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The microprocessor control of the Kavalur 234-cm optical telescope

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Abstract. This paper gives an introduction to the control system of the 234-cm optical telescope. The computer used in control is based on an INTEL 16 bit microprocessor. The VAX 11/780 system has a supervisory role in the control system and is used primarily to calculate the pointing errors due to mechanical imperfections of the telescope, atmospheric refraction, and other similar errors. The microcomputer and the VAX system are coupled with bidirectional drivers and exchange data at predetermined sidereal intervals. The various tasks involved in the control of the telescope are explained. The interface circuits developed at our electronics laboratory are briefly mentioned. Circuits necessary for the display to telescope position, celestial coordinates and sidereal time are included.

Key words : 234-cm telescope—control system

1. Introduction

It has become customary to incorporate computer system in the drive and control facilities of modern telescopes. Computers are being used at the telescope focus for real-time and on-line data gathering and related functions. At the 1-m telescope at Kavalur, a minicomputer is being used for automated spectrum scanning, photometry and other similar experiments (Bappu 1977).

Recent developments in microprocessor technology have made it possible to have computer facilities for most of the experiments at the telescope focus (Santhanam & Bhattacharyya 1985). Microcomputer-based systems are being incorporated to ease the operation of the telescope with modern facilities (Chinnappan 1982). Computers are being successfully used for the control of the telescope, apart from their data gathering functions. Some telescopes (for example the Anglo-Australian telescope) have a dedicated pair of computers for telescope drive alone (Wallace 1977). In the 234-cm telescope, the computer-controlled drive is incorporated as an integral part of the drive system. The advantages of a programmable drive system are well known and are not discussed in detail here.

The computer-based telescope control system is designed to control the positioning of the telescope in three modes. It is possible to select the mode of operation from the main operating console of the telescope. The three modes of operation are (i) Manual mode; (ii) Automatic mode using microcomputer; and (iii) Automatic mode using microcomputer supervised by VAX 11/780.

Manual mode is designed using rate multiplier hardwired circuit for control in case of emergency and at the event of failure of microprocessor-based automatic modes. The manual mode is not detailed here.

The automatic mode of control is based on 16 bit microcomputer. Absolute position optical encoders of 20 bit resolution are used in each axis to detect the angular positions of the telescope. The 20 bit encoders give 0.08239769 s resolution in hour axis and 1.235964 arcsec in declination. Incremental optical encoders which give 64 K pulses per rotation are used in the feedback loop of the control system to increase the positioning accuracy. Incremental encoders are mounted through gears and give one pulse in every 0.18 arcsec movement of the telescope.

2. The overall sehematic

The basic work of the microcomputer in the telescope control is to get the position information from the user of the telescope and to move the telescope to the required position and then to track the object at the sidereal rate. The two axes of the telescope are coupled with direct current torque motors. A pair of motors in each axis is used for the telescope movement. One motor giving opposite torque in the same axis is used to eliminate backlash in the gear system. The same pair of motors is used for slewing, setting, tracking and guiding motions of the telescope. Electromagnetic brakes are provided in each axis which actuate at the event of power failure. The telescope is provided with two feedback loops. A tachometer feedback in the innermost loop of the control system increases the stiffness of the system, thus providing a first order safety to the telescope. An incremental encoder mounted in the outermost loop increases positional accuracy. The PID controller used in the control system has a provision to change the system gain, the phase margin, and other control parameters. The PID controller is driven by a high precison 16 bit digital-to-analogue converters under microprocessor control. The PID controller drives the power amplifiers which in turn drive the motors.

In order to move the telescope to the desired coordinates the computer should know the present position of the telescope. This information of the telescope in hour axis and declination axis is given by the 20 bit obsolute encoders mounted on these axes. Depending on the distance to be moved, the computer selects various speeds and positions the telescope at the required object, then starts tracking the object. The coordinates of the telescope have to be computed using the encoder values. The 20 bit binary information in hour axis is converted to hours, minutes and seconds. The 20 bit information in declination axis is converted to degrees, minutes and seconds. The right ascension of the object is computed using sidereal time and the hour angle value. The computer then drives the displays of sidereal time, hour angle, right ascension and declination. It also displays the coordinates of the object to which the telescope is to be moved.

The block diagram of automatic control of the telescope is shown in figure 1. The microcomputer is at the centre of the control and is interfaced with the VAX 11/780 for supervisory functions. In the microcomputer control mode, coordinates of the celestial object after being corrected by the observer for a particular time are fed into the microcomputer using keyboard of a CRT terminal. The microcomputer positions the telescope to the required coordinates and tracks the object of interest.

In the VAX 11/780 computer supervisory mode, the coordinates of celestial objects, which are kept as data bank in the secondary storage of the computer after being corrected for mechanical flexures of the telescope, error in the gear, non-perpendicularity of hour axis and declination axis, collimation errors and other similar errors are fed to the microcomputer. The microcomputer positions the telescope and tracks the object.

3. The microcomputer system

The microcomputer system consists of one microcomputer board and three interface boards. The microcomputer is an INTEL SBC 86/14 single board computer. It is a 16 bit computer with 8/16 bit data bus and 20 bit wide address bus. SBC 86/14 can support a total memory capacity of 16 megabytes and supports a numeric data

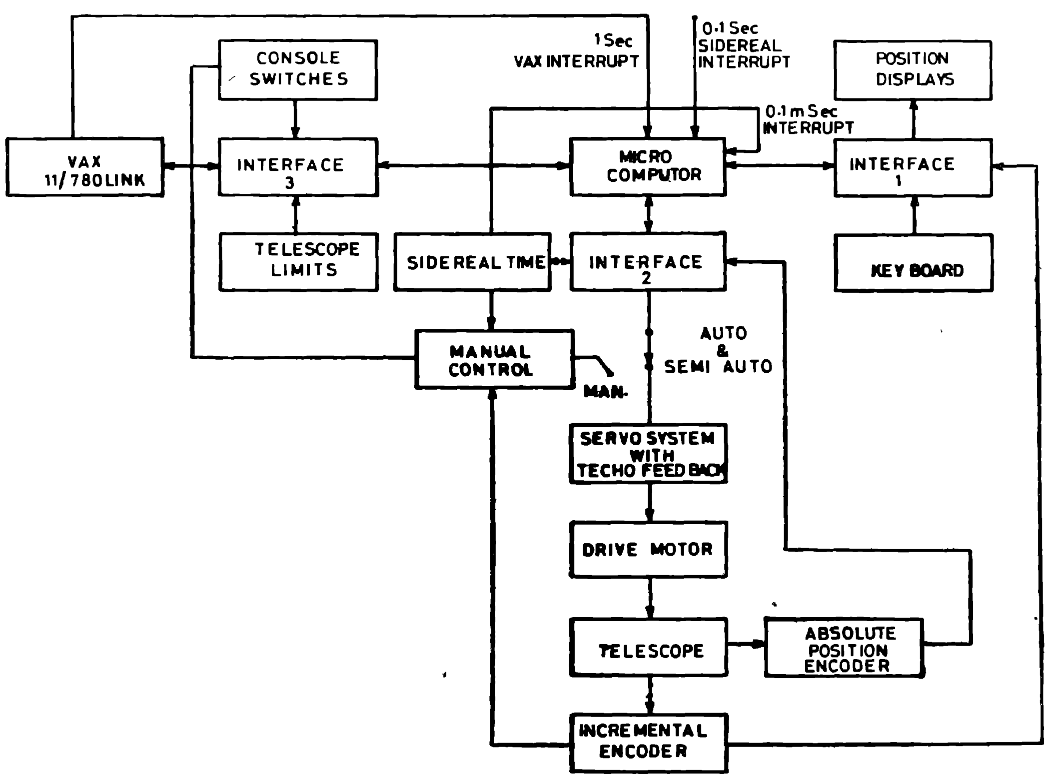

Figure 1. Schematic diagram of automatic control of telescope.

processor for the floating point calculations and other trigonometric and transcendental functions. The computer board has 32k dual port RAM and sockets for upto 64k EPROM. It has 24 programmable input/output lines and supports one programmable R232C interface. The processor works with 8 MHz clock (5 MHz clock with numeric data processor). It has one instruction cycle time of 1.2 μs. The processor has instructions prefetch feature. Upto 6 instructions are prefetched and kept in a queue. With this pipelined architecture it takes only 250 ns for a single instruction execution. It supports seven bus vectored priority interrupt lines to service external interrupts.

4. The interface boards

The various input and output lines coming from and going to the telescope are distributed in three INTEL multibus compatible interface boards. The design of hardware is detailed elsewhere. The interface boards have input/output lines to read in the encoder values, the sidereal time and to input telescope limit conditions to the computer. It has programmable timer counters for generating real time interrupts of various duration for the different tasks to be done. The interface has programmable keyboard and displays interface circuits to drive the various displays in different consoles of the telescope. High precision 16 bit digital-to-analog converters are provided, which feed the analog voltage to the PID controller which in turn feeds the voltage to power amplifiers. The power amplifier drives the motor in each axis.

The interface boards also have facility to communicate with VAX 11/780. Upon the arival of 1s interrupt to the microcomputer, it passes the sidereal time, hour angle, and declination of the telescope to VAX 11/780. VAX 11/780 reads information about temperature, humidity, pressure etc. It then computes the coordinates correcting all the errors and then transfers the information to the microprocessor. The microcomputer moves the telescope to the required coordinates. The tracking of the object is then made possible. The control circuits have provision for different tracking rates other than sidereal rates at both axes. This provision enables the telescope to accurately track solar system objects also which have movements different from the general sidereal rate.

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References

Bappu, M. K. V. (1977) *Kodainkanal Obs. Bull. Ser. A* 2, 64.
Chinnappan, V. (1981) *J. Instr. Soc. India* 2, 64.
Santhanam, P. & Bhattacharyya, J. C. (1985) *Kodaikanal Obs. Bull.* (in the press).
Wallace, P. T. (1977) Optical Telescope of the Future, ESO, p. 123.