ATMOSPHERIC DATA REDUCTION

and

PROCESSING USING A PDP 11/10 MINICOMPUTER

THESIS

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by

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ABSTRACT

Use of the minicomputer PDP 11/10 for reduction and processing of atmospheric data is discussed in this thesis. An asynchronous serial approach to the problem of interfacing between the tape search system and the PDP 11/10 is presented. Also software control of the Laboratory Peripheral System's programmable real time clock and DL11 asynchronous serial interface is discussed. Most of the programming is done in assembly language to insure the fastest possible processing. Possible use of the PDP 11/10 as a controller is briefly discussed. Error analysis on the system is made and presented. Greater accuracies resulted using the techniques than had been possible with the conventional manual analog method.

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CHAPTER 1

INTRODUCTION

The Electrical and Mechanical Engineering departments at the University of Texas at El Paso in connection with The Atmospheric Sciences Laboratory (ASL) at White Sands Missile Range are engaged in atmospheric studies. These studies involve measurements of various parameters of the upper atmosphere such as temperature, pressure, water vapor density etc., through the use of sensors which are mounted on balloons and rockets. These sensors measure the parameters in the form of a voltage or current. The data is then converted into a frequency modulated square wave, frequency multiplexed, and telemetered to a ground station where, it is demultiplexed and recorded on a fourteen track magnetic tape for later analysis. Each instrument is calibrated before it is flown by plotting frequency as a function of the simulated atmospheric parameter. References at certain time intervals are used to account for drift.

On one track of the tape, time is recorded in the form of amplitude modulated wave riding on a sinewave carrier. The Inter-Range Instrumentation Group Band width (IRIG B) is 0.5 Hertz - 1.25 K Hertz. The time information when compared with radar track gives the altitude of the instruments at which each data point is taken.

At present, a major problem confronting the research effort is efficient data reduction. At this time it is being done by analog manual method. Each track is processed by an integration technique, the frequency is manually read, corrected from the references, and the

atmospheric parameter is then determined from the calibration curve, recorded on a strip chart. The time track is decoded by the use of a tape search unit (Astrodata, Model 6222) which displays the time digitally on the front panel as well as giving the output in Binary and Binary Coded Decimal (BCD) form at the back. The Binary output gives time up to nine days, twenty-three hours, fifty-nine minutes and fifty-nine seconds. The higher order bits of the binary output (Unit, tens and hundreds of days bits) are presented as three BCD digits. Therefore, the binary output is not all binary but it is partly binary and partly BCD. The BCD output gives time up to three hundred and sixty four days, twenty-three hours, fifty-nine minutes and fifty-nine seconds. The front time readings are copied manually on to the chart paper. They are then compared with radar altitude versus time charts for altitude determination.

This data reduction system is time consuming so a computer aided technique should result in a much faster data reduction method. The Electrical Engineering Department at U. T. El Paso has two minicomputers, a PDP 11/45 and PDP 11/10, which could be used to solve the data reduction problem. This required the development of an interface between the tape drive unit, the search unit and one of the two computers. In addition, software was needed to read in the incoming data and time information at proper times, to manipulate it, to print out the data in a readable form on the teleprinter, and to store the reduced data on Magnetic disk, tape or cassette for later analysis.

The objective of this thesis was to implement a computer - interface system as described above.

The interface should be able to take in outputs from the tape drive and tape search units. The output from the tape drive unit is a frequency modulated square wave with an amplitude of +1.4 volts. The frequency of this square wave varies from 3hz to 200hz. The output from the tape search unit can be obtained in BCD and binary form combined. The BCD output has 8 bits for seconds, 8 bits for minutes, 8 bits for hours and 12 bits for days, while BCD and binary form combined has 6 bits for seconds, 6 bits for minutes, 5 bits for hours and 10 bits for days.

The BCD output has positive logic (+7 volts = 1 and zero volts = 0) and the other output has negative logic (-7 volts = 0 and zero volts = 1).

The output of this interface should be in serial form to make it more economical. Parallel output can also be acceptable under some conditions.

There is more than one way to solve the interface problem. One of these could be to use a microprocessor. This has been done using the INTEL 8008 micro-processor [9]. A disadvantage of this interface is slow execution speed and high cost. This interface is parallel, but is quite slow and has a data frequency limit of about 1000 Hertz. The main advantage of this kind of interface is probably its ability to act as a buffer storage area until the computer is ready to accept more data. In this way the interface could be used

in a time sharing computer system. In this application it is not possible because the high speed of the incoming data prevents it.

The method which is developed in this thesis to solve the interface problem uses an existing Laboratory Peripheral System unit (LPS) [5,6] and a DL 11 Asynchronous Line Interface [7] of the mini-computer. The LPS system of the PDP 11/10 minicomputer contains two schmitt triggers, a real time clock, two twelve bit digital to analog (D/A) conversion channels, one twelve bit analog to digital (A/D) conversion channel, a 16 bit digital input register and a 16 bit output register. Schmitt trigger II with real time clock can be used to decode the frequency modulated waveform. The time can be input into the computer through a digital input register (DIR). In that case the interface would be parallel. If the computer is remotely located from the tape transport and tape search units, the line cost can be very high. Therefore, it was decided to use an existing DL 11 serial line interface which accepts data serially into the computer.

The main advantage of this direct interface over the micro-processor based interface is its fast execution speed. The interface takes only few micro-seconds to sample the incoming data and store it on a magnetic disk. Hence, unlike the microprocessor based system, atmospheric data of over 1000 hz may be sampled with this interface. Another important advantage is its low cost as hardware and software costs are minimal. At the same time, the software capability of the PDP 11 is much more extensive and versatile than that of the micro-processor based system.

The primary disadvantage of this system is its slow transmission rate of the time data because of the serial interface system used as compared to the microprocessor based interface system which is parallel. However, the developed system is adequate since the time information is read only once or twice a second.

CHAPTER 2

SYSTEM DESCRIPTION

This chapter presents the actual computer interface in block diagram form. In the following sections the theory of operation is covered in detail. Frequently during the discussion, certain options will be pointed out. Many of them are not used in this system but can be added later to make the system more flexible.

2.1 System-Block Diagram

The overall block diagram of the data reduction and processing system is shown in Figure 1. The system consists of a tape transport unit (Sangamo, SabreII) [1], a Universal Tape-Search unit (Astro-data, Model 6222) [2], a Mini-computer (DEC, PDP 11/10) [3,4], a multiplexing circuit and an RS232 serial-parallel interface [8].

The inputs to this system originate from the tape transport unit and are of two basic types.

(1) Atmospheric data

(2) Time data

The atmospheric data is recorded on thirteen tracks of the tape and is in the form of a frequency modulated square wave. The time data is recorded on one of the channels of the tape and is in the form of an amplitude modulated sine wave carrier.

The tape-search system is used to decode the time data. The decoded data is available in the following formats:

(1) Binary Coded Decimal (BCD) format

(2) Binary and BCD combined format

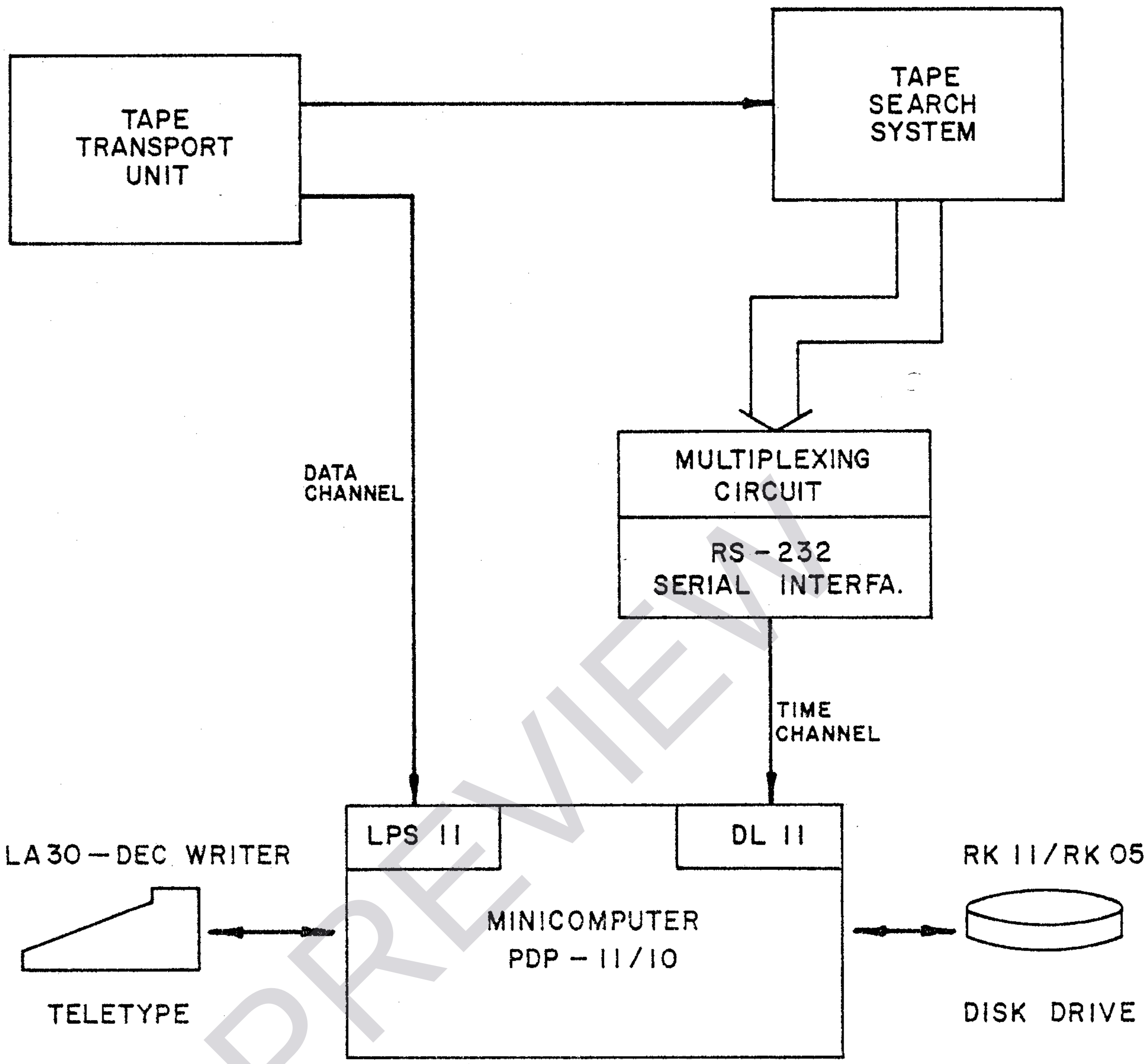

FIGURE 1. The System Block Diagram

Both outputs are available on the back panel of tape-search system.

The multiplexing circuit accepts outputs from the Universal Tape-Search System. It converts the voltage level to TTL logic, changes polarity of the inputs and outputs, eight bits at a time to the RS232 serial interface.

The RS232 serial interface system accepts outputs from the multiplexing circuit, adds one start bit, two stop bits and transmits it to the PDP 11/10 minicomputer in RS232 compatible form at one of the standard frequency selectable rates.

The minicomputer is used to process the incoming analog data signal. The Laboratory Peripheral System (LPS) [5] of the PDP 11/10 converts analog data into digital form. The computer reads its corresponding time via receiver status register of the asynchronous serial line interface DL11 [7], averages a specified number of points, stores reduced data on a magnetic disk and provides a hard copy of the data via its teletype.

2.2 Tape Transport Unit

The tape transport unit is a Sangamo, Sabre 11 (model 3614; serial #7629) [1] portable tape recorder/reproducer. A one inch wide tape with fourteen tracks is used with the transport unit for recording or reproducing data. Thirteen of these tracks contain FM modulated atmospheric data. The fourteenth track of the tape contains timing data. The tape recorder/reproducer has several speeds to select from. Among these speed are 60, 30, 15, 7 1/2, 3 3/4, 1 7/8, and 15/16 inches per seconds (ips). All speeds are

electrically selectable and bi-directional. The transport unit also has a rewind/fast forward speed of 750 feet per minute. It has a minimum signal amplitude of 2 volts and a maximum amplitude of 50 volts peak to peak.

Besides operating the recorder/reproducer manually it can also be operated remotely if an external circuit is designed to interface with the REMOTE JACK on the recorder. The remote control can only be used to find data points of interest on the tape either by rewinding it or fast forwarding it. However it cannot be used to turn on or off the recorder/reproducer or to change its speed. Remote control was not required in this system. Therefore it wasn't included in initial system design but could be added later to make the system more versatile.

As it was mentioned earlier the atmospheric data is recorded in the form of a frequency modulated square wave. An example of the signal is shown in Figure 2 as it may appear on one of the thirteen outputs. The information of interest is the period of the waveform. This can be obtained two ways:

(1) By measuring full period of the wave or

(2) By measuring period of the positive portion of the the wave and multiplying it by two.

The modulated signal may be corrupted by noise in the telemetry link and from recording. Due to bandwidth restrictions, data is filtered before being recorded but noise may still appear as high frequency spikes. Filtering causes an increase in the rise and fall times of the modulated square wave. This increase in rise

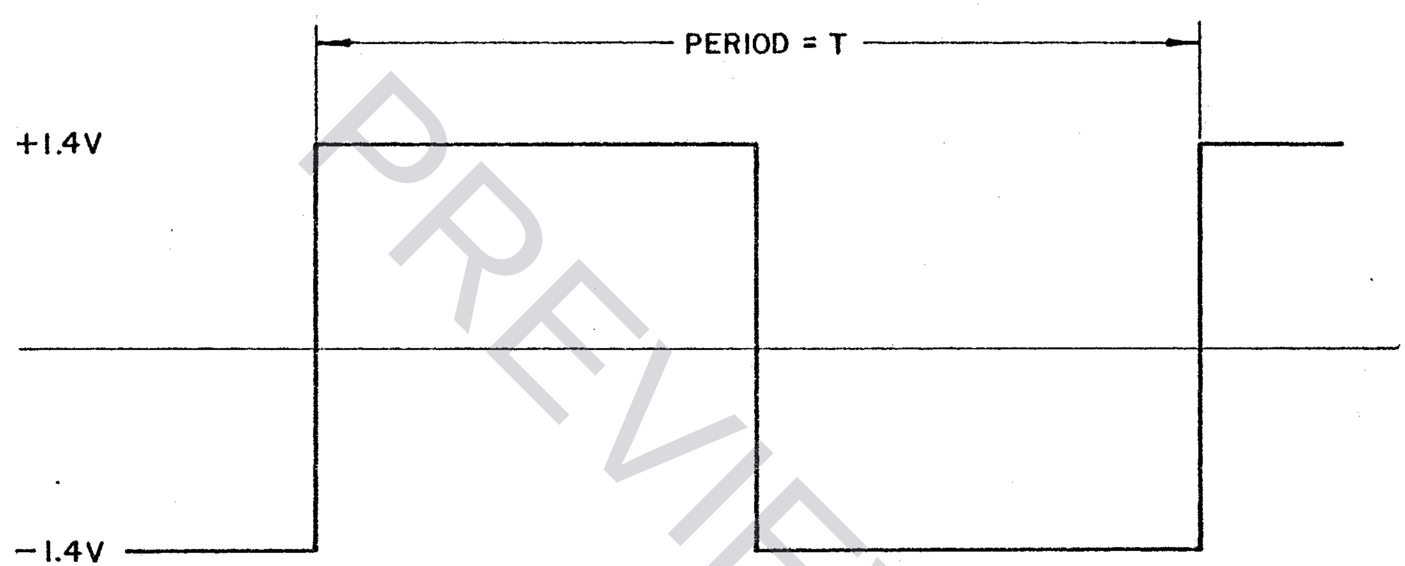

FIGURE 2. Frequency Modulated Wave

and fall time may result in errors in data processing at higher frequencies over 1KHz. Figure 3, shows an example of this type of signal as it may appear at one of the thirteen outputs.

2.3 Universal Tape Search System (Model 6222)

The Universal Tape Search System (Astrodata, Model 6222) [2] accepts serial time code data of a specific format and translates it into parallel binary coded decimal (BCD) digits. These BCD outputs are available at the back of the system and represent the time of the day and/or time of the year, depending on the format of the input time code. A nixie-tube display on the front panel provides a visual indication of the time. The input time code is prerecorded on a magnetic tape, and is provided to the tape search system from a tape transport unit (Sangamo, Sabre II).

The tape search system has outputs for remote control of a tape transport unit. This facility enables the operator to select a specific time on the magnetic tape at which code translation begins (Preset Start Time). It also enables the operator to stop the tape transport unit at a specific time. This option wasn't included in the initial system design but can be added later to increase system versitility.

Besides controlling the tape search system manually, it can be controlled by the mini-computer. When the system is under computer control, the operating mode is controlled by inputs at connector J21 which is located on the back panel. More information about these inputs is provided in section 3.9 of the Universal Tape Search System's instruction manual.

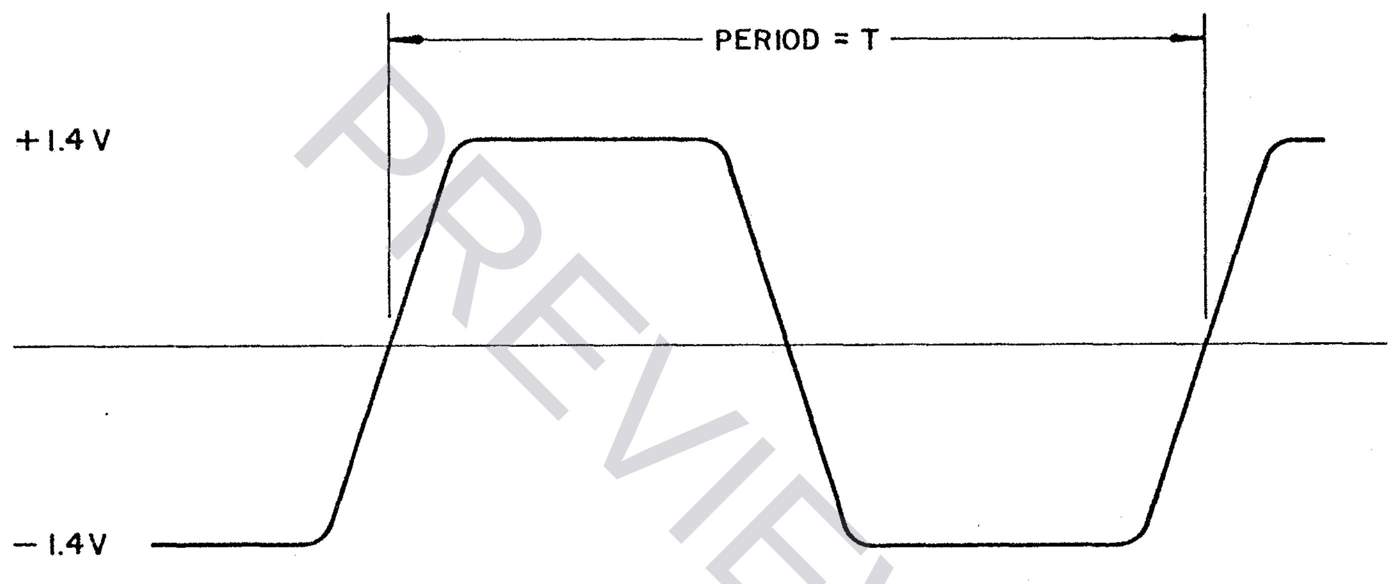

FIGURE 3. Frequency Modulated Wave Distorted By Pre-Filtering

Computer control of the tape search system also means computer control of the tape transport unit because after accepting inputs from the computer, the tape search system outputs necessary bits to control the tape transport unit, but this output is not compatible with Sabre II. Also, the output of minicomputer is not compatible with Astrodata Model 6222 so interfacing equipment is required for this purpose. This interfacing equipment could be extensive and isn't required to operate the system. Therefore, remote control functions of the two systems weren't included in the initial system design.

The last track on the magnetic tape contains time code information in the form of an amplitude modulate sine-wave carrier (see Figure 4). This timing code is a serial code and the Universal Tape Search System is used to decode it. The input decode logic of the search system consists of a carrier demodulator, a pulse width generator, a code pulse counter, a code pulse decoder and a reference counter. After decoding the serial code, the output register receives data from the accumulator and supplies it to parallel code connector J10, located on the tape search system rear panel (see Figure 5), from where it can be used by the system.

The output from the tape search system, give the following information: milliseconds through 999, seconds through 59, minutes through 59, hours through 23 and days through 399. For this application, not all time units are needed because the maximum flight time utilized to date was three days. To leave room for long flights in the future,

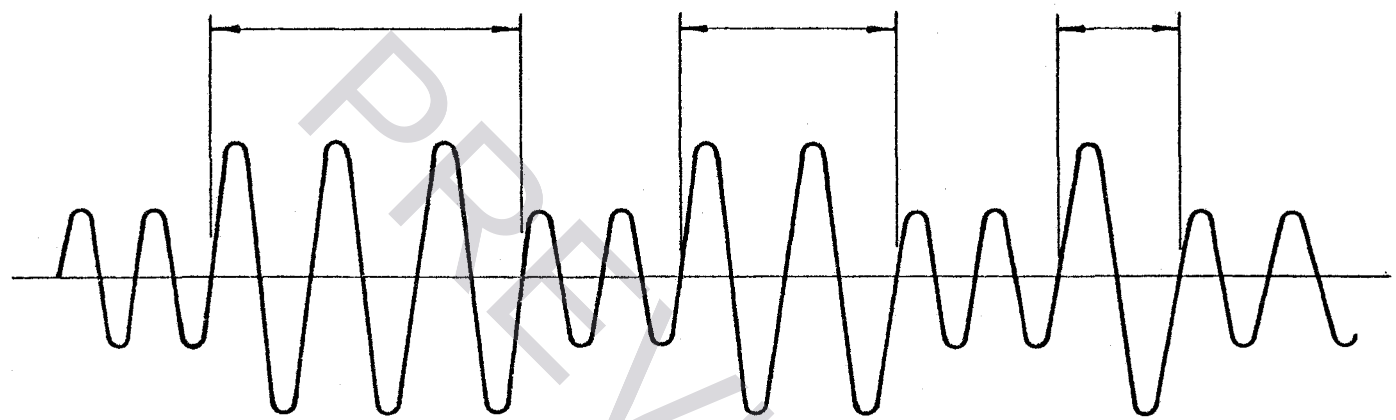

FIGURE 4. Time Data: Amplitude Modulated Wave
Sine-Wave Carrier