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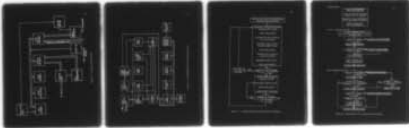
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BALLOON-BORNE PCM TELEMETRY AND COMMAND SYSTEM

Final Report

David G. Murcray, James N. Brooks, John Van Allen,  
Dale Steffen and Robert C. Amme

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29 October 1976

U.S. Army Research Office  
P. O. Box 12211  
Research Triangle Park, NC 27709

Grant No. DAAG29-76-C-0113

University of Denver  
Denver, Colorado 80208

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DAAG29-76-G0113	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) Balloon-Borne PCM Telemetry and Command System		5. TYPE OF REPORT & PERIOD COVERED Final Report, 1 Dec 1975 - 1 Aug 1976
7. AUTHOR(s) David G. Murcray, Dale/Steffen James N. Brooks, Robert C. Amme John/Van Allen		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Denver Univ., Colo Denver, CO 80208		8. CONTRACT OR GRANT NUMBER(s) DAAG29-76-G0113 new
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 15 p.		12. REPORT DATE 29 October 1976
		13. NUMBER OF PAGES 13
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for Public Release; Distribution Unlimited 18 ARB 19 13816.1-65		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES The findings in this report are not to be construed as an official Department of the Army position; unless so designated by other authorized documents.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Balloon Instruments PCM Telemetry		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A balloon-borne command and data handling PCM telemetry system suitable for use with complex payloads is described. While the unit was designed for a particular payload, care was used throughout the design to make the system easily adaptable to other balloon-borne instruments.		

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## INTRODUCTION

Our group at the University of Denver has been constructing a balloon-borne  $\pm$  ion mass spectrometer system on another U.S. Army Research Office contract. This instrument is typical of the sophisticated instruments that are being built for balloon measurement in that it generates data of high precision at a high rate. In addition, the instrument is complex and has many operational modes which can be commanded from the ground. To fully utilize the instrumental capabilities, a data handling system which does not degrade the data generated by the instrument and a command system capable of performing a large number of different functions which can be selected from the ground are necessary.

The objectives of this program were to construct a command and telemetry system along with a suitable mini computer and ground display capable of handling the requirements of the  $\pm$  ion mass spectrometer system as well as other balloon borne instruments. The  $\pm$  ion mass spectrometer system requires that the command system have a 0.1% resolution and a choice of many discrete commands. The output data from the system comes 6 bits per byte, 4500 bytes per second. These data must be handled on a real-time basis and displayed so that the experimenter can decide the future course of the experiment. These requirements have been met by purchasing segments of the system when commercially available and cost effective. The remaining segments were designed and fabricated by our group under this grant. The complete system, shown in Figure 1 includes appropriate interfaces and has been assembled and checked out as part of the program. Figures 2 through 7 show diagrams of each system built here which are discussed in detail below.

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## COMMAND ENCODER

The first segment built under this program is the command encoder. It enables the ground personnel to make choices during a balloon flight concerning the course of the experiment. Figure 2 shows the encoder in detail including data switches, discrete switches and the select switch connected to the parallel shift register where these choices are physically made. The serial bit stream thus produced enters a frequency shift keyed generator where it is transformed to two tones, representing the binary values. At the left of the figure the ARM and XMIT buttons are shown: ARM keys the General Electric Master II transmitter on and XMIT sends the command.

To insure that there are not mistaken commands when the signal level at the receiver drops due to distance or random noise or other interference generates spurious commands, a correct command containing the information is transmitted twice. This serial bit stream consists of 16 data bits to control the mass spectrometer, five for discrete commands and three for prefix. The five bits for discrete commands are generated from 16 toggle switches on the front panel of the command encoder that are encoded to a 4 bit binary code and another switch that selects a data or discrete transmission. There are 16 toggle switches for selecting a data word to be transmitted: this includes the fixed peak value as a binary word.

## AIRBORNE COMMAND DECODER

The airborne system outlined in Figure 1 consists of the receiver, command decoder, data encoder and S-band transmitter. These units are included in a card rack 17" x 10" x 7 1/2" and designed to interface with the quadrupole mass spectrometer electronics. The receiver is taken from General Electric's Master line of mobile radios and is crystal controlled

at 138.06 MHz. The transmitter is an Aydin Vector model T202S. The other subsystems were designed here.

The command decoder itself is shown in Figure 3. The audio frequency signal from the receiver goes to the demodulator where it is transformed into a 48 bit serial signal and a timing pulse. This signal, containing two commands, enters the shift register. When the first bit excites the shift register, the first bit of the repeated command is at the demodulator and these two bits are compared by the exclusive or gate. In this manner the positive correlations of the command and the repeated command are counted until a count of 24 coincides in time with the end of message. A valid command now exists in the shift register and will be transferred to the data word latch register or to the discrete command latch register dependent upon the state of the bit originating from the select switch.

The 16 bit data word is structured to provide for the following choices and values: to scan or stop at a fixed peak, the value of that ( $\pm 0.1\%$ ), positive ion scan, negative ion scan, value of orifice voltage, and other possibilities. These commands are directly wired to the various parts of the airborne instruments.

The discrete commands come from double-pole double-throw relays that are used to turn the transmitter on or off, switch two high voltage supplies on and off, reset the microprocessor, and switch control of the experiment from the group to the airborne programmer. It should be noted that the capability of the command system exceeds its current use, but we intend a greater use for future experiments.

#### AIRBORNE DATA ENCODER

The data having been collected is transmitted from air to ground by pulse code modulation (PCM); a 50 kilo bits per second data stream

organized into frames of 128 nine-bit words. The frames must be transmitted at a uniform rate if they are to be decoded, but the data to be included in the frame is not received in synchronism with this transmission. A Motorola microprocessor (MPU) is used to solve this problem. The MPU can execute 72 instructions, most of them in less than 5 microseconds. Therefore the MPU, which must output one word every 180 microseconds, has ample time to make up a frame from incoming data that is asynchronous with the output.

The airborne data encoder in Figure 4 (exclusive of power) is contained on three printed circuit cards. The first of these include the MPU, 500 words of random access memory (RAM) and the Intel programmable read only memory (PROM) which contains the program for making up the frame. The frame in use for the current experiments consists of 5 sync words used to recognize position in the frame, two words from analog data inputs, and one flag word which is used to indicate if the following 120 words will contain digital data from the mass spectrometer. One circuit card contains the 12 bit analog to digital converter, a 16 position analog multiplex switch (MUX) and a peripheral interface adapter (PIA) to make contact with the data and address bus of the MPU. The program selects in sequence, one for each frame, the 16 inputs containing information such as temperature, pressure and the state of various instrument parameters.

Digital input, from the mass spectrometer and output to the shift register is accomplished on the third circuit card. Only eight bits are entered from the PIA to the shift register; however, a parity is generated from these eight bits to make a 9 bit word which is shifted to the transmitter at a 50 KHz rate.

#### NOVA INPUT/OUTPUT

To display the transmitted data on the plotter it is necessary first to separate the individual words from the bit stream. This is done by a frame synchronizer which was built on a input/output interface board (I/O)

purchased from MDB company. Figure 5 is the block diagram showing this frame synchronizer. The EMR model 2726 signal conditioner regenerates a bit clock in synchronism with the incoming data that is used to enter the data into the shift register shown at the top of Figure 5. The frame sync word is entered manually into the frame word comparator to correspond with the one in the airborne PROM, thus an identical match of the sync word with the 45 bit shift register will insure a correct start. The comparator resets the word count, frame count, frame check and enters the first word into the word register. The MPU will now accept this word through the interface and subsequent words depending upon the program executed by the MPU. Operation of the MPU in conjunction with the frame synchronizer permits a pre-structuring of the data to lessen the load on the I/O service routines used by the NOVA. The programs to do this are short and are written in the MC6800 instruction set. They are entered from the CRT terminal through the NOVA by means of a Motorola Firmware MIKBUG before the experiment or test is begun. The use of the microprocessor in this application is an improvement from existing commercial instrumentation because it retains flexibility, reduces the size from a large rack mounted chassis to a single card and reduces the I/O load on the computer.

## SOFTWARE

The ground station includes a Data General Corporation Nova 1200 minicomputer, CRT terminal and disk and a Varian Stratos 33 Printer/Plotter. Separate software packages were received with each of these items as part of the purchase. The programmer has integrated all of the above described devices into a program that reduces the data into a usable form.

That part of the software that is written for the telemetry system is diagrammed in Figures 6 and 7. Figure 6 shows the program in current use for the frame synchronization Input/Output. It can be seen that the program examines the flag word to determine if the remaining frame

contains data. Figure 7 shows the program in use for the airborne encoder. Initialization takes place when the instrument is turned on or after a reset pulse is transmitted from the ground. The data making up a frame is stored in the buffers. The program therefore consists primarily of input and output service.

#### LIST OF PERSONNEL

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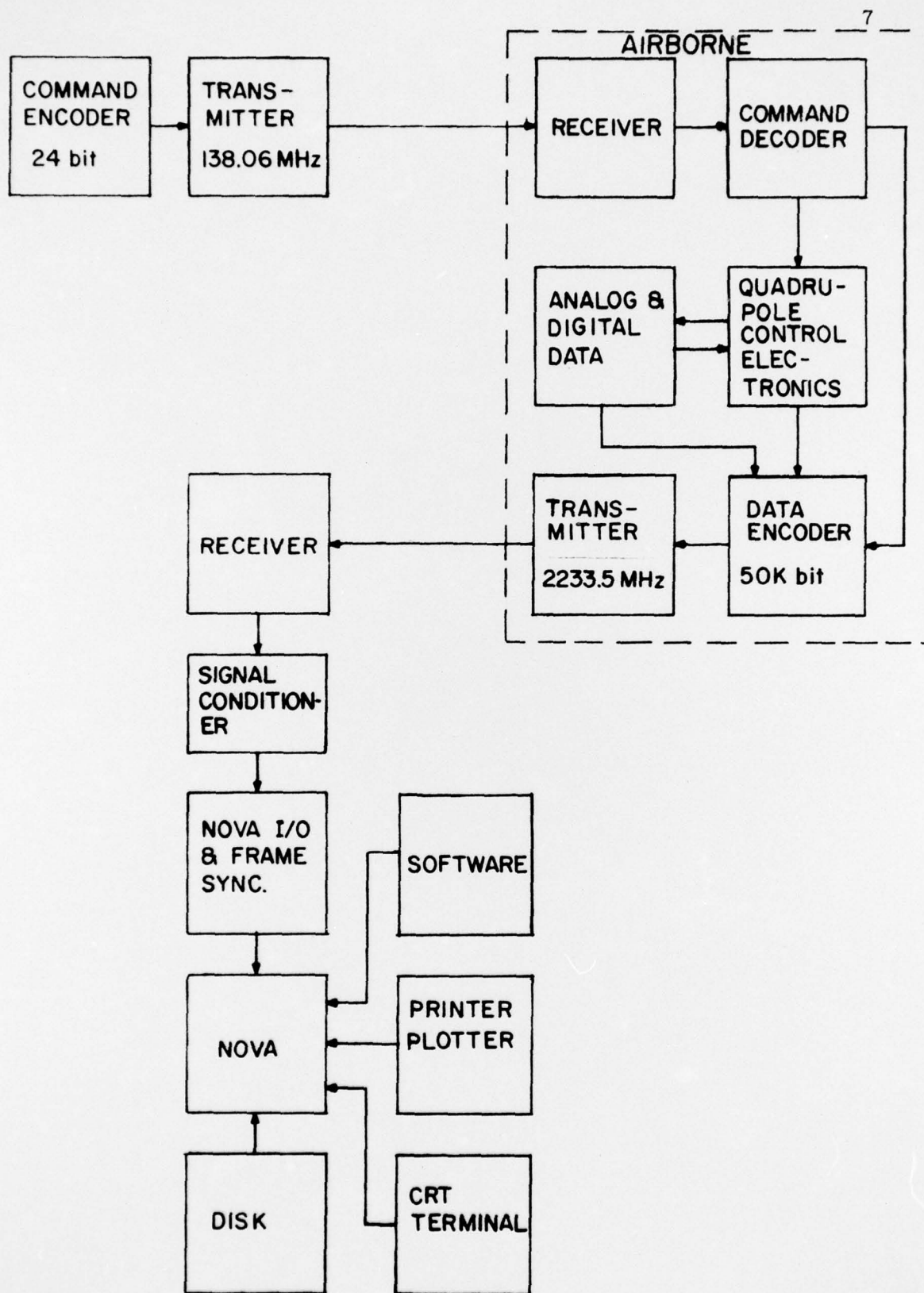


Figure 1. PCM Telemetry and Command System

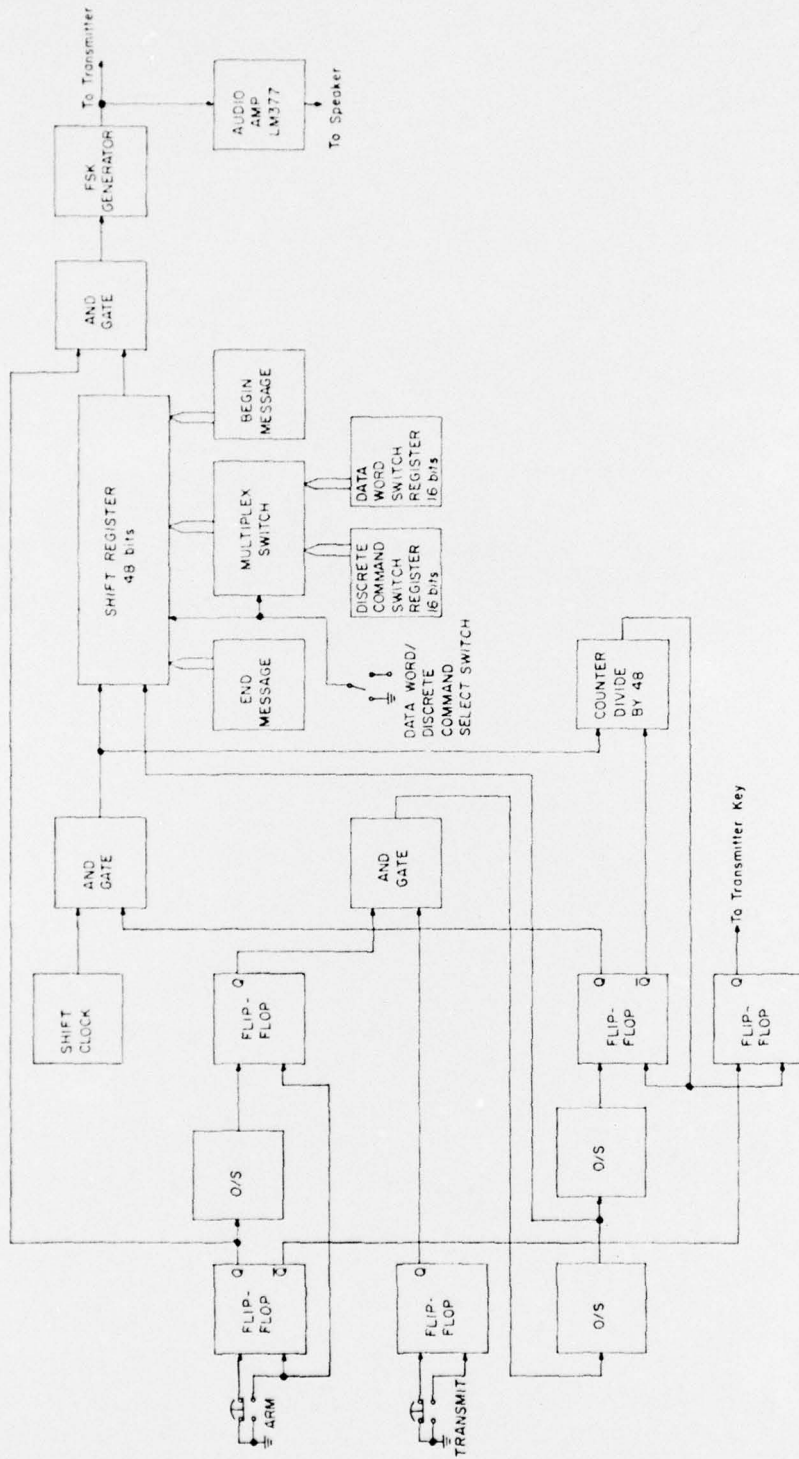


Figure 2. Command Encoder

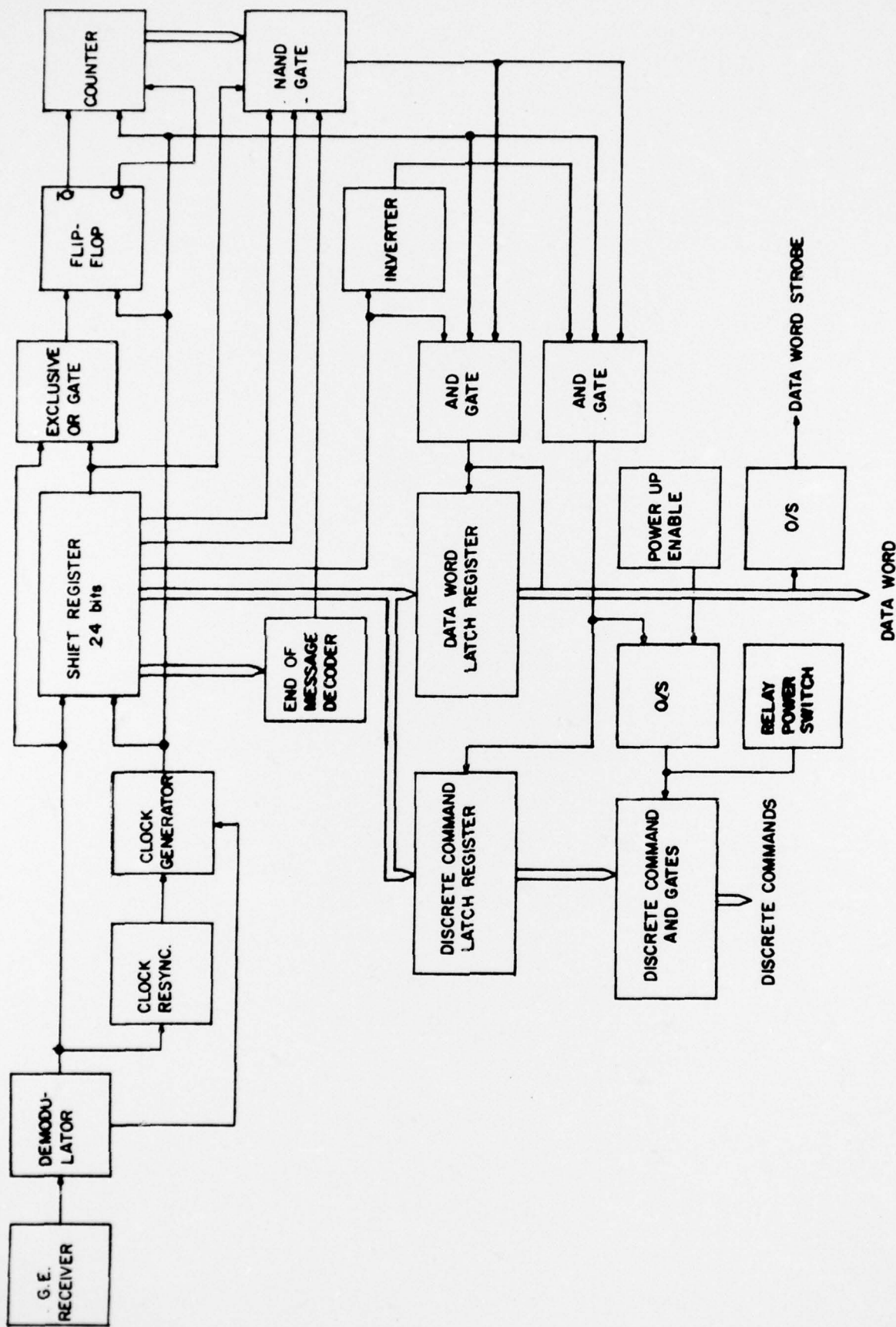


Figure 3. Airborne Command Decoder

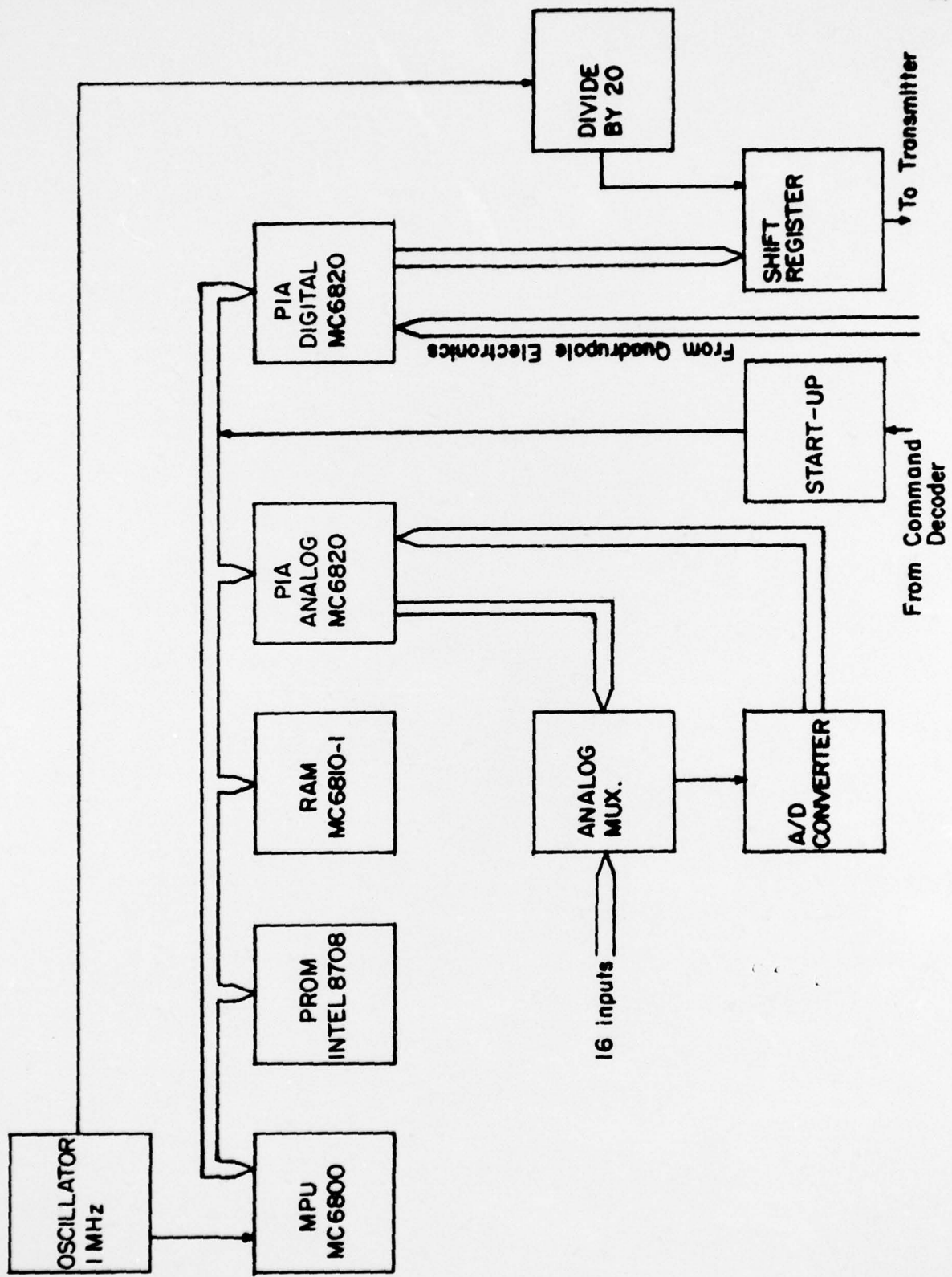


Figure 4. Airborne Data Encoder

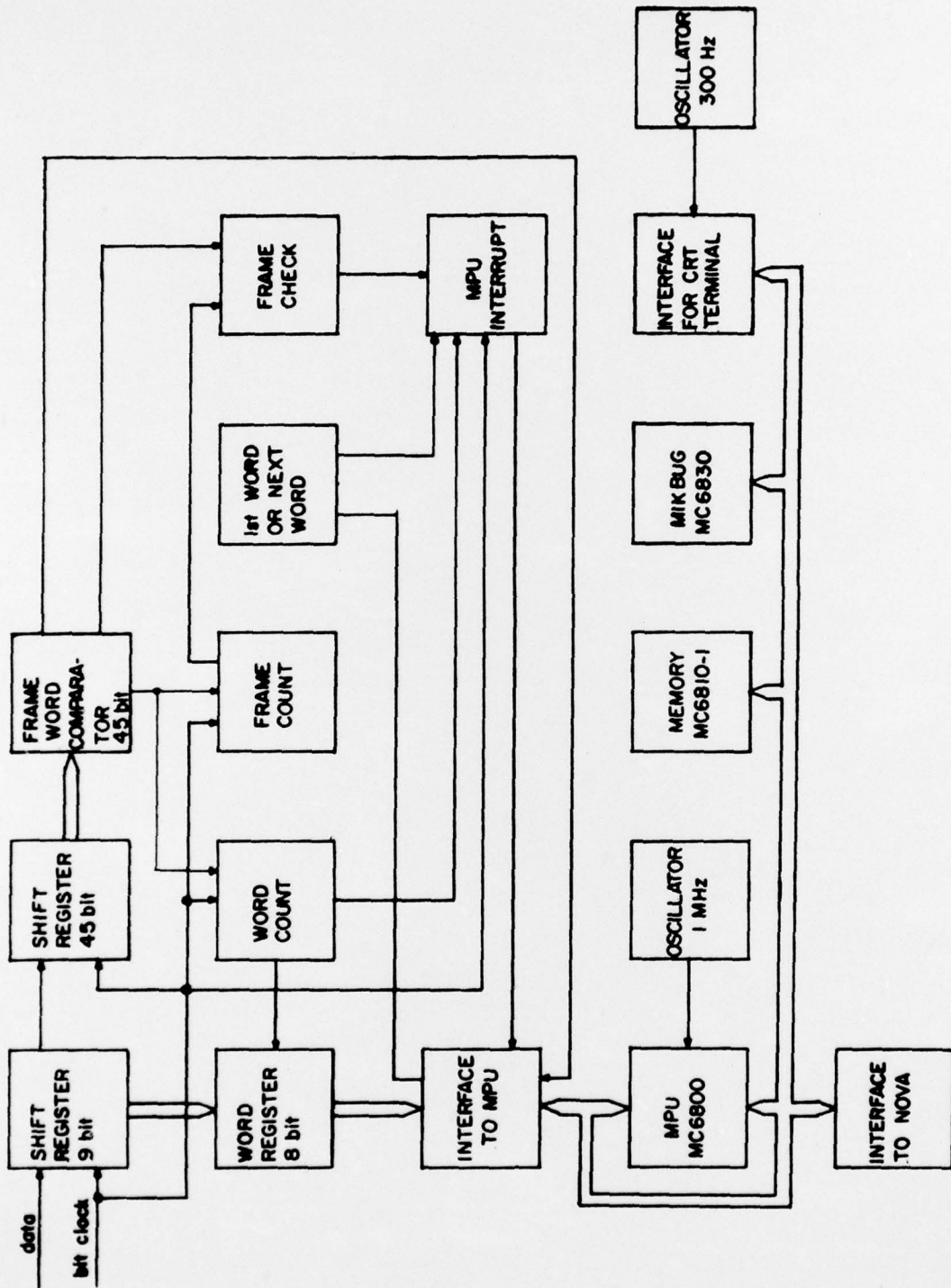


Figure 5. Input/Output and Frame Synchronizer

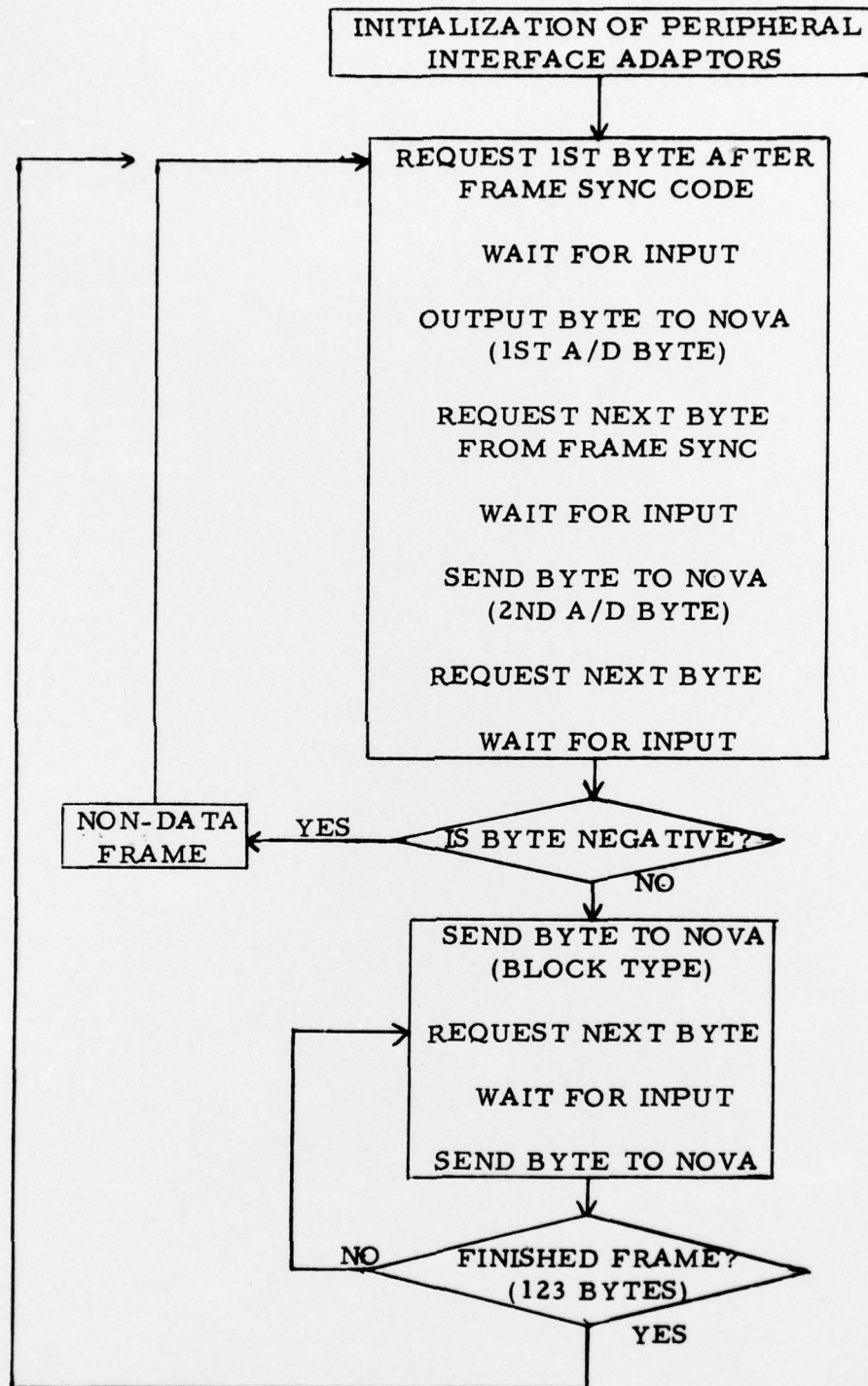
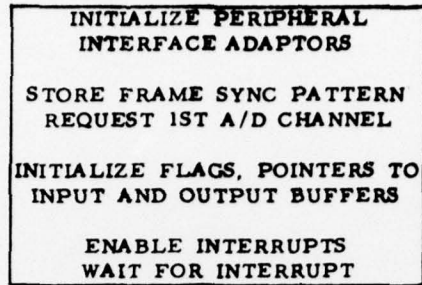
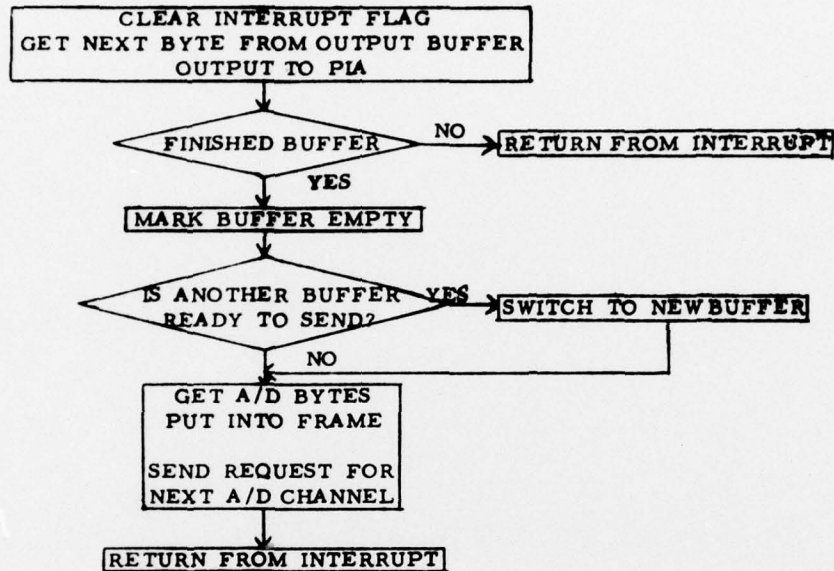


Figure 6. Ground Interface Microprocessor Program



## OUTPUT INTERRUPT SERVICE



## INPUT INTERRUPT SERVICE

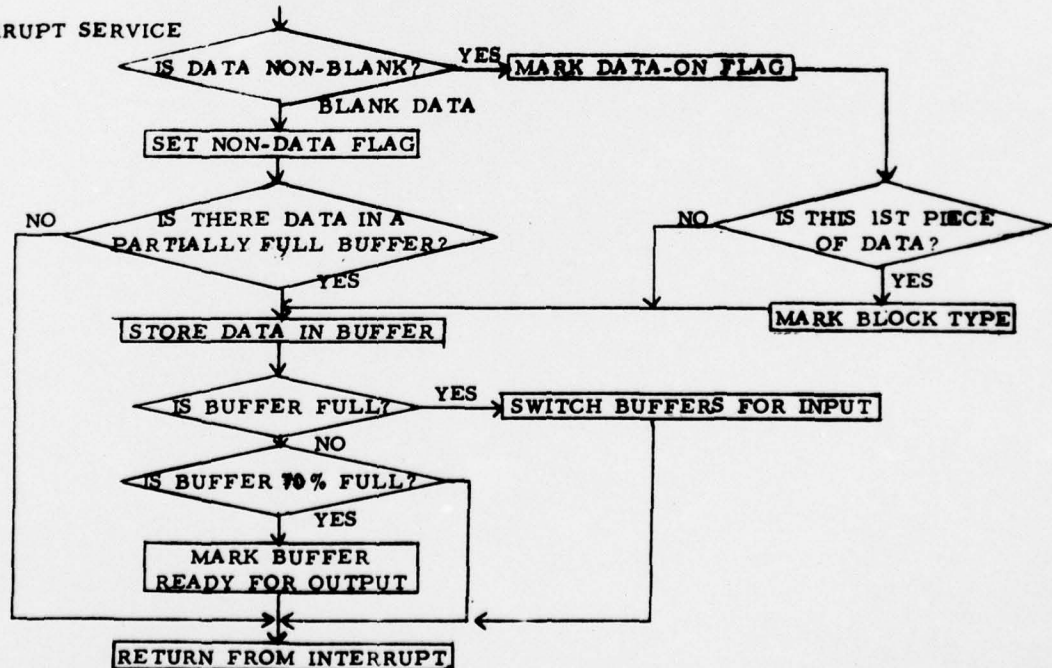


Figure 7. PCM Encoder Microprocessor Program