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AUTOMATED PCM DATA PROCESSOR

THEORY OF OPERATION

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ABSTRACT

The need for an automated PCM Data Processor became apparent during the generation, debugging and verification of Automatic Checkout Test Programs originating with the Saturn I Space Vehicle Launch Program. With the implementation of the Saturn I/IB Systems Development Breadboard Facilities (SDBF) the need for high speed digital equipment capable of performing on-line monitoring of incoming DDAS/PCM data became a necessity in order for test engineers to verify vehicle system integrity and certify test programs approved for use at Kennedy Space Center, Launch Complexes LC 34 and 37B. Such a data processing system would, under program control, scan incoming DDAS/PCM data and provide data information in the form of displays and as outputs to a high speed line printer.

The advent of economically priced, small, general purpose computers capable of operating at high speeds has provided the means for the initial development of an Automated PCM Data Processor. This paper describes the Systems Engineering Laboratories (SEL) Automated PCM Data Processor currently installed and operating within the Saturn IB Systems Development Breadboard Facility (SDBF) and its utilization in the verification of Saturn Launch Programs.

THEORY OF OPERATION

The Automated PCM Data Processor is capable of providing on-line data analysis/reduction at continuous data rates of fifty words per second. Additional hardware, a magnetic tape subsystem, including block transfer control (BTC) is currently undergoing procurement and will permit operating at data rates up to one hundred (100) kilohertz. Such a system will provide test engineers with a highly flexible tool capable of performing the following functions:

1. Real time monitoring of incoming DDAS information, printing those selected measurements on a high speed line printer.

2. By compiling predicted tables, a comparison is made of known vehicle data versus predicted data and permanent records made. Such comparisons are made on a frame by frame basis, with all changes being recorded in real time.

3. Special routines, generated for real time monitoring and analysis of selected telemetry measurements, i.e., LVDA/LVDC Telemetry Register, Switch Selector, during plugs out simulated flight tests, provide on-line information as to actual data words transmitted and quite ably detect errors in program routines. (It should be pointed out that the above tests have been successfully conducted by Chrysler personnel working within the Saturn IB SDF).

4. During other scheduled automatic checkout tests, the Automated PCM Data Processor provides test engineers with a permanent record available for immediate analysis of all vehicle telemetry signals. Such signals could then be correlated with outputs over hardwire that are recorded by the Digital Events Evaluator (DEE).

5. Utilizing the available PCM/FM R.F. link, on site data during launch through signal loss can be monitored and recorded, thus providing a composite flight record of telemetry data. Switch Selector functions originating after liftoff, for example, can be monitored in real time.

6. Automatic checkout of on-board telemetry systems can be accomplished utilizing the available outputs from the Integrated Ground Telemetry Receiving Station.

In order to provide a better understanding of the operational characteristics and advantages of the system, a brief description of the Digital Data Acquisition System (DDAS) and its implementation within the Saturn Program follows:

The current Digital Data Acquisition System (DDAS) is implemented within the Saturn IB/V Launch Complexes and Systems Development Facilities to perform the functions outlined in figure 1. The DDAS system provides real time analog and discrete displays to electrical support equipment (ESE) located within the

Launch Control Center (LCC) and within the Saturn IB/V complex. It also provides analog and discrete signals to checkout equipment within the Launch Umbilical Tower (LUT). By utilizing the Saturn IB/V DDAS Computer Interface, data originating either on vehicle stages or through the ESE Ground DDAS may be monitored by the Automatic Ground Control Station (AGCS) and LCC RCA-110A launch computers, thus providing a means for closed loop checkout.

DDAS-System Description

The operation of the Digital Data Acquisition System is basically as follows. Those analog and discrete signals originating within the LUT or AGCS area desirable for transmission over the Ground Transmitter (ESE DDAS) are routed to centralized analog and discrete patch racks, where they are routed through common cables as inputs to the analog or digital multiplexer. The outputs of the ESE ground transmitter is routed to the AGCS DDAS line driver assembly, to be amplified and transmitted to the Launch Control Center (LCC) and also demodulated to provide a serial data wavetrain to the associated DDAS ground receiving station located within the AGCS area.

Similarly, discrete and analog information generated on board the respective stages of the space vehicle are conditioned, gathered in measuring distributors and routed to the respective analog or discrete inputs of on board pulse code modulation/DDAS (PCM/DDAS) telemeters, where they are made available over established R.F. links and via the frequency modulated (FM) 600 KC DDAS VCO, whose output is routed to the AGCS line driver rack. The respective stage inputs are then amplified, transmitted to the LCC and demodulated within the line driver assembly, where the video waveform is routed to the associated AGCS Digital Receiving Station.

The AGCS/LUT Digital Data Receiving Stations are primarily utilized for the purpose of decommutating and placing incoming DDAS data in a format suitable for the DDAS Saturn IB/V Computer Interface located within the AGCS/LUT area. Within the Saturn V program, the AGCS DDAS ground stations have the additional capability of supplying discrete and analog information to stage oriented checkout equipment.

The DDAS Line Driver Assembly fulfills four functions within the DDAS systems, as follows:

1. Amplifies the DDAS VCO output of stage and ground transmitters, providing the required driving capability to overcome long line transmission loss into the Launch Control Center (LCC).

2. Provides dual redundancy in data links to the Launch Control Center (LCC).

3. Demodulates the incoming DDAS signals and provides a video waveform input to the respective ground and stage DDAS ground receiving stations located in the AGCS/LUT areas.

4. Provides buffered DDAS VCO outputs (on a stage basis) to the measuring facilities located within the launch structure.

The line receiver in the LCC area receives the 600 kHz PCM/FM data signal from the line driver and attenuates it to approximately five volts. The line receiver provides two outputs: (1) a 600 kilohertz (kHz) PCM/FM data signal to a tape recorder, and (2) a demodulated data signal to a digital receiving station (DRS). The LCC DRS transfers the data to the LCC computer interface where it is stored in a magnetic memory. The data is then available to the RCA-110A computer, via the input-output data channel (IODC), upon command from the computer. The LCC Digital Receiving Station also feeds data to the digital to analog (D-A) converters where it is converted to a 0 to 10 volts (dc) level. These analog outputs are provided to display panels in the LCC networks area. Discrete outputs are also provided to LCC networks display panels.

System Implementation

The Automated PCM Data Processor is currently implemented within the Saturn IB SDF to provide capability for on line monitoring of vehicle and ESE DDAS signals on a stage basis. (Reference Figure 1) The following systems are currently interfaced into the Automated PCM Data Processor:

1. DDAS

   a. Serial PCM Data - Serial data in KRZ(S) format occuring at a 72 KHz bit rate. (Reference Figure 2).

   b. Bit Rate Clock - A 72 KHz clock occuring at the DDAS data bit rate.

   c. Reset Pulse - A reset pulse, 5 microseconds wide, occuring at master frame rate (250 ms) generated within the DDAS ground station utilizing existing circuitry.

2. Data Valid Signals - In order to determine that the DDAS data is of good quality, data valid signals currently available in the ESE display are utilized as priority interrupts. Receipt of any data valid signal (where that stage is being scanned) results in a message printout "DDAS DATA INVALID."

3. Count Clock - The twenty-seven bit Eastern Standard Time (EST) data (in Gray Code format) or Greenwich Mean Time (GMT) is required for input to the automated PCM Data Processor.

4. External system commands - In order to synchronize the "START SCAN" of various program routines, it is possible to utilize lower levels of priority interrupts (PI) to activate a specified program. Work is currently under way to make use of existing network "lift off" functions to permit synchronization of specified test programs and computer programs. Some examples of these signals are: a) Count clock liftoff command, b) vehicle (stage) liftoff commands, and c) recognition of specified discrete inputs to the vehicle networks that control the start of specified vehicle test programs.

System Operation

According to test requirements, a stage DDAS input and its associated synchronization and validation signals are selected by operator control at the computer interface unit. Within the computer interface unit, incoming data is received, reshaped, and shifted into a ten bit serial register shift pulses derived from the incoming bit rate clock. The bit rate clock is simultaneously counted down to data word rate (139 s) and a transfer clock generated on bit time ten (BT-10) is utilized to store incoming data from the ten bit serial register to a ten bit holding register where the stored data is made available to the input/out channel. Decoded count 10 of the bit rate clock is also stored and utilized as a word rate priority interrupt (PI) to the SEL general purpose computer.

A second priority interrupt (PI) is generated within the computer interface logic by detecting the incoming master frame synchronization pulse, storing it, and gating it out to the computer at bit time ten (BT-10) as the MFT priority interrupt (MFT-PI). This priority interrupt is utilized by the computer to ascertain that synchronization of incoming PCM data and a program derived word counter is maintained. Synchronization is maintained by checking the contents of the computer derived word counter upon receipt of the MFR priority interrupt for a count of one. Normal program action then calls for the word counter to be reset to count one. If the coincidence of the received reset P.I. and the word counter does not occur at count one, the word counter is automatically reset to count one and a "loss of sync" indication is generated by the computer. Automatic resynchronization is accomplished under program control.

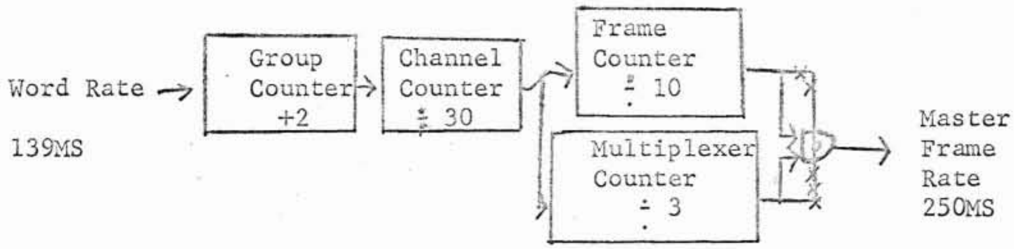
OPERATIONAL PROGRAMS

1. General

A. PCM Format - The standard Saturn IB and Saturn V PCM format is a serial wavetrain of 1800 ten bit words. Each complete cycle (1800 words) is called a "Master Frame". A master frame is completed every 250 milliseconds.

Each time slot (word) is identified by the following address format:

Group (A and B), Channel (1 through 30), Frame (1 through 10), multiplexer (1 through 3). The address is advanced from word 1 through word 1800 as shown in Figure 1.



B. Special Addressing - Many signals are multiplexed so that they occur on all frame and/or multiplexer addresses. These special addresses are referred to as frame 0 and/or Mux 0. Signals on these special addresses occur at the following rates:

MUX 0	-	3 times per master frame
FRAME 0	-	10 times per master frame
MUX AND FRAME 0	-	30 times per master frame

In a discrete scan a new word with a fully specified address may be inputted and compared to its previous value by using the index count to directly locate the previous word in an 1800 word table. If this method is used for a Frame 0 and/or Mux 0 address, the program will detect 3, 10 or 30 changes for 1 change in the input signal.

To eliminate this condition indirect addressing is used to refer a frame 0 and/or Mux 0 to one specific memory location. Precisely the first channel and group location in the 1800 word table. All other locations for this signal contain a "DIRECT ADDRESS CONSTANT" which refers to the first location.

2. Display Program

A. Description - The display program provides binary and decimal displays of selected signals in five different locations, 1 local display, three remote displays and a high speed line printer. A loader is provided in the program for loading predicted values for comparison with input signals. These are:

1 - High value
2 - Low value
3 - Nominal (run) value

Also provided is a loader for entering five alarm limits. If an out of tolerance condition is detected, a lamp will be illuminated on the display panels and also a relay contact closed for operation of an audible alarm or remote lamp.

Selection of signal(s) to be displayed on the decimal and binary lamps is made by a set of address switches on the associated display panel. Three switches; high, low, and run, select the actual, predicted, and difference values that will be displayed. The local binary displays are updated during the work interrupt time.

The main program, or "BACKGROUND PROCESSOR" examines the address select switches and pulls the specified data from the 1800 word table, and the predicted value from the predicted table. The difference is calculated, then all data is formatted and output to the respective display.

Other signals displayed are an in sync indication that verifies the program is "IN SYNC" with the incoming PCM, and a parity indication which serves as a data valid indication.

B. High Speed Line Printer - As a sense switch option, data may be outputted to a high speed photoelectric line printer. This printer is capable of printing data in real time at the maximum data rate of 120 samples per second, i.e. Mux 0 and Frame zero. Two modes of printout are available, binary or decimal. Selection of signals to be printed and mode of printout are made by switches on the printer control panel.

1. Discrete Monitor

a. Program Description - The Discrete Scan Test will perform real time scan on a stage basis (10 bits at a time). Changes will be stored in a change table along with an identification word and the time (EST Gray Code). The Real Time Scan will be under control of the word rate interrupt. The main program or "Background Scan" will scan the change table. If a "Change" exists the data will be converted and printed on the high speed line printer. The change table will be capable of backlogging at least 1000 discrete changes.

b. Printout Format - One of two forms of printout may be selected:

1 - MEAS NUMBER	ON/OFF	TIME
2 - DDAS ADDRESS	WAS/IS	TIME

c. Discrete Change Rate - The discrete scan test will be capable of handling short term bursts of 1000 discrete changes and thereafter sustaining 10 changes per second.

NOTE: This does not limit the rate of change to 10 per second unless the "Backlog" is full.

d. Selection of Signals to be Monitored - To allow for updating due to changes in vehicle configuration, the selection of signals to be monitored will be loaded on a separate tape or through the typewriter keyboard at run time.

e. Memory Required

1 - Main Program	Approx 2K
2 - Tables	Approx 11K
3 - Total	Approx 13K

2. Flight Computer Monitor

a. Description - The present flight computer monitor program monitors the tag bits and real time latch bits 4 and 5 for a change. Upon detection of a change the entire 40 bit flight computer word is printed out. A forced print may be obtained by sense switch option.

b. Format of Printout

Tag	Real Time Latch	Data	Parity	Time
XXX$_{(8}$	XX$_{(8}$	XXXXXXXXX$_{(8}$	X	

c. Speed - The program is capable of backlogging 1000 flight computer words, and printing ten words per second.

3. Switch Selector Monitor

a. Description - The switch selector monitor program will be capable of real time monitoring of the switch selector output. Upon detection of a change in output the new data and the time will be stored in an output table under control of the word rate interrupt. The main program will then scan the output table and print the changes on the line printer.

b. Output Format

FUNCTION	VERIFICATION BITS	TIME

c. Speed - The program will be capable of backlogging 1000 changes and printing at 10 changes per second.

CONCLUSION

The Automated PCM Data Processor described in this paper was designed for the primary purpose of performing on line data monitoring and evaluation. The present system is quite capable of handling the normal telemetry system data rates, i.e., the rate of change of incoming data permits the data of processor to operate in real time. For those telemetry data measurements that are supercommutated, the addition of the magnetic tape unit and associated block transfer control will permit the data processor to handle data changes occurring at rates in excess of two hundred and forty samples per second. Within the Saturn IB Systems Development Breadboard Facility (SDBF), this particular data system will be utilized as a test aid to verify the proper operation of Automatic Launch Checkout Programs generated for use at Kennedy Space Center Launch Complexes LC-34 and LC-37B.

It is expected that as the technique of automatic launch and checkout continues to be refined that additional systems such as the one described in this paper will assume larger roles in data reduction.

ACKNOWLEDGMENT

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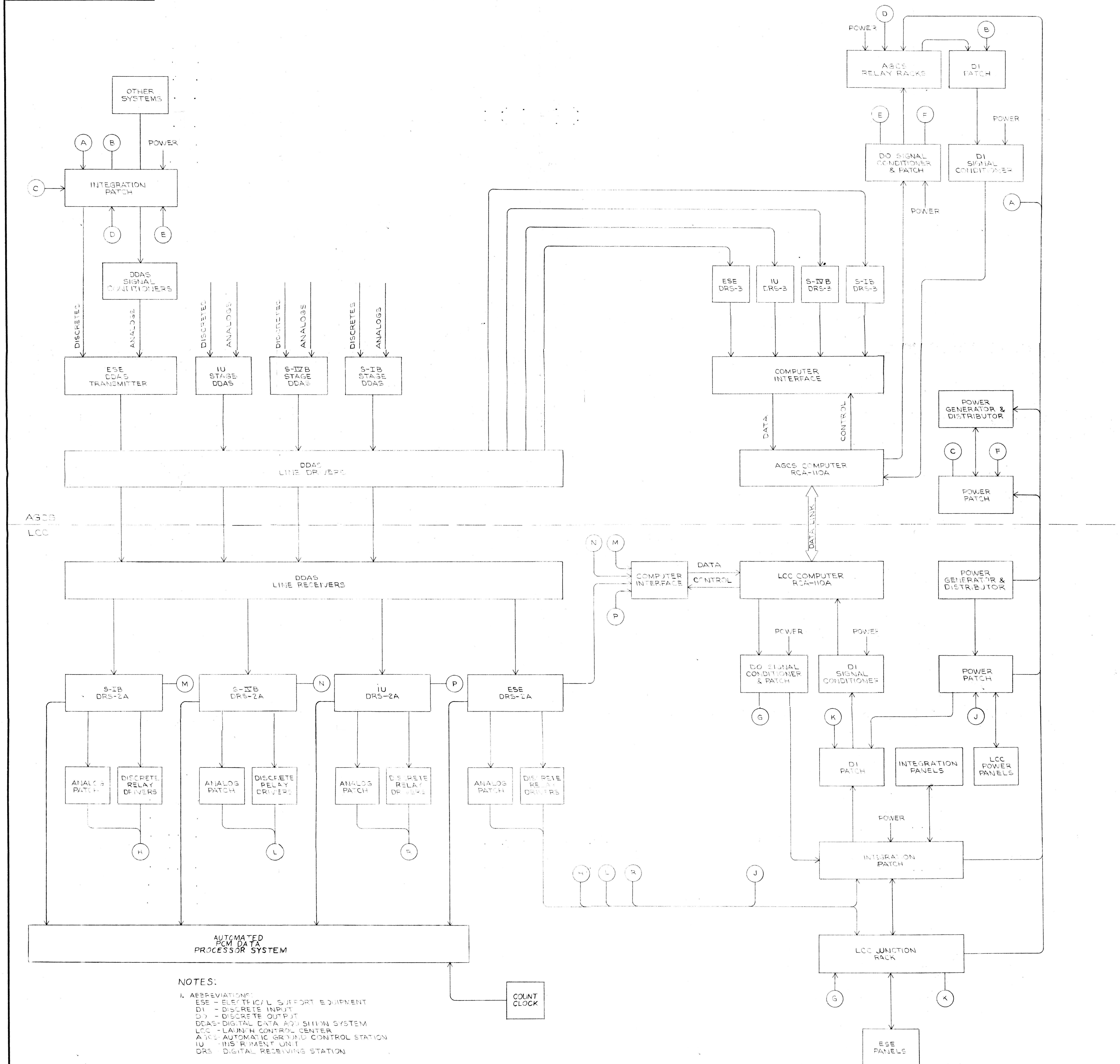
PART No.	NP	REVISIONS				
		ZONE	SYM	DESCRIPTION	DATE	APPROVAL



NOTES:

1. ABBREVIATIONS:
   - ESE - ELECTRICAL SUPPORT EQUIPMENT
   - DI - DISCRETE INPUT
   - DO - DISCRETE OUTPUT
   - DDAS - DIGITAL DATA AQUISITION SYSTEM
   - LCC - LAUNCH CONTROL CENTER
   - AGCS - AUTOMATIC GROUND CONTROL STATION
   - IU - INSTRUMENT UNIT
   - DRS - DIGITAL RECEIVING STATION

FIG. DDAS SYSTEM BLOCK DIAGRAM

NO REQD PER ASSY · ASSY DASH NO · ZONE · FIND NO OR ITEM NO · MFR CODE · PART OR STOCK NO · DRAWING NO · REV · SPECIFICATION, STANDARD OR REMARKS · DESCRIPTION · STOCK SIZE · MATL SPEC · FINISH CODE · WT · UNIT WT · DISTR CODE

LIST OF MATERIAL

SEE ENGINEERING RECORDS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES

ORIGINAL DATE OF DRAWING · DRAFTSMAN · CHECKER · STRESS · ENGINEER · SUBMITTED · APPROVED · DIRECTOR

MATERIAL · HEAT TREATMENT · FINAL PROTECTIVE FINISH

NEXT ASSY · USED ON · APPLICATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

DWG SIZE E · WEIGHT CHECKER · DATE · CODE · SCALE · UNIT WEIGHT · SHEET OF

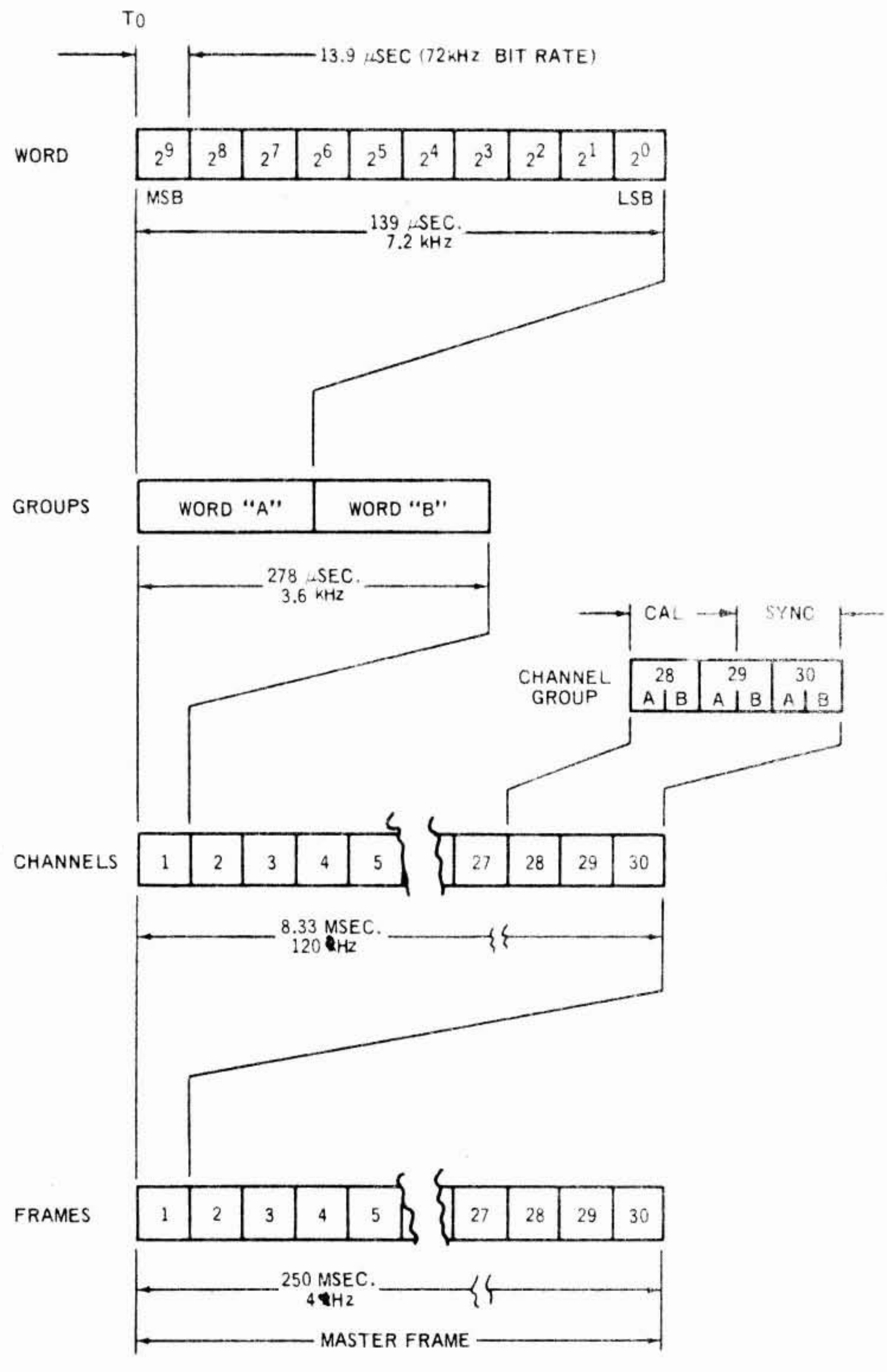


FIGURE 2 PCM/DDAS TIME FORMAT