (horizontal) and *y* (vertical). Coordinate (0,0) is at the top left corner of the screen.

Channel-list and Difarray are two arrays holding the list of channel addresses and the normalized count values. The display procedure joins two data points with straight lines, if the successive 'next channel' number follows the 'previous' channel. If the channels are isolated, then the procedure plots the two values as points.

4.5 Print routine

A hard copy of the spectrum can be obtained on a printer using this routine. Here again, a normalization procedure is carried out before printing. If necessary rescaling can be done to suit the observer's requirements. This helps the observer to see the fainter lines better.

4.6 Hold routine

The user can take over the control from PC and suspend the operation of the system using the 'hold' facility. This control is useful to suspend data acquisition temporarily, like when clouds pass by. During the 'hold' mode the user can abort, display spectra, print or store the results as desired by selecting appropriate command. The flow-chart for the entire scan operation is shown in Fig. 4.

4.7 Data storage

The spectral data are saved on to the disk, after all the scans are completed, under a file-name specified by the user. The file is organised as records with the following fields.

comments	: string [80];
object name	: string [10];
pmt-identify	: string [10];
slit-width	: string [10];
filter	: string [10];
sthr	: integer;
stmin	: "
stsec	: "
ethr	: "
etmin	: "
etsec	: "
channellist	: array [1...400] of integer;
total scans	: integer;
count intervals	: array [1...400] of integer;
time units	: array [1...400] of clear;
data	: array [1...400] of real;

(sthr through etsec: specify starting and ending time (hour, minute and second))

In addition, if the number of scans is greater than ten, the system automatically stores the data at the end of every tenth scan in a temporary file. This feature is particularly useful during long exposures to recover data, till the last tenth scan on power failures.

5 Performance of the Instrument

We monitored the instrumental performance for several nights during the period August '88 to January '89. Initially an EMI 9658 tube was used and was later replaced by a more efficient RCA C31034. A new fabry lens was made to match its smaller photo cathode. The repeatability of channel position accuracy over many tens of scans was found to be very good in both the sequential and random modes. There was no channel shift at all. Backlash was
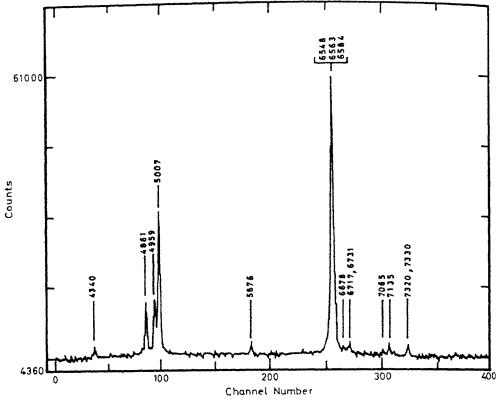
Fig. 5—The scan of Orion nebula with the entrance slit centred on a region near the trapezium (The well known emission lines are indicated.)
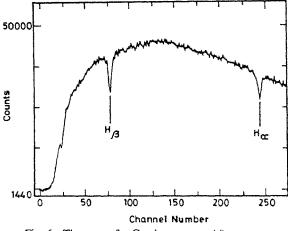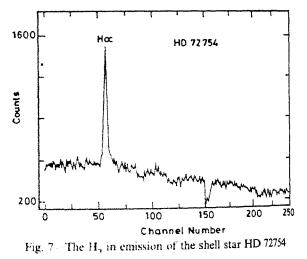

Fig. 6—The scan of γ Geminorum, an A0 type star

Fig. 7 The H, in emission of the shell star HD 72754

eliminated by the use of an anti-backlash gear for coupling the stepper motor to the grating. Hg or Ne lamps were used for wavelength calibration. We observed a few objects and the results were very satisfactory; Fig. 5 shows the scan on Orion nebula with a rectangular slit centred near the trapezium. The well known lines have been identified. The [N II] lines at 6548Å and 6584Å are blended with the H_α, since we had used a 600 lines/mm grating in the I order and an exit slit width of 20Å (The channel width in the

I order is set at 10Å). Similarly, the [S II] lines 6717Å and 6731Å are merged together.

Scans of γ Geminorum, an A0 type star are shown in Fig. 6. The strong Balmer absorption lines H_α and H_β are shown. In Fig. 7, we can see the H_α in emission in the shell star HD 72754. We also checked the performance in the random scan mode with the channels selected for known emission (diagnostic) lines of a planetary nebula. This mode thus saves the time spent on scanning unwanted channels and
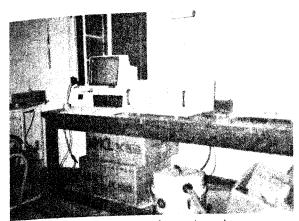
Fig. 8—The PC and the interface unit to the scanner

therefore is very useful in reducing the total time of observation on a single object. The on-line display of the spectrum getting updated upon completion of every scan and the protection of data collected in case of unexpected power failure are quite useful features, which enhance ease of observations. The PC XT (with 4 MHz clock) used by us took about 7 seconds to refresh the display at the end of each scan. This could be reduced easily by a factor of 4 with PC/AT operating at 16 MHz clock.

6 Conclusion

We have shown that a PC provides flexible and versatile instrument control and data acquisition for the spectrum scanner. Our system (see Fig. 8) has been operational with the 1 metre telescope at Vainu Bappu Observatory, Kavalur, since August 1988. Though this unit was mainly developed for spectrum scanner experiments, it can be easily adapted for use as a photon counter or data acquisition system for occultation studies, with some changes in software while the hardware system essentially remains the same. For persons interested in these programs, the software can be provided by the authors on request.

References

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