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AIR FORCE REPORT
SD TR-79-12
VOLUME II

LEVEL III

GLOBAL POSITIONING SYSTEMS (GPS) HIGH DYNAMIC USER EQUIPMENT (HDUE) SET DESCRIPTION

VOLUME II

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This report has been reviewed by the Information Office (OIS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations. This technical report has been reviewed and is approved for publication.

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18 SAMSO

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VOLUME II

HDUE SET DESCRIPTION

1.0 INTRODUCTION

This section of the Texas Instruments HDUE Final Report as called out in Contract Data Requirements List (CDRL) sequence number A003 on contract F04701-75-C-0180 describes the design of the HDUE set as implemented in Phase I of the Navstar Global Positioning System (GPS). Historically, sophisticated equipment was designed and fabricated to meet its specific requirements. Although such an approach may be simplest to undertake, it provides only minimum production advantages to each user application. Life-cycle cost and risk for each configuration are typically high. In an attempt to offset some of these disadvantages, there is an inclination toward the development of three or four standard system configurations, one of which may be selected for a specific user application. Such an approach does afford some advantages as a result of the potential increase in production of each configuration, but in most cases it will result in compromise of performance and physical characteristics.

A more effective approach for achieving utility and affordability can present perhaps the more difficult initial design and development issues. This approach requires establishing user equipment commonality, not at the system level, but at the subsystem level so that similar functions in different user configurations can be isolated and generalized to use identical circuits or subroutines. These building blocks or common modules can be used to satisfy every user equipment requirement and consequently, provide the maximum production volume advantage. Because of the flexibility and commonality established at this level, performance and physical characteristics are not compromised for specific user requirements. Component technology improvements can be incorporated with minimum perturbations to other functional elements. The results is an approach that permits the concentration of efforts in subsequent development phases to be aimed toward product and cost improvements that are beneficial to all users and not encumbered with the difficulties of the "slight" variations of system characteristics and performance that often result in major system level incompatibilities, forcing the evolution toward uniqueness, rework or redesign.

The design of common modules must be preceded by a careful definition of the functions to be performed by each module. This definition is evolved through an iterative elevation process centered upon variables such as GPS equipment functions to be performed, current and projected component technology, performance, physical characteristics, and cost. Basically, this process follows the general steps listed below (illustrated in Figure 1-1 and 1-2):

1. Definition of functions to be performed by GPS user equipment

2. Separation of these functions into two catagories:
   - Those sensitive to applications and
   - Those not sensitive.

3. Subdivision of application-insensitive functions into elements grouped to provide maximum commonally over the span of identified user requirements.

4. Design of common modules that provide the performance required of these elements.

The design of each common module was guided by imposing constraints defined by the requirements containing the worst case condition applicable to the module. For example, the design requirement for size, weight, and power may be driven by a man-portable requirement while performance and environmental constraints may be driven by missile or satellite requirements. In addition, other constraints and controls were eatablished that guided the common module design to cost efforts.

The system concept and design resulting from this effort permit maximum commonality between various system designs through the use of different quantities of common modules to satisfy specific performance requirements. Also, because of the functional nature of modules, improvements to accommodate performance requirements were incorporated with minimum impact.

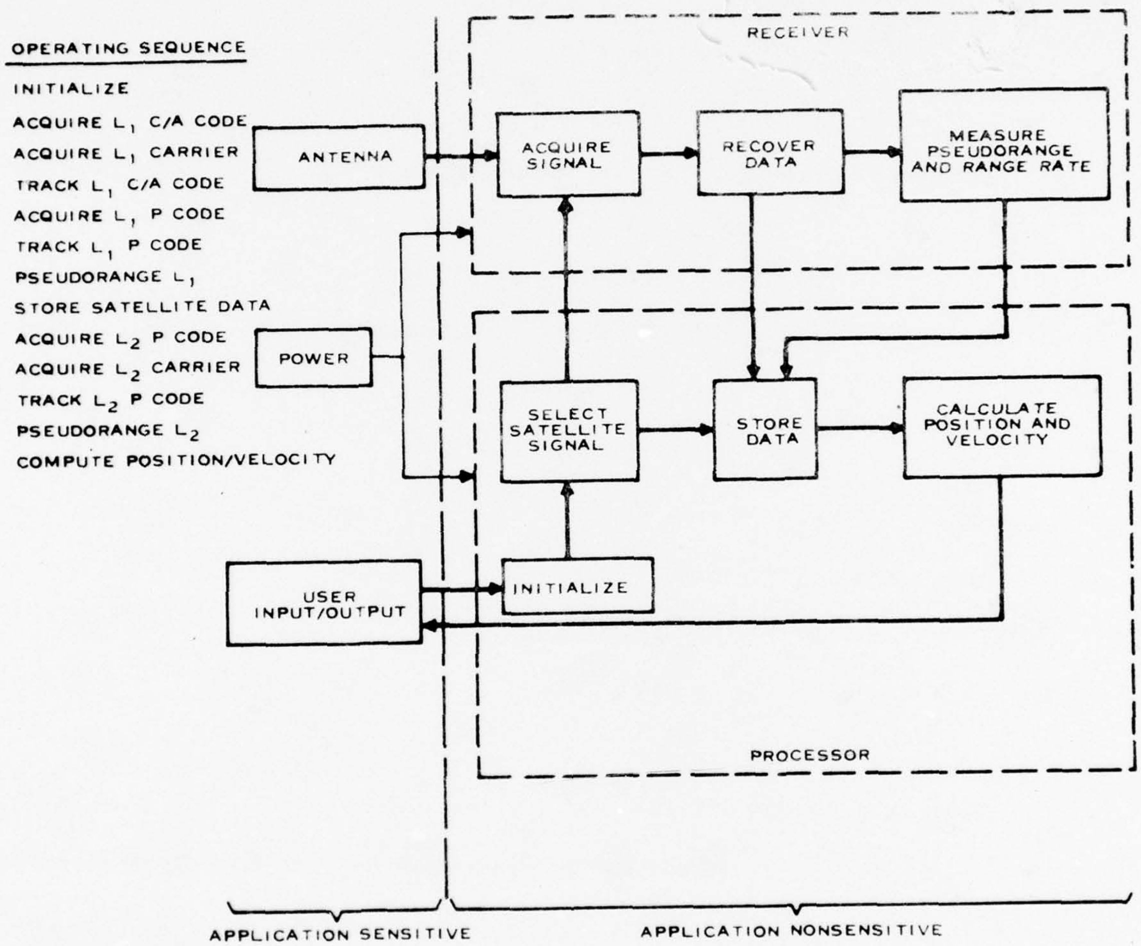

Figure 1-1. Functional Systems Operation

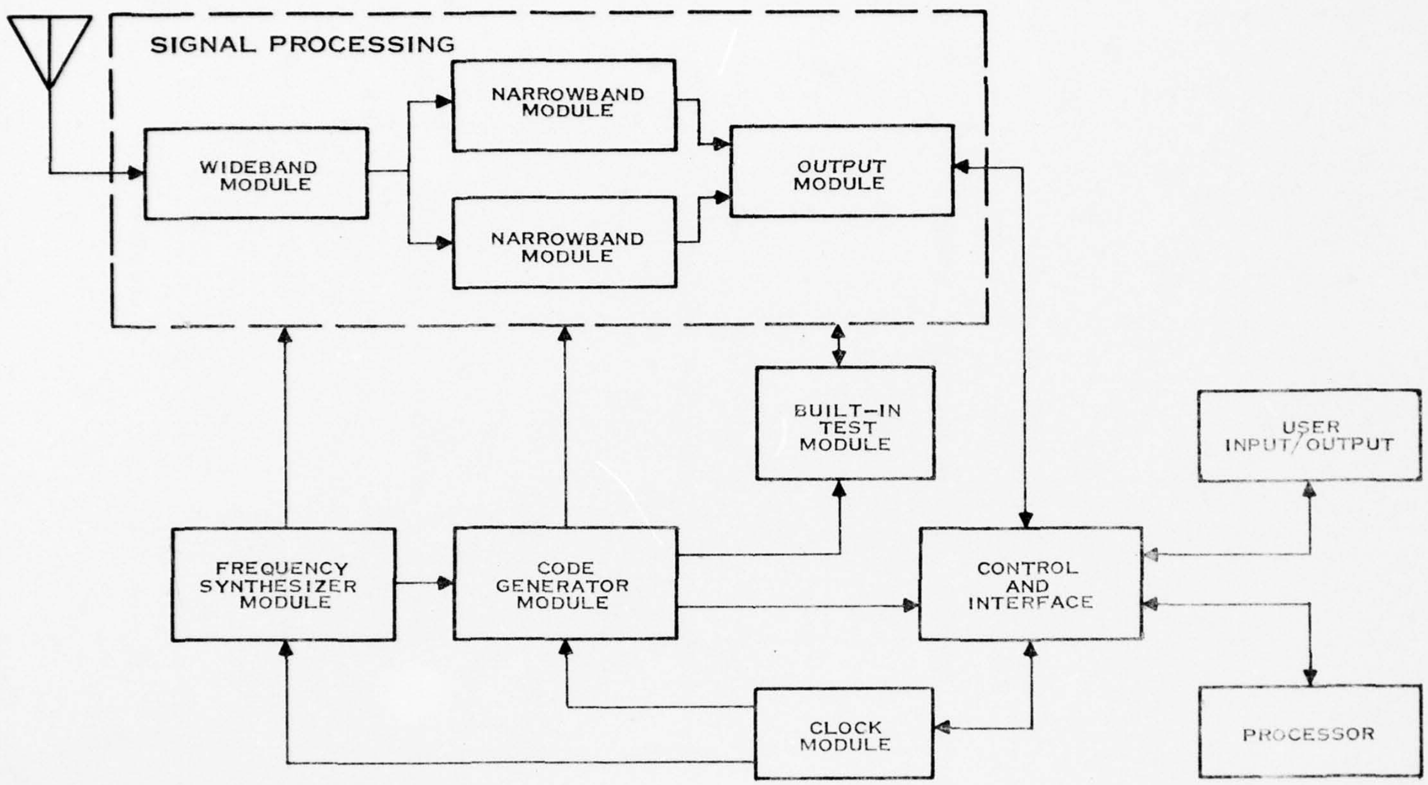

Figure 1-2. General Block Diagram

2. SYSTEM DESCRIPTION

The HDUE set consists of four major line replaceable units (LRUs). They are the receiver, data processor, AD/DC converter and CDU. There is also an optional instrumentation interface LRU. The units are shown in Figure 2-1. The receiver LRU is composed of five continuous tracking receiver channels and a receiver control processor. An existing GFE antenna/preamplifier was used for tests. The data processor LRU consists of the master state controller and the navigation processor. All GPS-control processors are designed around the SBP 9900 microprocessor. The CDU has a calculator-type keyboard and an incandescent daylight readable alphanumeric display. A block diagram of this set is shown in Figure 2-2. Major characteristics of HDUE performance are presented in Table 2-1. Requirements for detailed characteristics are shown in Table 2-2. The HDUE major modes of operation are shown in Figure 2-3.

The HDUE set tracks four satellites continuously using four receiver channels. The fifth receiver channel is used for SV acquisition, L1/L2 ionospheric correction measurement, and reading of data. The HDUE tracks both L1 and L2 satellite frequencies and uses both C/A and P codes during the acquisition process. Navigation calculations are made using an 11-state Kalman filter.

The HDUE set can handle two antenna inputs (inverted range or satellite antenna) and switch either of these two inputs to any one of the five receiver channels (2 X 5 matrix switch). Input initialization data (position and time) are entered by means of the keyboard on the CDU. Output data (position, velocity, time, etc.) are displayed on the CDU. The same receiver and processor common modules are used in the HDUE as are used in the MVUE. Software is programmed in both Fortran and 990 assembly language. The hardware characteristics of the HDUE implementation are summarized in Table 2-3.

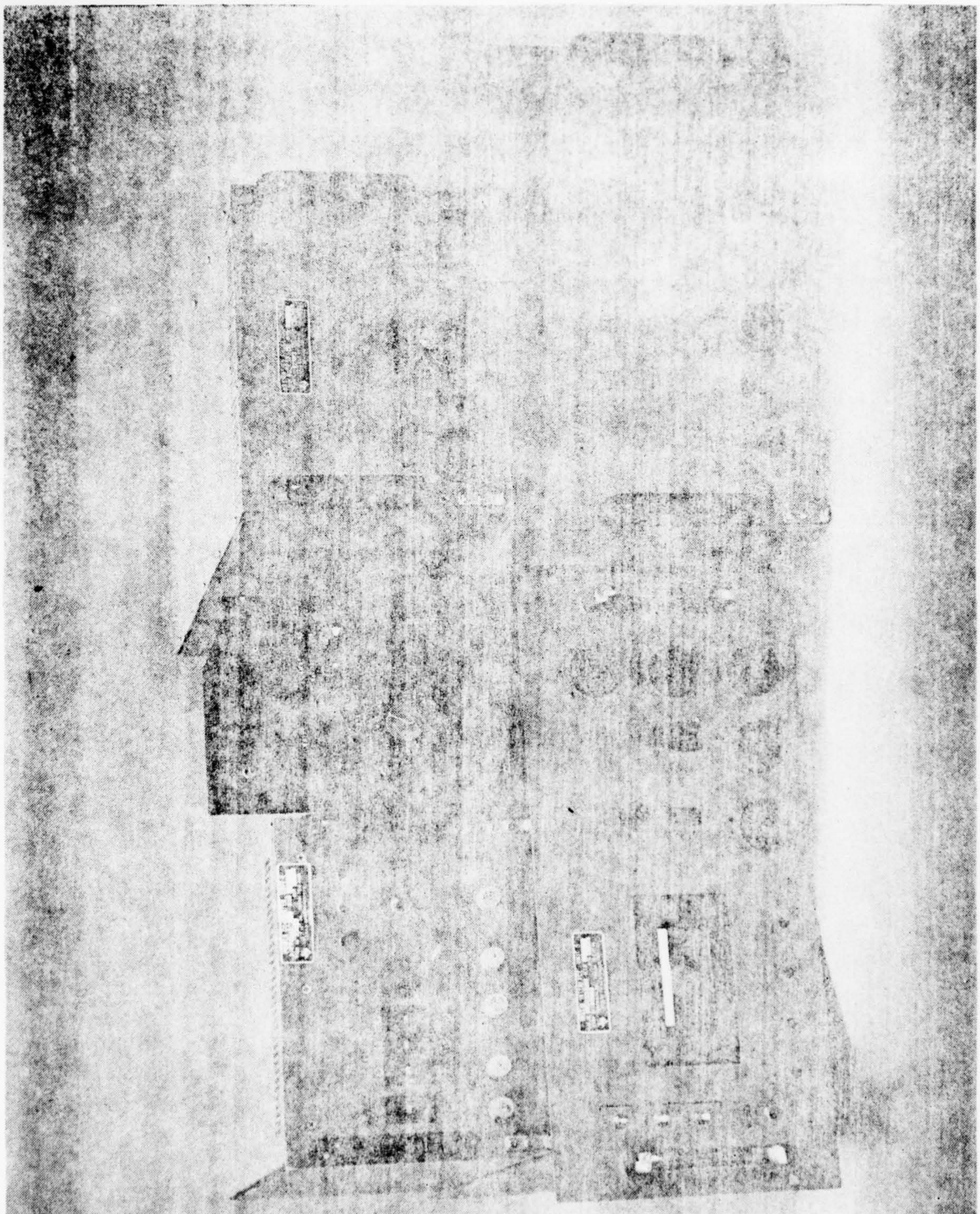

Figure 2-1. High Dynamic User Equipment

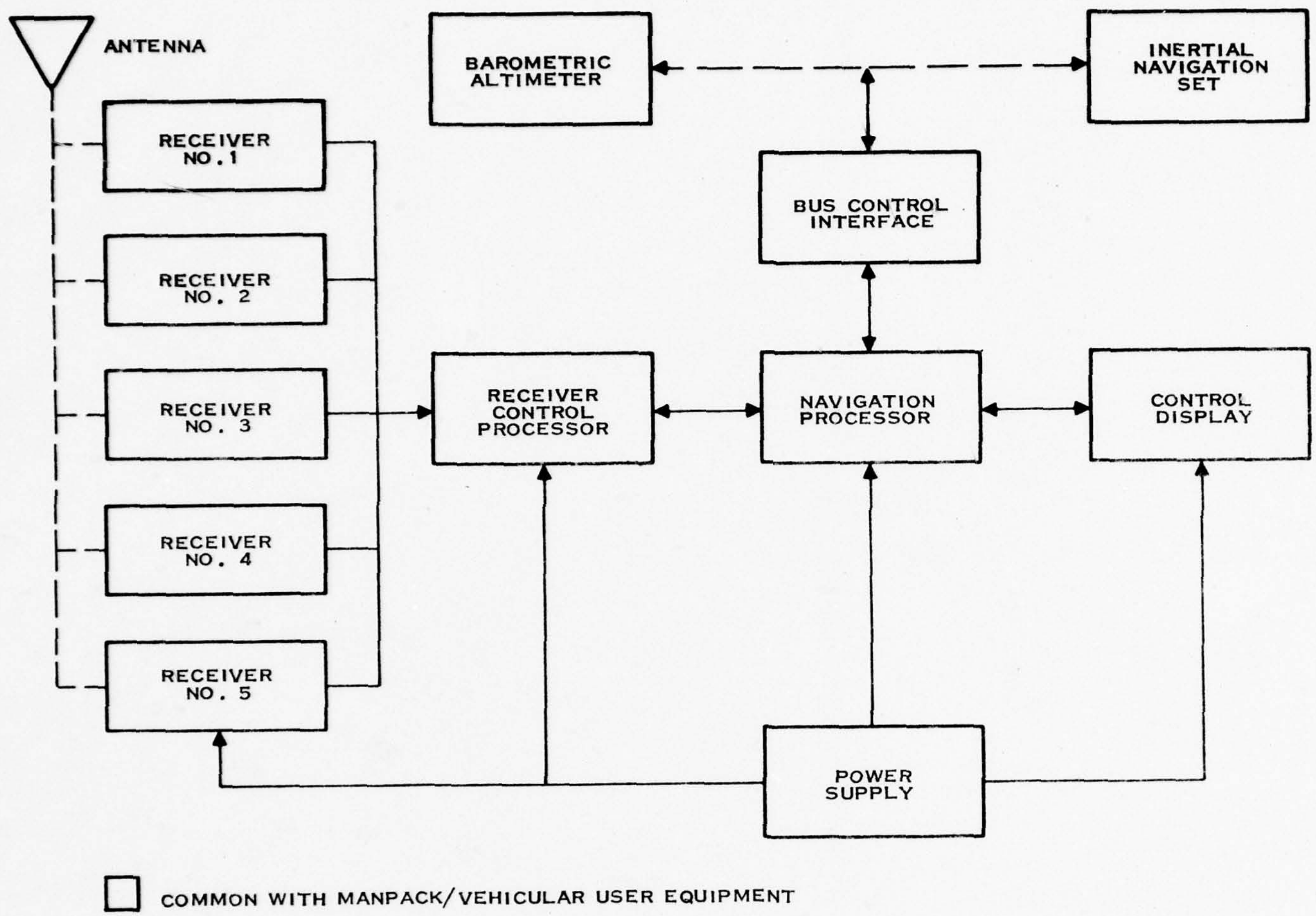

Figure 2-2. High Dynamic User Equipment Block Diagram

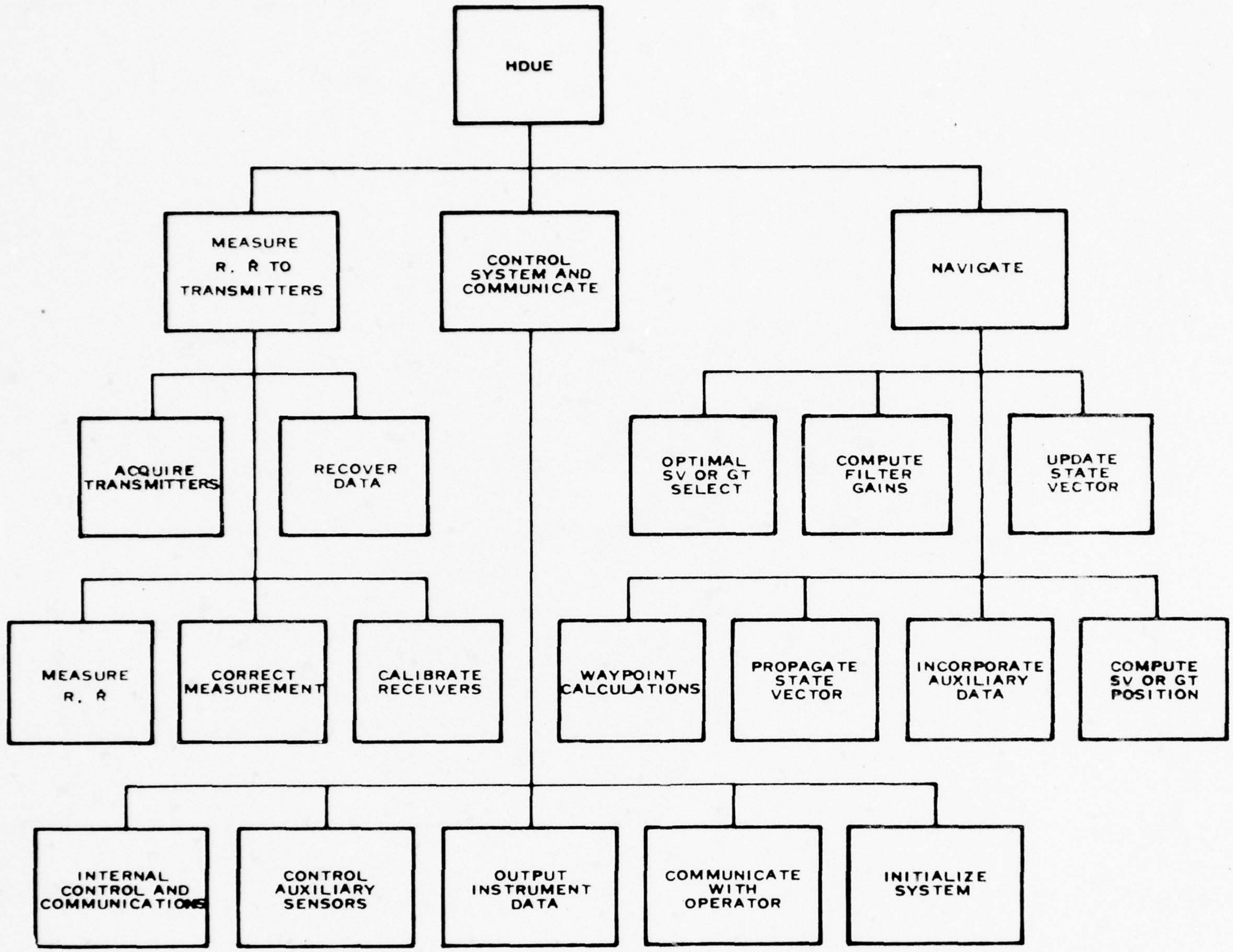

Figure 2-3. HDUE Major Modes of Operation

TABLE 2-1. HDUE MAJOR CHARACTERISTICS

Range measurements accuracy	
(J/S = 30 -40 dB)	
Coarse (C/A code)	15 meters (1)
Fine (P code)	1.5 meters (1)
Resulting position accuracy	
Horizontal	10 meters (CEP)
Vertical	10 meters (PE)
Intrinsic Maintainability design	
LRU replacement	5 minutes
SRU replacement	10 minutes
	20 minutes maximum

TABLE 2-2 HDUE DETAILED CHARACTERISTICS

SV carrier signal from antenna L and L (dBW)	-166 to -156
Code demodulation	P-code C/A code
User velocity (maximum) (meters/second)	1,100
User acceleration (maximum) (meters/second)	80
User jerk (maximum) (meters/second)	50
Jamming levels, J/S (dB)	
Acquisition	24 (C/A)
Track/lock	40 (P)
Weak-signal hold on	47 (P)
Time-to-first fix (seconds)	152
Pseudo range rate accuracy at (C/No)	1.5 meters (30 dB-Hz)
Pseudo range rate accuracy (meters/second)	0.2
Mean time between failures (hours)	500
Temperature range	-20 to +55 C

TABLE 2-3. HDUE HARDWARE CHARACTERISTICS

No of LRUs	4*
No of receiver channels	5
Size (ft)	3.5
Weight (pounds)	200
Power (watts)	529
Design-to-cost goal (1,000 units)	25K
Receiver modules/channel	6
Total common modules	65
Total unique units	13
Memory size (maximum capability	68K
Memory size required	62.3K
Bits/word	16
Hardware floating point	yes

*5 LRUs including Instrumentation Interface Unit

3.0 HDUE SOFTWARE SYSTEM

General

The HDUE Software operates within the framework of a three processor distributed processing network. Each SBP9900 microprocessor controls a well defined functional subset of the overall GPS user equipment software requirements. The Receiver Control Processor has an extensive hardware control interface and manages the acquisition, tracking and recovery of measurements from GPS signal sources. Because of the hardware control, the Receiver Control software is written in assembly language. The Master Control processor manages the operator interface through the CDU and implements the required Navigation Subsystem and Receiver Subsystem control functions. Each SV data word is passed from the Receiver to Master Control as the word is received from a GPS source. Master Control manages the collection of this data and the overall data block processing mechanism. It also manages the movement of instrumentation data through the IIU hardware to the in-flight UFTIN recorder. The Navigation Subsystem includes the real-time implementation of the Kalman filter. It also contains a Relative Navigation function which handles the conversion of data to different coordinate systems. The SV task in the Navigation Subsystem computes the SV position for use in the incorporation of Receiver measurements into the Kalman filter. Both the Master Control and Navigation Subsystems are implemented in Fortran with the exception of two special purpose Master Control modules in assembly language. There is an Executive Subsystem which is common to all the processors. It is table driven to maximize the commonality both within the HDUE and with the MVUE and MBRS systems. This Subsystem contains all interrupt handlers and implements task scheduling and reentrancy requirements. The executive also maintains the system clock or fundamental time frame (FTF) which is incremented on each 20 millisecond interrupt. All processors are maintained in strict FTF synchronization with this synchronization verified each 320 milliseconds. The 20 millisecond interrupt is generated in the Receiver and is routed to the other processors.

Each of the three processors contains a set of Random Access Memory modules which are loaded through the IIU when the system is powered up. The term word, used to describe memory, refers to 16-bit memory units. The 3 Microprocessor Modules each contain 256 words of Read-only memory (ROM) and 256 words of Random- access memory (RAM). The ROM memory contains front panel access routines and software used during the cold-start load process. The IIU contains a Master Reset control switch which is used to force all processors to execute a cold-start power-up sequence. This control is used following the load process.

The Master Control and Navigation subsytems communicate through a shared memory area of 4096 words which is designated Communications Memory. Each of these two processors has an additional 24576 words of local memory which may be used in any combination of program and data space. The floating point hardware may be used by either of these two processors, but the current software restricts its use to the Navigation Processor in order to eliminate contention problems during critical Navigation computations. The Receiver Processor and other Receiver hardware reside in a separate Line Replaceable Unit (LRU). The Receiver Processor thus shares no common memory with the other processors. Its communications with Master Control are handled with the Serial Data Bus which transfers a 15 word message each 20 milliseconds. The Receiver Processor has 16384 words of memory which may be divided as desired between program areas and data areas.

Software Version History

In the following paragraphs a brief description is given of each of the software versions used during evaluation of the HDUE System at the Yuma Proving Grounds. Each version represents a major step in the evolution of the final software design.

Version 6A

The initial software version to include Navigation capabilities was 6A. Prior to delivery of this version, compatibility of the hardware with the T-pallet and the ability of the Receiver to acquire and track GPS signals was confirmed. Version 6A was delivered to YPG in May, 1978 and provided Navigation convergence with altitude hold on the test range with four ground transmitter sources. Navigation with 1 SV and 3 GT's without altitude hold was demonstrated. Data obtained during version 6A testing provided a baseline for future software enhancements.

Version 6B

This version was sent to YPG in August of 1978 and provided improved filter stability as a result of modelling changes and better filter initialization. Many of the changes in this version were fixes for coding and implementation errors discovered in the field test environment.

Version 6C

Version 6C represented a major stabilization of the Navigation filter design. This version was used in UH-1H testing from September, 1978 through November, 1978 and on the C-141 during November. The Navigation performance was characterized on the UH-1H and extensive analysis of the mission data was performed. The ability of the system to perform in an operational environment was clearly established while parallel software development was proceeding based on minor field discrepancies. The Receiver Software essentially reached its final configuration in this version. Only minor interface changes were made in later versions and no Receiver related problems were reported during subsequent field evaluation.

Version 6D

Version 6D was delivered to YPG in November, 1978 to support the C-141 testing. It contained enhancements to the 6C version and the implementation of additional features not previously part of the software. Some of these improvements included:

1. Rejection of bad Receiver measurements by Navigation
2. Improved filter initialization
3. Revised Ionosheric/Tropospheric equations
4. Full Waypoint computations
5. UFTIN data flow stabilization
6. Improved Filter convergence and stability

7. Resolution of almanac/ephemeris ambiguities

8. Generation of data required by Navy

This software version was the tool used to evaluate the filter performance under the dynamic stress encountered in the C-141.

Version 6E

This version was generated for use with the Navy HDUE system. The only difference from the verion 6D is the addition of patches to the Master Control load module to suppress all IIU blocks except 2 and 206.

Version 7A

The results of the testing with versions 6C and 6D demonstrated less than optimal performance particularly with respect to velocity errors. In addition the version 6D Navigation subsystem was close to 100 percent utilization in both loading and memory with some functions yet to be implemented. Therefore a redesign of the basic filter was implemented in Version 7A which was delivered in February, 1979. The filter was implemented within the basic Master Control framework used in Version 6D and the operator interface remained the same. The most significant improvements were position and velocity accuracy. The convergence region was widened to the point that it ceased to be a problem in the operational environment. Filter stability was such that entire missions were often flown with no operator intervention required after initial convergence. The filter mechanics were modified to allow an outer loop rate of 3.84 seconds versus 7.36 seconds in version 6D. At the same time the Navigation processor loading dropped from near 100 percent to approximately 60 percent with 8000 words of memory made available for additional features to be added in version 7B. Field performance with this version is discussed in the HDUE Field Test Report.

Versions 7B and 7C

In May, 1979 Version 7B was delivered to YPG for initial evaluation. This final HDUE software version contains all the Navigation filter enhancements described in Version 7A with the only differences being in the degraded mode operation (primarily 3 SV altitude hold). The Master Control subsystem and the interface areas of the Navigation subsystem were modified extensively in order to allow the constellation change mechanism to be implemented. Full coordinate conversion capability is a part of this version. The operator interface through the CDU was modified based on field comments received during the first year of testing. In addition the CDU data update rate was increased from 3.84 seconds to 0.64 seconds. The software functions were somewhat reorganized between Master Control and Navigation subsystems in order to distribute the processing load more evenly and to make the subsystems more functional. Automatic SV selection has been implemented and tested at YPG. This software version meets all the operational requirements for the HDUE system.

Version 7C is the equivalent Navy version with all IIU blocks except 2 and 206 supressed.

3.1 HDUE RECEIVER CONTROL SUBSYSTEM

3.1.1 General

The purpose of the Receiver Control Subsystem (RCSS) is to acquire and track those SV'S specified by the Master Control Subsystem (MCSP). Pseudo-range, Range-rate, and time tag information are recovered from each tracking source and passed to MCSP on a 320 millisecond basis. The RCSS executes a General Health Check/ Master Time Delay Calibration in response to a MCSP command. Upon receipt of a Precision Mode command, the RCSS uses the spare channel to execute sequential L1/L2 acquisitions on the SV'S being tracked by the other four channels, with the data from these acquisitions used by MCSP to calculate the Ionospheric delays associated with each SV. The Concentrated Search Mode used for SV acquisition is accomplished by applying all available channel resources to the SV search in the order that those SV'S are commanded by MCSP.

3.1.2 Communications

Data is passed between RCSS and MCSP exclusively via the Serial Data Bus. One 15 word message is transferred each 20 milliseconds with 14 of the words being useable. With the exception of the aiding data messages, all messages operate at a basic 320 millisecond cycle rate based on the local clock (FTF). To allow double buffering of the aiding data it is written into alternate buffers each 320 millisecond period. Data is passed to the RCVR on 4 of the 16 20-millisecond subframes and on the other 12 data is returned to MCSP.

The RCSS-MCSP interface is structured so as to minimize the data flow required to implement the control mechanism. The entire control of the RCSS is contained in the RCV3B buffer. A single command word initiates all mode changes and a corresponding 5 word SV Queue specifies the GPS sources to be acquired and tracked. RCSS contains all the logic required to execute and complete the various required modes. Specific mode descriptions and command interpretations are described in the R1MRC module section. A complete description of the Serial Bus data items is contained in the Master Control Subsystem description.

The data flow out of the receiver is organized as follows. A control message RCV2B is the response to the RCV3B command message and contains information about the completion of or failure to complete the various modes. It also contains an SV Status table which corresponds one-for-one with the input SV Queue and maps the SV'S into RCVR channels. The RCSS passes measurement and other SV data to the MCSP in channel order because of foreground loading restraints. The MCSP then uses the SV status array to properly associate channel oriented measurement data with the corresponding SV. The five channel status messages (RCV2A) contain the channel status information described in the R1SRC module section. Three messages (RCV2C, RCV2D, and

RCV2E) contain the measurement data described in the R1RNG section.

3.1.3 Software Design

This section contains a description of the overall software structure and its relationship to the receiver hardware. The topic of reentrancy which is a fundamental part of the receiver system design is also discussed. The software hierarchy is presented along with the relationship of the data sets to this structure.

3.1.3.1 Hardware Interface

The Receiver LRU hardware under processor control includes 5 identical receiver channels and the Built-in-test module. The individual channels are quite similar to the channels used in the MVUE and MBRS Receivers but the number of channels is different in each version of user equipment. In order to maximize software commonality, the software is structured around the concept of individual channel controllers common to each type of UE with unique top level controllers implementing the set unique requirements.

In the HDUE an individual channel is guided through the acquisition sequence by the processor, but once the hardware carrier loop is closed, the processor serves primarily to recover pseudo-range and range-rate data from the hardware and maintain the code tracking loop. During acquisition the Voltage Controlled Crystal Oscillator (VCXO) on the

Frequency Synthesizer is aligned by the processor to the best estimate of Doppler. The code generator is stepped through its search region by the processor while the processor is monitoring the correlation data from the Narrowband Module as read by the Output Module. When the local and received signals are adequately correlated, one of the Narrowband Loop Filters is used to control the carrier loop with the bandwidth of the loop under processor control. The Wideband module, which is used for amplification of the received signal, has only its time constant under processor control. The processor may select either L-band frequency output from the Synthesizer and may route either antenna preamplifier's signal to any channel.

The Built-in-test(BIT) module generates both L1 and L2 signals with X1 code modulation for use within the RCSS. Control of this module is done exclusively by the processor. The processor controls the start-up and synchronization of the BIT code generator and controls the data modulation of the signal. The BIT signal is normally shut off when the module is not being used by the processor.

A complete description of the hardware/software interface is contained in Texas Instruments Drawing 2008917. Portions of this document which are essential for the understanding of the various software modules are contained in the appropriate software module descriptions in this report.

3.1.3.2 Reentrancy

Reentrancy is the key design feature of the RCSS which allows the implementation of the common individual channel controller to be achieved and permits the RCSS to occupy a realistic of amount processor memory. A reentrant program is one which is capable of being executed concurrently by several users. Each user has a separate data area out of which the program operates when that user is active, but only a single copy of the executable code resides in processor memory. There are both software and hardware requirements for reentrancy in the RCSS.

The software reentrancy is met by designating the register R10 as an index register to be used as an offset in all symbolic memory references. The reentrant data base in RCSS is hexadecimal 300 bytes long per channel. The Executive passes the appropriate multiple of this value in the R10 location when the task is activated. The Executive also sets the Workspace register for the task into the correct data area.

The hardware reentrancy is met by the method in which the Communication Register Unit (CRU) is decoded in the hardware. The CRU is the address bus used for processor control of the hardware. The 12 bit field is divided into four 3 bit sub-fields, the most significant of which is interpreted by the hardware as a channel identifier. When the software is initialized it computes a channel unique offset which is later added to all CRU address computations.

Then all software modules address the hardware in the same manner regardless of the channel number.

3.1.3.3 Software Structure

The RCSS Software can be divided into 2 categories: reentrant and non-reentrant. All hardware control with the exception of the Serial Bus Interface Module is contained in the reentrant section. The Built-in-test module, which logically falls in the non-reentrant area, is selected for control by one of the reentrant processes which then locks out the other processes. The reentrant section may be viewed as a channel control utility process with HDUE unique control requirements implemented for the most part in the non-reentrant section. R1SRC controls all modules in the reentrant sections. Details of this control are contained in that software module description. R1MRC controls the non-reentrant section and the 5 reentrant processes. It has 3 non-reentrant foreground tasks under its control: R1MTM, R1AID, and R1FMT.

R1MRC and R1SRC are background tasks while all others are foreground tasks with their priority dictated by processing requirements or hardware interface timing. The controllers are background tasks for 2 primary reasons:

1. Foreground processing time is made available for critical hardware control functions.
2. Since the control load is normally heavy when foreground activity is light, the background has

large sections of processing time available when needed for rapid execution

Figure 3.1-1 is a diagram showing the hierarchical structure of the RCSS. This diagram shows the logical relationship of the various software tasks but does not illustrate the fact that there are actually 5 reentrant processes under control of the R1MRC task.

```
        --> SBIM TO MCSP
        !
        !                          *********
        !                          *       *
        !                          * R1MRC *
        !                          *       *
        !                          *********
        !                              !
        !   ---------------------------!---------------------------
        !   !              !           !          !              !
**********     *********               !    *********      *********
*        *     *       *               !    *       *      *       *
* B1SLIO *     * R1AID *               !    * R1FMT *      * R1MTM *
*        *     *       *               !    *       *      *       *
**********     *********               !    *********      *********
                                       !
                                       !      NON-REENTRANT SECTION
                                       !
*************************************  !  **********************************
                                       !
                           *********           REENTRANT
                           *       *            SECTION
                           * R1SRC *
                           *       *
                           *********
                               !   !
                               !   ---------------------------------
                               !                                   !
          HARDWARE INTERFACE   !  CONTROL TASKS                    !
        ***************************************************        !
        *                                                 *        !
        *     R1CAL, R1SET, R1NSE, R1SCH,                 *        !
        *     R1PIN, R1BSN, R1RNG, R1CC,                  *        !
        *         R1RRM, R1DDT, R1PCK                     *        !
        *                                                 *        !
        ***************************************************        !
                               ^                                   !
                               !                    ----------------
                               !                    !
                               V                    V
        ***************************************************
        *                                                 *
        *              RCVR HARDWARE CHANNEL              *
        *                                                 *
        ***************************************************
```

FIGURE 3.1-1
RECEIVER CONTROL SOFTWARE STRUCTURE

3.1.3.4 RCSS Global Data Sets

Each of the global data sets within the RCSS is described from a functional standpoint. The variables within the data sets are described in the module sections where they are used. The variable naming convention within the RCSS requires that the first two letters of each variable within a data set be the same as the first two letters of the data set. For example, all variables in RPCOMM are of the form RPxxxx. Data sets RICOMM, RMCOMM, and RSCOMM are part of the reentrant data base and as a result there are five copies of these data sets in memory. The non-reentrant data sets include RPCOMM, RCV2XY, and RCV3XY.

RICOMM (Reentrant)

RICOMM contains variables used for communication between R1SRC and the interface control tasks and between the interface tasks themselves. Both control and numerical data is passed in this data set, with it being the only data set used by most of the interface control tasks.

RMCOMM (Reentrant)

RMCOMM serves 2 primary purposes: 1. It contains the control variables used in the communications between R1MRC and R1SRC. 2. R1SRC uses this data set to store those status variables which are passed to MCSP by R1FMT.

RSCOMM (Reentrant)

The purpose of RSCOMM is to provide a single data set to contain all the SV dependent data necessary for R1SRC to execute an acquisition sequence. The data is placed there by R1MRC and R1AID. The data set is also used to pass the recovered SV data words from R1PCK to R1FMT for transmission to MCSP.

RPCOMM (Non-reentrant)

This data set is analagous to the reentrant RICOMM. It contains communication and numerical data passed between the non-reentrant tasks. It also contains a group of variables used by R1SRC to control access to the Built-in-test module.

RCV2XY (Non-reentrant)

RCV2XY contains buffers for all data which is to be passed to MCSP. The basic buffer length is 15 words and B1SLIO transmits data from this area directly to MCSP.

RCV3XY (Non-reentrant)

RCV3XY is the area in which all messages from MCSP are stored. Based on the value of the routing indicator associated with the message B1SLIO will place the message in one of the six 15 word buffers in the data set.

3.1.4 Processor Memory Utilization

The following table contains a listing of all RCSS tasks and their associated memory requirements. In order to minimize the reentrant data base (since 5 copies of it exist in memory) the SHARE command is used at Link time on several of the reentrant modules. This means that, for these tasks which do not execute simultaneously, their local data areas are overlaid in memory. The total RCSS requirements include the full reentrant data base areas. All figures are 16 bit words.

RECEIVER SUBSYTEM PROCESSOR MEMORY UTILIZATION

MODULE	PRIORITY	BACKGROUND/ FOREGROUND	REENTRANT	MEMORY USED PROGRAM	MEMORY USED DATA
R1MRC	160 MS	B	N	3030	108
R1AID	20 MS	F	N	178	29
R1FMT	20 MS	F	N	101	16
R1MTM	20 MS	F	N	192	37
R1SRC	160 MS	B	Y	2356	43
R1BSN	1 MS	F	Y	209	56
R1CAL	5 MS	F	Y	276	30
R1CC	20 MS	F	Y	383	18
R1DDT	10 MS	F	Y	412	17
R1NSE	5 MS	F	Y	51	16
R1PCK	140 MS	F	Y	422	23
R1PIN	5 MS	F	Y	568	32
R1RNG	20 MS	F	Y	970	46
R1RRM	5 MS	F	Y	78	19
R1SCH	5 MS	F	Y	490	26
R1SET	5 MS	F	Y	96	16
RPCOMM			N		43
RCV2XY			N		165
RCV3XY			N		90
RICOMM			Y		59
RMCOMM			Y		12
RSCOMM			Y		23
RCSS TOTAL (INCLUDING EXECUTIVE)				11688	2797
AVAILABLE MEMORY				12288	4096
PERCENT UTILIZATION				95.1	68.2

3.2 HDUE MASTER CONTROL SUBSYSTEM

3.2.1 General

The Master Control Subsystem consists of the following tasks:

A. M1CMSC, Master State Control Task

20 ms Foreground Priority

M1CMSC is activated by the Executive Subsystem, and it activates all other tasks in the Master Control Subsystem. It provides the initialization function for the master state control processor, and calls subtask B2MSTR, master bus controller subtask.

B. M1CCIO, Control Display Unit Message Control Task

100 ms Foreground Priority

M1CCIO is activated by M1CMSC during initaialization, and it calls M2CRUS, communications register unit interface subtask.

C. M1CRNC, Receiver/Navigation Control Task

160 ms Foreground Priority

M1CRNC is activated by M1CMSC during initialization, and it calls the following subtasks:

a. M2STIN, receiver/navigation status subtask

b. M2BUSO, RCV3B bus message controller subtask

c. M2IIUT, IIU message buffer subtask

D. M1DBPR, Data Collection Task

160 ms Foreground Priority

M1DBPR is activated by M1CMSC during initialization.

E. M1ADIS, Control Display Unit Command Processor

640 ms Foreground Priority

M1ADIS is activated by M1CMSC during initialization and calls the following subtasks:

a. M2CVNM, integer to ASCII conversion subtask

b. M2BLNK, blank leading zeroes subtask

F. M1PDBR, Data Block Processing Task

Background Task

M1DBPR is activated by M1CMSC during initialization and calls the following subtasks:

a. M2DBS1, subframe 1 data processor subtask

b. M2DBS2, ephemeris data block processor subtask

c. M2DBS3, almanac data block processor subtask

G. M1IIUO, IIU Data Conversion Task

Background Task

M1IIUO is activated by M1CMSC during initialization and calls subtask M2HPFP, Hewlett Packard floating point conversion subtask.

The following data sets are used by the Master State Control Subsystem in order to facilitate communications between major subsystem tasks:

A. MFDATA, Cold-start almanac constants,

B. MAXXXX, Constants for receiver and IIU control,

C. CCXXXX, Constants for CDU displays,

D. CKXXXX, Constants for CDU control,

E. MKXXXX, Constants for STDM Bus control,

F. MXXXXX, Multi-processor initialization and sync.

control,

G. MDXXXX, Buffer for past CDU control history,

H. MSXXXX, Variables for receiver control.

Data set MZXXXX is used to communicate between Master Control tasks and the IIU interface.

The following data sets are used to communicate between Master Control Subsystem tasks and Navigation Subsystem tasks:

A. MNXXXX, General Inter-processor data, STDM Bus data, IIU data, and CDU data,

B. MTTCDS, Data Block I, Clock Corrections,

C. MIEPHM, Data Block II, Ephemeris,

D. MWDMSD, Subframe 4, SV Message Block,

E. MPALMC, Data Block III, Almanac,

F. MMALRT, Constellation Control,

G. NINTRF, Navigation interface for IIU and CDU processing,

H. MBDBPR, Data block processing, control.

3.2.2 Memory Utilization and Processor Loading

A. Master Control Modules and Data Sets (16 bit words)

Name	Program	Data	Total
B2MSTR	205	19	224
M1ADIS	4465	80	4545
M1CCIO	1064	47	1111
M1CMSC	977	59	1036
M1CRNC	230	35	265
M1DBPR	716	40	756
M1IIUO	465	58	523
M1PDBR	126	29	155
M2BLNK	46	28	74
M2BUSO	172	25	197
M2CRUS	158	19	177
M2CVNM	368	41	409
M2DBS1	342	74	416
M2DBS2	325	67	392
M2DBS3	237	57	294
M2HPFP	151	27	178
M2IIUT	153	29	182
M2MOVE	68	31	99
M2STIN	1117	50	1167

Name	Program	Data	Total
MFDATA		396	396
MAXXXX		86	86
CKXXXX		449	449
MKXXXX		343	343
CCXXXX		12	12
MXXXXX		4	4
MDXXXX		50	50
MSXXXX		26	26
MNXXXX		1915	1915
MTTCDS		50	50
MIEPHM		130	130
MWDMSD		120	120
MPALMC		432	432
MMALRT		38	38
NINTRF		49	49
MBDBPR		484	484
MZXXXX		260	260

B. Master Control Processor Memory Summary

Desc.	Available	Utilized	Spare	Percent used
Program	18432	13512	4920	73.3
Constants	2048	1285	763	62.7
Variables	4096	1231	2865	30.1
Comm. Memory	4096	3226	870	78.8
Total	28672	19254	9418	67.1

C. Memory by Major Master Control Functions

a. Receiver/Navigation State Control:

B2MSTR, M1CMSC, M1CRNC, M2BUSO, M2STIN, MAXXXX,
MKXXXX, MNXXXX, MXXXXX, MSXXXX 5263

b. Data Block Processing:

M1DBPR, M1PDBR, M2DBS1, M2DBS2, M2DBS3, M2MOVE,
MFDATA, MTTCDS, MIEPHM, MWDMSD, MPALMC, MBDBPR 3724

c. Control Display Unit Support:

M1ADIS, M1CCIO, M2BLNK, M2CRUS, M2CVNM, CCXXXX,
CKXXXX, MDXXXX 6827

d. Instrumentation Interface Unit Support:

M1IIUO, M2HPFP, M2IIUT, MZXXXX 1143

D. Foreground Task Processor Time Utilization

Processor loading for foreground tasks was studied by means of calling X3TIMM with an argument equal to the task's priority in 20 ms counts just prior to calling X3WAIT in the task. X3TIMM therefore returns the number of 20 ms periods which have transpired prior to task completion since the task was scheduled at its priority boundary. Peak loading was determined by accumulating the maximum of the resulting X3TIMM output values during a period in which a great variety of processing modes were exercised. Therefore, the following table represents an approximation to processor loading by giving the peak value of time utilized by each task in the time interval allocated for the task.

Task	Priority	Max finish	Percent
M1CCIO	100 ms	20 ms	20
M1CRNC/M1DBPR	160 ms	40 ms	25
M1ADIS	640 ms	80 ms	13

3.2.3 Receiver/Navigation State Control Function

The Master Control Subsystem communicates with the Receiver Subsystem by means of the Serial Bus Interface Module (SBIM). The names of the different bus messages and their contents are :

A. RCV2A, Receiver to Master Control Channel Data

Messages with identical format are sent every 320 ms for each of the five receiver channels at 3,5,7,9 and 11 twenty ms counts past each 320 ms boundary respectively. All must have unique routing indicators (RI) which are 2,4,6,8,10 for channels 1,2,3,4,5 respectively. Any other value of RI will be an error.

The word numbers and their corresponding contents for RCV2A are:

1	Routing Indicator (2,4,6,8,A)
2	Receiver Status
3	SV or GT Generic ID No (0 to 5)
	0 indicates unassigned channel
4	Commanded Mode
5	Receiver Frequency (0 is L1, -1 is L2)
6	Receiver Antenna (0 is Upper, -1 is Lower)
7	Subframe Number
8	Word Number
9	Data Word Part 1
10	Data Word Part 2
11	Data Validity

12	(spare)
13	Current Receiver Time Delay
14	Update Flag (0 No Update, -1 Update)
15	(spare)

where

Receiver Status	<0	Bad
	0	Idle
	1	R1CAL VXCO Calibrate
	2	R1SET VCXO Set
	3	R1NSE, Noise Calibrate
	4	R1SCH, C/A Search
	5	R1CC, Code Center
	6	R1BSN, Bit Sync
	7	R1PIN, P Code Initialization
	8	R1RRM, Range Rate Measurements
	9	R1RNG, C/A Range
	10	R1RNG, C/A Range, Weak Hold
	11	R1RNG, P Range
	12	R1RNG, P Range, Weak Hold
	13	Reacquisition

and

Commanded Mode	0	No Response
	>0	MRC command
	<0	Error in Processing Command

and

Data Validity	0	Good
	1	Subframe Count Bad

2	Z Count Bad
3	Z Count and Subframe Count Bad
4	Excess Parity (>7 in a row)

A negative subframe number indicates a roll momentum dump or a sync error. Bit 0 is set for roll momentum dump. Both bits 0 and 1 are set for sync errors. A negative word number implies that the error flag on the data is set. The data in the message will be ignored. No invalid data word will be sent without indicating that the word is invalid using either the subframe ID, the word ID or the data validity not equal to 0.

For data words 2 through 10, Part 1 contains the first 16 bits of the 24 bit data word. Part 2 contains the last 8 bits left adjusted. For the HOW word the right most bit of Part 1 contains the first bit of information, and the remaining 16 bits are in Part 2.

The Receiver Subsystem transmits its best estimate of each of the above at the time of transmission. If a best estimate cannot be supplied then the update flag will be set to no update. Status updates for all data are for actual states, not necessarily for commanded states.

B. RCV2B, Receiver to Master Control Status Information

These messages are sent every 160 ms at 4 and 12 twenty ms counts past each 320 ms boundary and contain:

1	Routing Indicator (3,B)
2	Update Flag (0 No Update, -1 Update)

3	Receiver LRU Status
4	(spare)
5	Command Acknowledge
6	Command Complete
7	(spare)
8	Sv 1 Status
9	Sv 2 Status
10	Sv 3 Status
11	Sv 4 Status
12	Sv 5 Status
13	Precision Mode Receiver (0 unassigned)
14	(spare)

The *receiver LRU status word* is normally 0. Bit 0 on indicates LRU failure, and bits 11 to 15 on indicate failure for receiver channels 1 to 5 respectively. The command acknowledgement word and the command complete words are sent only once for each MRC command. A value of -1 indicates command rejected, whereas a value of 0 means no response. A positive value implies success and is equal to the command code. Anytime that the receiver acknowledges an action command, then all accompanying status information corresponds to the new command.

The SV status word can have the following values:

0	Not selected
-1	Concentrated Search in progress
-2	Track

+K Selected receiver K (0<K<5)

C. RCV2C, Pseudo Range Measurements

Measurements are sent every 320 ms at 13 FTF counts past each 320 ms boundary. A routing indicator of C is sent in the first word. The next 10 words contain the five 32 bit range measurements ordered by receiver channel number. Words 12 to 15 are spares. A negative value indicates either a bad measurement or a bad time tag. The least significant bit is p-chip/(17*16) or 0.1077398 meters. No valid range will be sent for any receiver not in a valid ranging mode, or for any receiver after acknowledging a non-ranging mode. The reported ranges are valid at 11 twenty ms counts past each 320 ms boundary.

D. RCV2D, Sync Data

This data is transmitted at FTF(MOD16) = 14 count every 320ms, and word 1 is the routing indicator D. The next 10 words contain the five double word bit counts ordered by receiver channel. Words 12 to 15 are spares. Sync data gives the number of bit epoch from the start of the week corresponding to the pseudo range measurement, and the values range from 0 to 30239999.

E. RCV2E, Pseudo Range Rate Measurements

Range rate measurements are transmitted at every FTF(MOD16) = 15 count. The first word is the routing indicator E. The five measurements follow in the next 10 words ordered by receiver number. Words 12 to 15 are spares. The measured range-rate count (MRR) sent is such that SV pseudo range rate in meters per second is 0.1040668*(1232000. - MRR).

F. RCV2F, Error Report

This is transmitted at FTF(MOD16) =2, and its routing indicator, word 1 is 1. Word 2 contains a semaphore which is set to -1 when a message is present. Word 3 contains the number of words to follow in the report, and word 4 the Error Code Word (ECW). Words 5 to 15 contain the additional information for the error report. See Section 3.4.2, Executive Subsystem Error Reporting.

G. RCV2G, Memory Read/Write

RCV2G is transmitted at FTF(MOD16) = 10, and the first word is the routing indicator 9. The second word is the memory command word and is always 0. A value of -1 in word 3 means that data is available. Word 4 is the read/write flag and 1 indicates read, while -1 is used for a write operation. Words 5 and 6 contain the memory address and its contents. The remaining 9 words are spares.

H. RCV3A, Master Control to Receiver Executive Commands

RCV3A is transmitted at every FTF(MOD16)=6. The following table describes the contents of RCV3A:

1	Routing Indicator (1)
2	Update Flag (0 no update, -1 update)
3	Sync Reset Update (0 no update, -1 update)
4	Sync Reset Command (0 no action, -1 software reset, +1 start FTF on indicated next FTF)
5 and 6	FTF

7	Memory Read/Write (0 complete, -1 command)
8	Data Available (always 0)
9	Read/Write (+1 read, -1 write)
10	Memory address
11	Contents of Address
12 to 15	Spares

I. RCV3B, Master Control to Receiver Commands

RCV3B is transmitted at FTF(MOD16)=8. The contents of the message identified by word number are:

1	Routing Indicator (2)
2	Update Flag (0 no update, -1 update)
3	Action Flag
4	(spare)
5 to 9	Identification Numbers for SV 1 to 5
10 to 15	(spare)

where

Action Flag	0	No Action
	1	Soft Cancel
	2	Total Idle
	3	Combined GHC and MTD
	4	Search, C/A Acquisition, C/A Ranging
	5	Search, C/A Acquisition, P Ranging
	6	Search, P Acquisition, P Ranging
	7	Precision Mode

A Soft Cancel will terminate the present command and leave all tracking receivers in track. All other commands must be prefaced by a soft cancel. A Total Idle terminates all activity.

J. RCV3C and RCV3D, Velocity and Time Aiding

RCV3C and RCV3D are transmitted at a 320 ms boundary and contain the following:

1	Routing Indicator (3 for RCV3C, 4 for RCV3D)
2	Update Flag (0 no update, -1 update)
3 to 7	Range Rate Aiding for SV 1 to 5
8	(spare)
9 to 10	Bias Aiding
11 to 12	1.5 Sec Z Count
13 to 14	FTF (20 ms)
15	(spare)

The routing indicator is alternately 3 for odd 320 ms periods and 4 for even ones. The units for velocity aiding are 2000/1920 meters per second, and the data is valid at FTF(MOD16)=11 of the current 320 ms bus frame. The unit for bias aiding is 100 ns. Bias is the difference of GPS time at the indicated FTF and GPS time at the indicated Z Count. The Z Count transmitted will always be divisible by 4.

K. RCV3E and RCV3F, Range Aiding

These messages are transmitted when FTF(MOD16)=1. RCV3E has a routing indicator of 5 and is transmitted on odd 320 ms periods. RCV3F has a routing indicator of 6 and is transmitted on even 320 ms periods. Word 1 is the routing indicator, and word 2 is the update flag. Words 3 to 12 contain the range aiding for SV 1 to SV 5 in units of 100 nano seconds valid at the same time as for velocity aiding. Words 13 to 15 are spares.

The interface between the Master Control Subsystem and Navigation is discussed in Section 3.3.6 of the Navigation Subsystem description.

3.2.4 Data Block Processing Function

The data block processing function is accomplished in two phases, data collection and data processing. Task M1DBPR controls the data collection phase in which data words are received one at a time from the Receiver Subsystem via the RCV2A bus message, collected into complete data blocks, and then passed on to data processing, which runs in the background. The data processing function is controlled by M1PDBR and it strips the appropriate bits for each data item from the collected data blocks, and formats the data so that it may be used by the Navigation Subsystem.

The following tables describe the data collected and processed from satellites. The scale factors and ranges are given as powers of two. The word number given is the word number within the subframe, from 3 to 10. Bits are numbered from the left from 1 to 24.

A. Clock Correction Data, Data Block I, Subframe 1.

Parameter	Word	Bits	Scale	Range	Sign	Units
TOC	8	9-24	4	20	+	sec
A0	10	1-22	-31	-10	+, -	sec
		1-24	-33	(for Ground Transmitters)		
A1	9	9-24	-43	-28	+, -	sec/sec
A2	9	1-8	-55	-48	+, -	sec/sec/sec
AODC	8	1-8	11	19	+	sec

B. Ephemeris Data, Data Block II, Subframes 2 and 3.

Parameter	Word/SF	Bits	Scale	Range	Sign	Units
AODE	3/2	1-8	11	20	+	sec.
	10/3	1-8	11	20	+	sec.
CRS	3/2	9-24	-5	10	+, -	met.
DN	4/2	1-16	-43	-28	+, -	semicircles/sec.
MO	4/2	17-24	-31	0	+, -	semicircles
	5/2	1-24				
CUC	6/2	1-16	-29	-14	+, -	radians
E	6/2	17-24	-33	-1	+	
	7/2	1-24				
CUS	8/2	1-16	-29	-14	+, -	
SQA	8/2	17-24	-19	13	+	sqrt(met.)
	9/2	1-24				
TOE	10/2	1-16	4	20	+	sec.
CIC	3/3	1-16	-29	-14	+, -	radians
OMO	3/3	17-24	-31	0	+, -	semicircles
	4/3	1-24				
CIS	5/3	1-16	-29	-14	+, -	radians
IO	5/3	17-24	-31	0	+, -	semicircles
	6/3	1-24				
CRC	7/3	1-16	-5	10	+, -	meters
OMG	7/3	17-24	-31	0	+, -	semicircles
	8/3	1-24				
OMD	9/3	1-24	-43	-20	+, -	semicircles/sec

C. Almanac data, Data Block III, Subframe 5

Parameter	Word	Bits	Scale	Range	Sign	Units
SVID	3	1-8	11	8	+	
EEE	3	9-24	-21	-5	+	
TOA	4	1-8	12	20	+	sec.
DTI	4	9-24	-19	-4	+, -	semicircles
Health	5	17-24	0	8	+	
OMD	5	1-16	-38	-23	+, -	semicircles/sec
SQA	6	1-24	-11	13	+	sqrt(meters)
OMO	7	1-24	-23	0	+, -	semicircles
OMG	8	1-24	-23	0	+, -	semicircles
MMO	9	1-24	-23	0	+, -	semicircles
A0	10	1-8	-17	-10	+, -	sec.
A1	10	9-16	-35	-28	+, -	sec./sec.

The clock data is processed by M2DBS1; the ephemeris is processed by M2DBS2; and the almanac data is processed by M2DBS3. M2DBS1 also processes ground transmitter position coordinates. Only Subframe 1 is collected for ground transmitters.

D. Ground Transmitter data, Subframe 1.

Parameter	Word	Bits	Scale	Range	Sign	Units
GT x	3	1-24	-7	24	+,-	met.
	4	1-8				
GT y	4	9-24	-7	24	+,-	met.
	5	1-16				
GT z	5	17-24	-7	24	+,-	met.
	6	1-24				
GTID	7	9-16	1	8	+	
Health	7	17-24	1	8	+	

The message subframe is processed for SV's. It is the contents of words 3 to 10 in subframe 4, and contains 23 eight bit ASCII characters. These characters are displayed on the CDU upon demand.

During the first pass through M1DBPR, cold start almanac is moved into the almanac data set MPALMC. Thereafter, it is replaced whenever almanac data is processed as received from a satellite.

Since the RCV2A bus message is keyed to receiver channel number, the collection process in M1DBPR is also. Before accepting a data word the update flag and SV ID are checked. Whenever SV ID changes, then the collection process is reinitialized for the given channel. The subframe number must be between 1 and 5 for an SV, or exactly 1 for a GT. The word number must be between 3 and 10. M1DBPR also checks for SV sync fail, roll momentum dump condition, data validity, and bad parity. Finally, a check is made to be sure that we are not already processing the given Data Block in the background. If all these tests pass then the word is collected in array MCDATA and a bit cleared in MCDWPC to record this fact.

When all words in Data Block I are collected then a flag is set to process it, provided either the AODC or TOC has changed from the last time that it was processed. Data Block II is processed provided the AODE'S in subframes 2 and 3 match and are different from the last time that that the block was processed. For the Message Block a sum is made for comparison purposes, and the block is processed whenever this sum changes. Data Block III is processed provided a valid SV ID has been received with a new TOA from that previously processed.

Clock data is stored by generic number in data set MTTCDS. SV Ephemeris data and GT position data are also stored by the 1 to 5 generic number. Almanac is stored by SV ID number in data set MPALMC. Message data is stored by receiver channel in data set MWDMSD. Data set MBDBPR is used to maintain data between successive executions of M1DBPR, and to communicate between M1DBPR and the background processing task M1PDBR.

3.2.5 Control Display Unit Support Function

A. General Description of the HDUE Control/Display Unit

The CDU is the primary man/machine interface. The main elements are: (1) DISPLAY, alphanumeric 16-segment, ordered as two rows by ten columns (20 characters), updated every 640-ms; (2) KEYBOARD, data entry, ordered as six rows by three columns; (3) DATA switch, 16-position, rotary; (4) WAYPOINT switch, 10-position, rotary; (5) CAUTION indicator lamp; (6) FORMAT switch, 2-position, toggle. See Figure 3.2.5-1 for the layout of the CDU switches and displays.

Each character of the display can indicate a number digit (0-9), a letter (A-Z), a symbol, or a combination of digit and symbol (such as three degrees). A lamp test function is included, which illuminates all 16 segments of a display character position simultaneously.

The data entry keyboard allows the following control and data inputs: (1) Data numbers (0-9); (2) Data letters (A, B, C, D, E, F, G, H, J, K, L, M, N, P, Q, R, S, T, U, V, W, X, Y, Z); (3) Data symbols (minus sign); (4) Control prefix for upper/lower display select (IN1, IN2); (5) Control data case (left upper case, right upper case); (6) Control warning command (WN); (7) Control position mark command (MK); (8) Control freeze command (FZ); (9) Control update command (UP) (10) Control clear command (CLR).

The Data switch allows the operator to select one of fifteen types of data input or output: RCVR, ERR, UTM, LAT,

RNG, XTRK, HDG, WIND, TIME, ALT, SPD, VEL, MSG, MEM ,STAT. The sixteenth position is not used.

The Waypoint switch allows the operator to select the input/output operation corresponding to a navigation waypoint, or to multiply the number of operations for a given data type, for example, select receiver status by channel number.

The Caution lamp indicates that an error condition is present, or that important secondary information is available.

The Format switch is used to select the alignment of the user direction data relative to "True" North or "Magnetic" North, or to activate the display lamp test in conjunction with the Data and Waypoint switches.

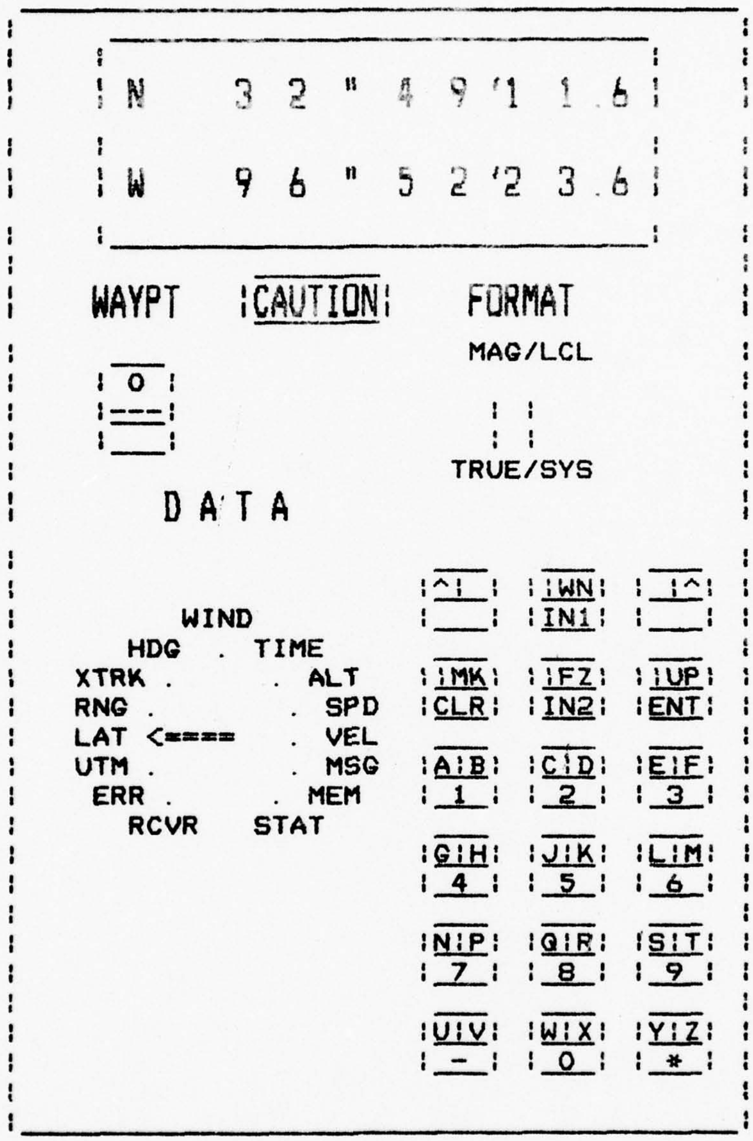

FIGURE 3.2.5-1 CDU POSITION DISPLAY

B. Keyboard Entry Operations

The key entry of data is initiated by pressing either the IN1 or IN2 key. The associated display (upper or lower) then shows underscore characters to indicate the spaces to be filled with alphanumeric data. Data keys are pressed to fill the display, left to right, until no more underscore characters remain. Finally, the data entry process is terminated by pressing the ENT key. To correct an error entry, begin the entry sequence again. The uppercase keys are used to select letters for data entry. For example, to enter the letter A, precede the A keypress with the uppercase left key. The decimal point key is not used for data entry, since decimal points are displayed in appropiate positions.

The control warning command key, WN, is used to command display of a warning message (10 characters, maximum) in the upper display.

The control freeze command key, FZ, is used to store present position in a temporary buffer for subsequent use with the mark function, MK.

The control position mark command key, MK, will copy the contents of the temporary buffer (containing a 'frozen position') into a Waypoint position buffer. To use the command, turn the Data switch to LAT, the Waypoint switch to the desired waypoint position (1-9), and press the MK key. The saved position then appears in the display, replacing the previous waypoint position.

The control clear command key, CLR, resets any CDU keyboard entry process, and any alert or warning message.

The control update command key, UP, initiates an automatic navigation subsystem initialization sequence, which utilizes the operator CDU inputs for time, heading, true air speed, altitude, and position. Since there are several positions which the operator can pre-store as waypoints, the operator must select one to be used for navigation initialization: turn the Data switch to LAT or UTM, the Waypoint switch to select the desired value, and press the Update key. The update command must be given at least once before the GPS acquisition sequence.

C. Functional Switch Combinations

The functional switch combinations for data input and output are described in tabular form according to the Data Switch position, the Waypoint Switch position, the Upper Display, and the Lower Display. Table 3.2.5-1 shows the functions of each Data Switch position in combination with the Waypoint Switch, shows the parameters in the upper and lower displays, and indicates whether these parameters are system inputs (I) and/or outputs (O). System inputs are parameter values which can be entered by the HDUE operator; entered values are echoed on the display in all but a few cases. System outputs are parameter values or messages initiated by system processing, other than the data display echo function. Table 3.2.5-2 lists the CDU parameter formats, ordered by Data Switch, Waypoint Switch, whether Upper or Lower Display, Format, and Range. The convention for the abbreviated parameter format description is as follows:

(1) Each unique format consists of ten columns, corresponding to the display columns.

(2) Values of variable quantities are represented by the letters, 'P', 'Q', 'W', 'J', with underscores at each of the variable digit positions; these letters do not otherwise appear on the CDU display. Where more than four unique variables are represented, additional letters are included. The number of digits for any variable is denoted by repeating the letter. That is, the variable, 'PPP', has a value of three digits maximum.

TABLE 3.2.3-1 CDU SWITCH FUNCTIONS

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
RCVR	0	RCVR COMMAND RESPONSE	N	Y	LAST COMMAND NUMBER	Y	N
		OR					
	0	NUMBER OF CURRENT NAV SOURCES IN USE	N	Y	LAST COMMAND NUMBER	Y	N
	1	SV NUMBER AND STATUS FOR RCVR CHAN. 1	N	Y	FIRST DESIRED/SELECTED SV NUMBER (SEE NOTE 1)	Y	Y
	2	SV NUMBER AND STATUS FOR RCVR CHAN. 2	N	Y	SECOND DESIRED/SELECTED SV NUMBER (SEE NOTE 1)	Y	Y
	3	SV NUMBER AND STATUS FOR RCVR CHAN. 3	N	Y	THIRD DESIRED/SELECTED SV NUMBER (SEE NOTE 1)	Y	Y
	4	SV NUMBER AND STATUS FOR RCVR CHAN. 4	N	Y	FOURTH DESIRED/SELECTED SV NUMBER (SEE NOTE 1)	Y	Y
	5	SV NUMBER AND STATUS FOR RCVR CHAN. 1	N	Y	FIFTH DESIRED/SELECTED SV NUMBER (SEE NOTE 1)	Y	Y
	6	(NOT USED)	-	-	LOCAL DATUM NUMBER FOR COORDINATE TRANSFORMATIONS	Y	N
	7-9	(NOT USED)			(NOT USED)		
ERR	0-9	BLANK, EXCEPT WHEN A PROCESSOR FAILURE EXISTS: (SEE NOTE 2)			(NOT USED)		
	0	ERROR MSG - WORD 1	N	Y	(NOT USED)		
	1	ERROR MSG - WORD 2	N	Y	(NOT USED)		
	2	ERROR MSG - WORD 3	N	Y	(NOT USED)		
	3	ERROR MSG - WORD 4	N	Y	(NOT USED)		
	4	ERROR MSG - WORD 5	N	Y	(NOT USED)		
	5	ERROR MSG - WORD 6	N	Y	(NOT USED)		
	6	ERROR MSG - WORD 7	N	Y	(NOT USED)		
	7	ERROR MSG - WORD 8	N	Y	(NOT USED)		
	8	ERROR MSG - WORD 9	N	Y	(NOT USED)		

TABLE 3.2.5-1 CDU SWITCH FUNCTIONS (CONTINUED)

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
	9	ERROR MSG - WORD 10	N	Y	(NOT USED)		
UTM	0	PRESENT POSITION, EASTING	N	Y	PRESENT POSITION, NORTHING	N	Y
		OR			OR		
	0	EASTING INPUT FOR WAYPOINT 0	Y	N	NORTHING INPUT FOR WAYPOINT 0	Y	
	1	EASTING INPUT FOR WAYPOINT 1	Y	N	NORTHING INPUT FOR WAYPOINT 1	Y	N
	2	EASTING INPUT FOR WAYPOINT 2	Y	N	NORTHING INPUT FOR WAYPOINT 2	Y	N
	3	EASTING INPUT FOR WAYPOINT 3	Y	N	NORTHING INPUT FOR WAYPOINT 3	Y	N
	4	EASTING INPUT FOR WAYPOINT 4	Y	N	NORTHING INPUT FOR WAYPOINT 4	Y	N
	5	EASTING INPUT FOR WAYPOINT 5	Y	N	NORTHING INPUT FOR WAYPOINT 5	Y	N
	6	EASTING INPUT FOR WAYPOINT 6	Y	N	NORTHING INPUT FOR WAYPOINT 6	Y	N
	7	EASTING INPUT FOR WAYPOINT 7	Y	N	NORTHING INPUT FOR WAYPOINT 7	Y	N
	8	EASTING INPUT FOR WAYPOINT 8	Y	N	NORTHING INPUT FOR WAYPOINT 8	Y	N
	9	EASTING INPUT FOR WAYPOINT 9	Y	N	NORTHING INPUT FOR WAYPOINT 9	Y	N
LAT	0	PRESENT POSITION, LATITUDE	N	Y	PRESENT POSITION, LONGITUDE	N	Y
		OR			OR		
	0	LATITUDE INPUT FOR WAYPOINT 0	Y	N	LONGITUDE INPUT FOR WAYPOINT 0	Y	N
	1	LATITUDE INPUT FOR WAYPOINT 1	Y	N	LONGITUDE INPUT FOR WAYPOINT 1	Y	N
	2	LATITUDE INPUT FOR WAYPOINT 2	Y	N	LONGITUDE INPUT FOR WAYPOINT 2	Y	N

TABLE 3.2.5-1 CDU SWITCH FUNCTIONS (CONTINUED)

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
	3	LATITUDE INPUT FOR WAYPOINT 3	Y	N	LONGITUDE INPUT FOR WAYPOINT 3	Y	N
	4	LATITUDE INPUT FOR WAYPOINT 4	Y	N	LONGITUDE INPUT FOR WAYPOINT 4	Y	N
	5	LATITUDE INPUT FOR WAYPOINT 5	Y	N	LONGITUDE INPUT FOR WAYPOINT 5	Y	N
	6	LATITUDE INPUT FOR WAYPOINT 6	Y	N	LONGITUDE INPUT FOR WAYPOINT 6	Y	N
	7	LATITUDE INPUT FOR WAYPOINT 7	Y	N	LONGITUDE INPUT FOR WAYPOINT 7	Y	N
	8	LATITUDE INPUT FOR WAYPOINT 8	Y	N	LONGITUDE INPUT FOR WAYPOINT 8	Y	N
	9	LATITUDE INPUT FOR WAYPOINT 9	Y	N	LONGITUDE INPUT FOR WAYPOINT 9	Y	N
RNG	0	(NOT USED)	-	-	(NOT USED)	-	-
	1	RANGE TO WAYPOINT 1	N	Y	BEARING TO WAYPOINT 1	N	Y
	2	RANGE TO WAYPOINT 2	N	Y	BEARING TO WAYPOINT 2	N	Y
	3	RANGE TO WAYPOINT 3	N	Y	BEARING TO WAYPOINT 3	N	Y
	4	RANGE TO WAYPOINT 4	N	Y	BEARING TO WAYPOINT 4	N	Y
	5	RANGE TO WAYPOINT 5	N	Y	BEARING TO WAYPOINT 5	N	Y
	6	RANGE TO WAYPOINT 6	N	Y	BEARING TO WAYPOINT 6	N	Y
	7	RANGE TO WAYPOINT 7	N	Y	BEARING TO WAYPOINT 7	N	Y
	8	RANGE TO WAYPOINT 8	N	Y	BEARING TO WAYPOINT 8	N	Y
	9	RANGE TO WAYPOINT 9	N	Y	BEARING TO WAYPOINT 9	N	Y

TABLE 3.2.5-1 CDU SWITCH FUNCTIONS (CONTINUED)

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
XTRK	0	(NOT USED)			(NOT USED)		
	1	VERTICAL STEERING ERROR TO WAYPOINT 1	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 1	N	Y
	2	VERTICAL STEERING ERROR TO WAYPOINT 2	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 2	N	Y
	3	VERTICAL STEERING ERROR TO WAYPOINT 3	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 3	N	Y
	4	VERTICAL STEERING ERROR TO WAYPOINT 4	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 4	N	Y
	5	VERTICAL STEERING ERROR TO WAYPOINT 5	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 5	N	Y
	6	VERTICAL STEERING ERROR TO WAYPOINT 6	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 6	N	Y
	7	VERTICAL STEERING ERROR TO WAYPOINT 7	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 7	N	Y
	8	VERTICAL STEERING ERROR TO WAYPOINT 8	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 8	N	Y
	9	VERTICAL STEERING ERROR TO WAYPOINT 9	N	Y	HORIZONTAL STEERING ERROR TO WAYPOINT 9	N	Y
HDG	0	USER HEADING INPUT (SEE NOTE 3)	Y	N	LOCAL MAGNETIC VARIATION	Y	N
	1	VERTICAL APPROACH ANGLE TO WAYPOINT 1	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 1	Y	N
	2	VERTICAL APPROACH ANGLE TO WAYPOINT 2	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 2	Y	N
	3	VERTICAL APPROACH ANGLE TO WAYPOINT 3	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 3	Y	N
	4	VERTICAL APPROACH ANGLE TO WAYPOINT 4	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 4	Y	N
	5	VERTICAL APPROACH ANGLE TO WAYPOINT 5	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 5	Y	N

TABLE 3.2.5-1 CDU SWITCH FUNCTIONS (CONTINUED)

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
	6	VERTICAL APPROACH ANGLE TO WAYPOINT 6	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 6	Y	N
	7	VERTICAL APPROACH ANGLE TO WAYPOINT 7	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 7	Y	N
	8	VERTICAL APPROACH ANGLE TO WAYPOINT 8	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 8	Y	N
	9	VERTICAL APPROACH ANGLE TO WAYPOINT 9	Y	N	HORIZONTAL APPROACH ANGLE TO WAYPOINT 9	Y	N
WIND	0	SUM OF NORMALIZED RESIDUALS OF NAVIGATION FILTER (SEE NOTE 4)	N	Y	GOODNESS OF SV GEOMETRY INDEX (SEE NOTE 4)	N	Y
	1-9	(NOT USED)			(NOT USED)		
TIME	0	PRESENT DATE, DAY-MONTH-YEAR	Y	Y	PRESENT TIME, HOUR-MINUTE SECOND	Y	Y
	1	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 1 FROM PRESENT POSITION	N	Y
	2	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 2 FROM PRESENT POSITION	N	Y
	3	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 3 FROM PRESENT POSITION	N	Y
	4	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 4 FROM PRESENT POSITION	N	Y
	5	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 5 FROM PRESENT POSITION	N	Y
	6	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 6 FROM PRESENT POSITION	N	Y
	7	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 7 FROM PRESENT POSITION	N	Y
	8	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 8 FROM PRESENT POSITION	N	Y

TABLE 3.2.5-1 CDU SWITCH FUNCTIONS (CONTINUED)

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
	9	(LEGEND)	-	-	TIME TO GO TO WAYPOINT 9 FROM PRESENT POSITION	N	Y
ALT	0	PRESENT USER VEHICLE ALTITUDE ABOVE MEAN SEA LEVEL	N	Y	PRESENT USER VEHICLE ALTITUDE ABOVE REFERENCE ELLIPSOID, WGS-72	N	Y
		OR			OR		
	0	ALTITUDE OF WAYPOINT 0 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	1	ALTITUDE OF WAYPOINT 1 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	2	ALTITUDE OF WAYPOINT 2 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	3	ALTITUDE OF WAYPOINT 3 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	4	ALTITUDE OF WAYPOINT 4 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	5	ALTITUDE OF WAYPOINT 5 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	6	ALTITUDE OF WAYPOINT 6 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	7	ALTITUDE OF WAYPOINT 7 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	8	ALTITUDE OF WAYPOINT 8 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
	9	ALTITUDE OF WAYPOINT 9 ABOVE MEAN SEA LEVEL	Y	N	(NOT USED)		
SPD	0-9	PRESENT USER VEHICLE TRUE AIR SPEED (SEE NOTE 3)	Y	N	(NOT USED)		
VEL	0	PRESENT USER VEHICLE GROUND SPEED	N	Y	PRESENT USER VEHICLE GROUND TRACK ANGLE	N	Y
	1	PRESENT USER VEHICLE NORTH VELOCITY	N	Y	(SAME AS WYPT 0)	N	Y

TABLE 3.2.3-1 CDU SWITCH FUNCTIONS (CONTINUED)

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
	2	PRESENT USER VEHICLE EAST VELOCITY	N	Y	(SAME AS WYPT 0)	N	Y
	3	PRESENT USER VEHICLE VERTICAL VELOCITY	N	Y	(SAME AS WYPT 0)	N	Y
	4	RANGE BIAS RATE OF NAVIGATION FILTER	N	Y	(SAME AS WYPT 0)		
	5-9	(SAME AS WYPT 0)			(SAME AS WYPT 0)		
MSG	0	(NOT USED)			(NOT USED)		
	1	ALPHANUMERIC MESSAGE FROM SV ASSIGNED TO RCVR CHANNEL 1	N	Y	(NOT USED)		
	2	ALPHANUMERIC MESSAGE FROM SV ASSIGNED TO RCVR CHANNEL 2	N	Y	(NOT USED)		
	3	ALPHANUMERIC MESSAGE FROM SV ASSIGNED TO RCVR CHANNEL 3	N	Y	(NOT USED)		
	4	ALPHANUMERIC MESSAGE FROM SV ASSIGNED TO RCVR CHANNEL 4	N	Y	(NOT USED)		
	5	ALPHANUMERIC MESSAGE FROM SV ASSIGNED TO RCVR CHANNEL 5	N	Y	(NOT USED)		
MEM	0	(NOT USED)			(NOT USED)		
	1	ABSOLUTE ADDRESS FOR MEMORY READ/WRITE FUNCTION IN MSCP (SEE NOTE 2)	Y	N	DATA CONTENTS AT ADDRESS IN UPPER DISPLAY (SEE NOTE 2)	Y	Y
	2	ABSOLUTE ADDRESS FOR MEMORY READ/WRITE FUNCTION IN NAVP (SEE NOTE 2)	Y	N	DATA CONTENTS AT ADDRESS IN UPPER DISPLAY (SEE NOTE 2)	Y	Y
	3	ABSOLUTE ADDRESS FOR MEMORY READ/WRITE FUNCTION IN RCVP (SEE NOTE 2)	Y	N	DATA CONTENTS AT ADDRESS IN UPPER DISPLAY (SEE NOTE 2)	Y	Y

TABLE 3.2.5-1 CDU SWITCH FUNCTIONS (CONTINUED)

DATA	WYPT	UPPER DISPLAY	I	O	LOWER DISPLAY	I	O
	4-9	(NOT USED)			(NOT USED)		
STAT	0	RELATIVE ADDRESS FOR COMMUNICATIONS MEMORY READ/WRITE FUNCTION (SEE NOTE 2, 7)	Y	Y	DATA CONTENTS AT ADDRESS IN UPPER DISPLAY (SEE NOTE 2)	N	Y
		OR			OR		
	0	CLEAR PRESENT COPY OF ERROR MESSAGE IN COMMUNI-CATIONS MEMORY FOR ALL PROCESSORS (SEE NOTE 6)	Y	N	(NOT USED)		
	1	SV NUMBER AND RCVR CHANNEL ASSIGNMENT FOR FIRST NAVIGATION SOURCE	N	Y	STATUS FOR FIRST NAVIGATION SOURCE	N	Y
	2	SV NUMBER AND RCVR CHANNEL ASSIGNMENT FOR SECOND NAVIGATION SOURCE	N	Y	STATUS FOR SECOND NAVIGATION SOURCE	N	Y
	3	SV NUMBER AND RCVR CHANNEL ASSIGNMENT FOR THIRD NAVIGATION SOURCE	N	Y	STATUS FOR THIRD NAVIGATION SOURCE	N	Y
	4	SV NUMBER AND RCVR CHANNEL ASSIGNMENT FOR FOURTH NAVIGATION SOURCE	N	Y	STATUS FOR FOURTH NAVIGATION SOURCE	N	Y
	5	SV NUMBER AND RCVR CHANNEL ASSIGNMENT FOR FIFTH NAVIGATION SOURCE	N	Y	STATUS FOR FIFTH NAVIGATION SOURCE	N	Y
	6-9	(NOT USED)			(NOT USED)		

NOTE 1: THE ORDER OF DESIRED SV'S IS INDEPENDENT OF SV NUMBERS IN UPPER DISPLAY
NOTE 2: HEXADECIMAL FORMAT
NOTE 3: USED FOR INITIALIZATION ONLY
NOTE 4: NO WIND ESTIMATES ARE AVAILABLE; THIS POSITION USED FOR DISPLAY OF DIAGNOSTIC DATA
NOTE 5: THIS POSITION USED FOR DISPLAY OF DIAGNOSTIC DATA
NOTE 6: ENTER FFFF TO CLEAR PRESENT COPY OF ERROR MESSAGE
NOTE 7: WITH FORMAT SWITCH AT 'MAG', LAMP TEST FUNCTION USES THE WAYPOINT SWITCH TO TEST EACH COLUMN OF THE DISPLAY

TABLE 3.2.5-2 CDU PARAMETER FORMATS

DATA	WYP	U/L	FORMAT	RANGE	COMMENTS
RCVR	0	U	NUM PQ OR	P='F', 'C'; Q=0 TO 7	WHEN NOT IN GPS NAVIGATION MODE.
	0	U	NUM W	W=1 TO 5	WHEN IN GPS NAVIGATION MODE; THIS IS THE NUMBER OF CURRENT NAV. SOURCES.
	0	L	CMD PQ	P=0, 1; Q=0 TO 6;	P IS SV SELECT MODE, 0=AUTO, 1=MAN Q IS RCVR COMMAND; Q=0 RESULTS NO CHANGE FROM PREVIOUS COMMAND.
	1-5	U	SVPP QWJK	PP=1 TO 24, 33 TO 36 Q=0 TO 9, A, B, C, D; W =0 TO 5; J=0, 1; K= 0, 1	WHEN Q=0, 0 IS SUPPRESSED
	1-5	L	DSV PP	PP=1 TO 24, 33 TO 36	DESIRED SV IS ENTERED WHEN IN MANUAL SV SELECT MODE.
	6	U	(NOT USED)		
	6	L	LDN PP	PP=1 TO 46	LOCAL DATUM NUMBER.
ERR	0-9	U	ERR PPPP Z	PPPP=0000 TO FFFF, HEXADECIMAL	ERROR CODES APPEAR FOR MSCP FAIL NAVP FAIL, RCVP FAIL; OTHERWISE BLANK.
UTM	0-9	U	PPQQQWWWWW	PP=1 TO 60; QQQ ARE LETTERS, A-Z, EXCEPT I, O; WWWWW=0 TO 99999	POSITION, MILITARY GRID REFERENCE SYSTEM; PP IS ZONE NUM.; QQQ ARE ARE ZONE, COLUMN, ROW LETTERS; WWWWW IS EASTING; SEE NOTE 1.
	0-9	L	WWWWW	WWWWW=0 TO 99999	NORTHING; POSITION INPUT FOR EASTING AND NORTHING AT WYPT SWITCH=0 USED FOR INITIALIZATION ONLY, NO DISPLAY ECHO.
LAT	0-9	U	JPPP QQWWW	J=N, S; PPP=0 TO 89; QQ=0 TO 59; WWW=0 TO 59.9	POSITION, LATITUDE; N OR S, THEN DEGREES, MINUTES, SECONDS WITH TENTHS OF SECONDS; SEE NOTE 1.
	0-9	L	JPPP QQWWW	J=E, W; PPP=0 TO 179; QQ=0 TO 59; WWW=0 TO 59.9	LONGITUDE, EAST OR WEST, THEN DEG., MIN., SEC; POSITION WITH WYPT SWITCH=0 USED FOR INITIALIZATION ONLY, NO DISPLAY ECHO.

TABLE 3.2.5-2 CDU PARAMETER FORMATS (CONTINUED)

DATA	WYP	U/L	FORMAT	RANGE	NOTES
RNG	0	U, L	(NOT USED)		
	1-9	U	RG PPPPPNM	PPPPP=0 TO 99999	RANGE TO WAYPOINT, NAUTICAL MILES.
	1-9	L	BRGPPPPPDT	PPPPP=0 TO 99999	BEARING TO WAYPOINT, DEG. TRUE; USE FORMAT SWITCH TO GET DEGREES MAGNETIC READOUT.
XTRK	0	U, L	(NOT USED)		
	1-9	U	VE PPPPPFT	PPPPP=0 TO 99999	VERTICAL STEERING ERROR.
	1-9	L	XT PPPPPFT	PPPPP=0 TO 99999	HORIZONTAL CROSS-TRACK ERROR.
HDG	0	U	HDG PPPPDT	PPPP=000.0 TO 359.9	USER VEHICLE HEADING USED FOR INIT. ONLY; SEE NOTE 2.
	0	L	VAR QQQQDT	QQQQ=-99.9 TO 359.9	MAGNETIC VARIATION IS ADDED TO HEADING(DT) TO GET DEG. MAG.; SEE NOTE 2.
	1-9	U	DVA PPPPDT	PPPP=-90.0 TO 90.0	DESIRED VERTICAL APPROACH ANGLE TO WAYPOINT.
	1-9	L	DTK QQQQDT	QQQQ=0 TO 359.9	DESIRED HORIZONTAL APPROACH ANGLE TO WAYPOINT; USE FORMAT SWITCH FOR DEGREES MAGNETIC; SEE NOTE 2.
WIND	0	U	SNRPPPPP	PPPPP=0 TO 9999.9	SUM OF NORMALIZED RESIDUALS.
	0	L	GOGQQQQQ	QQQQQ=0 TO 99999	GOODNESS OF GEOMETRY.
TIME	0	U	MDYPPQQWW	PP=1 TO 12; QQ=1 TO 31; WW=78 TO 99	PRESENT DATE: MONTH, DAY, YEAR.
	0	L	HMSPPQQWWW	PP=0 TO 23; QQ=0 TO 59; WWW=0 TO 59.9	PRESENT TIME: HOURS, MINUTES, SECONDS WITH TENTHS OF SECONDS.
	1-9	U	TIME TO GO		LEGEND.
	1-9	L	HMSPPQQWWW	(SAME AS HMS ABOVE)	TIME TO TRAVEL TO WAYPOINT, WHEN MOVING ALONG DESIRED HORIZONTAL APPROACH ANGLE.

TABLE 3.2.5-2 CDU PARAMETER FORMATS (CONTINUED)

DATA	WYP	U/L	FORMAT	RANGE	NOTES
ALT	0	U	MSLPPPPPFT	PPPPP=-9999 TO 99999	MEAN SEA LEVEL ALTITUDE; INPUT WITH WYPT SW.=0 USED FOR INIT. ONLY, NO DISPLAY ECHO.
	0	L	GEOPPPPPFT	(SAME AS MSL)	WGS-72 GEODETIC ALTITUDE.
	1-9	U	ALTPPPPPFT	(SAME AS MSL)	WAYPOINT MSL ALTITUDES.
SPD	0	U	SPDPPPPPKT	PPPPP=0 TO 32767	TRUE AIR SPEED, KNOTS; USED FOR INIT. ONLY; DATA I/O FOR WYPT=0-9
VEL	0	U	GS PPPPPKT	PPPPP=0 TO 99999	GROUND SPEED IN KNOTS, ALSO DISPLAYED IN WYPT 5-9.
	0	L	GTK QQQQDT	QQQQQ=0 TO 359.9	GROUND TRACK ANGLE IN DEGREES TRUE; USE FORMAT SWITCH TO DISPLAY DEGREES MAGNETIC.
	1	U	VNIPPPPPKT	PPPPP=0 TO 99999	NORTH VELOCITY, INERTIAL.
	2	U	VEIPPPPPKT	PPPPP=0 TO 99999	EAST VELOCITY, INERTIAL.
	3	U	VVIPPPPPFM	PPPPP=-9999 TO 99999	VERTICAL VELOCITY, INERTIAL, ROUNDED TO NEAREST 50 FEET-PER MINUTE.
	4	U	RBRPPPPPMS	PPPPP=-999.9 TO 9999.9	RANGE-BIAS RATE IN METERS-PER-SECOND, A NAV FILTER PARAMETER.
MSG	0		(NOT USED)		
	1-5	U	____________	(N/A)	ALPHANUMERIC MESSAGE DECODED FROM SV DATA, 24 CHARACTERS MAX.
MEM	0		(NO USED)		
	1-3	U	ADR PPPP Z	PPPP=0000 TO FFFF, HEXADECIMAL	ABSOLUTE BYTE ADDRESS FOR MEMORY READ/WRITE FUNCTION.
	1-3	L	CNT QQQQ Z	QQQQ=0000 TO FFFF, HEXADECIMAL	CONTENTS FOR ADDRESS ABOVE.

TABLE 3.2.5-2 CDU PARAMETER FORMATS (CONTINUED)

DATA	WYP	U/L	FORMAT	RANGE	NOTES
STAT	0	U	STA PPPP Z	PPPP=0000 TO OFF7, AND FFFF, HEX.	RELATIVE WORD ADDRESS FOR STATUS INDICATION IN COMMUNICATIONS MEMORY.
	0	L	RSL QQQQ Z	QQQQ=0000 TO FFFF, HEXADECIMAL	RESULT OF STATUS INQUIRY.
	1-5	U	SVPP RNQQ	PP=0-24, 33-37; QQ= 0-5	SV ID AND RCVR ASSIGNMENT, ORDERED BY NAV. SOURCES.
	1-5	L	STAT W	W=0-5	NAV. STATUS.

NOTE 1: FOR A WAYPOINT TO BE CONSIDERED VALID, CDU KEYBOARD ENTRY MUST BE MADE FOR: (1) LATITUDE, LONGITUDE, ALTITUDE; OR (2) EASTING, NORTHING, ALTITUDE. MIXED MODES ARE ALLOWED, I.E., SOME WAYPOINTS IN LAT/LON AND SOME IN UTM. THIS PRACTICE IS STRONGLY DISCOURAGED, SINCE NO DIRECT INDICATION OF ORIGINAL INPUT FORMAT IS DISPLAYED ON THE CDU.

NOTE 2: IF VALUES FOR HEADING AND HORIZONTAL APPROACH ANGLES ARE TO BE INPUTTED AS 'DEGREES MAGNETIC', THE MAGNETIC VARIATION MUST BE INITIALIZED FIRST, EVEN IF IT HAS A VALUE OF 0.

D. <u>CDU Initialization Procedure</u>

Initialization of the HDUE consists of six parts: cold-start almanac, master time delay calibration, GPS time, user velocity, user position, and navigation subsystem update.

Prior to HDUE operation, the operator should have a valid set of almanacs for all the SV'S for which he will acquire and track GPS signals. Optimum performance for receiver acquisition of the SV PRN codes are dependent upon prior knowledge of the range rate between the user and each desired SV. This range-rate aiding is computed by the NAVP subsystem, using a 'cold start' almanac (residing in the MSCP memory), plus operator inputs for time, user position and velocity. A valid set of almanacs is defined as the set of SV Data Block III parameters centered on a day no more than three and one-half days away from the desired time of HDUE operation. An almanac set which does not coincide with this time window <u>will degrade the SV PRN acquisition sequence</u>, that is, the sequence will require extended time to complete, or fail to complete. Specifically, the calculated range-rate aiding must be within plus-or-minus 250 meters-per-second of the actual range-rate for the first two SV acquisitions, and within plus-or-minus 100 meters-per-second for remaining SV'S. A good practice, then, is to periodically operate the HDUE to obtain an almanac set for future use. Since each SV transmits valid almanac for every operative SV in earth orbit, the HDUE operator need only acquire and track one SV for a few minutes, until the almanac validity flags in Communications memory are set for every desired SV almanac. Then, the operator can use the CDU Memory-Read function to recover the data. Table 3.2.5-3 lists the absolute hexadecimal addresses in the MSCP memory for the validity flags and the almanac parameters for each SV. To use this data at a future date, this table also shows the addresses where the operator can load the almanac data, using the CDU Memory-Write function. The following procedure explains the steps to recover almanac from the HDUE Processor memory (addresses and values are hexadecimal):

1. Acquire and track at least one SV.

2. Using the CDU Memory-Read function for the Master State Processor, monitor the data validity flags for all SV'S for which almanac data is desired. Flag=0000 means no almanac; flag=FFFF means processing complete.

3. Record the value of the GPS week number at address, D140.

4. Record sixteen words of almanac, beginning at the start address. Use the decimal key on the CDU to increment the address; the minus key decrements the address.

5. Word thirteen of the almanac is 'SV health' (normally zero). If it is non-zero, do not use this almanac.

6. Substitute the GPS week number for SV health when making the final form of the cold-start almanac.

7. When this cold-start almanac is needed at a future time, use the Memory-Write function in the MSCP to alter the contents of the memory locations, beginning with the starting address for each SV for which the more current almanac is desired.

TABLE 3.2.5-3 SV ALMANAC HEXADECIMAL ADDRESS MAP

SV	RECEIVED ALMANAC				COLD-START ALMANAC		
	START ADR	HEALTH	END ADR	VALIDITY	START ADR	WEEK	END ADR
1	E15E	E176	E17C	E48E	9000	9018	901E
2	E17E	E196	E19C	E490	9020	9038	903E
3	E19E	E1B6	E1BC	E492	9040	9058	905E
4	E1BE	E1D6	E1DC	E494	9060	9078	907E
5	E1DE	E1F6	E1FC	E496	9080	9098	909E
6	E1FE	E216	E21C	E498	90A0	90B8	90BE
7	E21E	E236	E23C	E49A	90C0	90D8	90DE
8	E23E	E256	E25C	E49C	90E0	90F8	90FE
9	E25E	E276	E27C	E49E	9100	9118	911E
10	E27E	E296	E29C	E4A0	9120	9138	913E
11	E29E	E2B6	E2BC	E4A2	9140	9158	915E
12	E2BE	E2D6	E2DC	E4A4	9160	9178	917E
13	E2DE	E2F6	E2FC	E4A6	9180	9198	919E
14	E2FE	E316	E31C	E4A8	91A0	91B8	91BE
15	E31E	E336	E33C	E4AA	91C0	91D8	91DE
16	E33E	E356	E35C	E4AC	91E0	91F8	91FE
17	E35E	E376	E37C	E4AE	9200	9218	921E
18	E37E	E396	E39C	E4B0	9220	9238	923E
19	E39E	E3B6	E3BC	E4B2	9240	9258	925E
20	E3BE	E3D6	E3DC	E4B4	9260	9278	927E
21	E3DE	E3F6	E3FC	E4B6	9280	9298	929E
22	E3FE	E416	E41C	E4B8	9280	9298	929E
23	E41E	E436	E43C	E4BA	92C0	92D8	92DE
24	E43E	E456	E45C	E4BC	92E0	92F8	92FE

NOTE: THE CURRENT WEEK NUMBER MUST BE SUBSTITUTED FOR SV HEALTH WORD WHEN BUILDING A COLD-START ALMANAC. THE ADDRESS WHERE THE GPS WEEK NUMBER CAN BE FOUND IS 'D140'.

The master time delay (MTD) calibration in the RECEIVER LRU measures and records, automatically, the propagation delays in the R.F. signal paths for each channel, at both frequencies, and for each antenna port. The MTD calibration must be performed, as a minimum, once after a master reset of the HDUE processors; additional calibrations can be done at any time, as long as all receiver channels are idle. The MTD sequence can be started with a single command, and, when completion of the MTD is indicated, cancelled in the same manner.

NOTE
GPS TIME MUST BE VERIFIED AFTER ANY MTD CALIBRATION

To command an MTD sequence, turn the Data switch to RCVR, turn the Waypoint switch to zero, enter '03' in the lower display. Wait for the upper display to indicate 'F3' (approximately one minute).

The operator should initialize GPS Time with his best estimate of present date and Greenich Mean Time. The reference day for the GPS System is January 1, 1978, which is a Sunday; this is the default date at system power-up. Since the year entry on the CDU is two digits, any date between 78 and 99 is for the 20-th Century, and any date between 00 and 77 are for the 21-th Century.

The initial user velocity consists of two parts:

heading, and true air speed. Use the best estimates of both; velocity (direction and magnitude) is assumed to be constant during the acquisition sequence which follows. If the user is static, no keyboard entries are necessary.

To initialize position, the operator must make available a 'best estimate', either LATITUDE/LONGITUDE or UTM, for the user vehicle position. One of the nine waypoints can be used for this, or a temporary position buffer available for position initialization (Waypoint switch position 0). If the user is moving, then the initial position should be one at which the vehicle will pass at the navigation update, described next.

The system update commands a complete navigation initialization process, initiated by the operator. The update is commanded, using the update key on the CDU.

This completes the HDUE initialization. The following example procedure details each step of the initialization sequence. Assume that all software has been loaded, including a valid cold-start almanac.

> Scenario: User vehicle moving at a constant altitude of 10,500 feet, true air speed of 250 knots, heading of 56 degrees, magnetic. The vehicle will pass over a landmark at 32 degrees, 49 minutes, North, and 96 degrees, 52 minutes, West. The magnetic variation

in this area is -15.0 degrees.

1.	MTD	Data sw. => RCVR Wypt sw. => 0 Enter, lower display => 03 (wait as upper display sequences from 'C3' to 'F3' in approximately one minute) Enter, lower display => 02
2.	TIME	Data sw. => TIME Wypt sw. => 0 Enter, upper display => (month, day, year) Enter, lower display => (hour, minute, sec)
3.	VELOCITY	Format switch => MAG Data sw. => HDG Wypt sw. => 0 Enter, lower display => -150 Enter, upper display => 056 Data sw. => TAS Wypt sw. => 0 Enter, upper display => 00250
4.	ALTITUDE	Data sw. => ALT Wypt sw. => 0 Enter, upper display => 10500
5.	POSITION	Data sw. => LAT Wypt sw. => 0 Enter, upper display => N03249000 Enter, lower display => W09652000 (keyboard entry at Wypt=0 is not echoed to display after 'ENT' is pressed)
6.	UPDATE	(when user vehicle passes over landmark) Data sw. => LAT Wypt sw. => 0 Depress 'UP' key (initial position then appears in the display and begins propagating according to user velocity)

E. Acquisition and Tracking Command

The SV acquisition and tracking sequence is initiated through one of several combinations of commands and SV constellations. Once begun, the process is controlled automatically by the receiver processor. The operator determines one of two SV selection modes, manual or automatic, and one of two acquisition/tracking commands, C/A acquisition - C/A track or C/A acquisition - P track.

When the automatic SV selection mode is used, the Navigation Subsystem selects the optimum set of SV'S to be tracked for GPS measurements. For the manual mode, the operator inputs the desired set of SV'S through the CDU. In either case, the normal SV constellation consists of four SV identification numbers (ID'S), with the minimum number of satellites being two and the maximum, five.

NOTE

TWO AND THREE SV CONSTELLATIONS CAUSE A DEGRADED GPS SOLUTION

The following example sequence details the CDU entry procedure for SV acquisition and tracking. Assume that all initialization has been completed.

Scenario: Use manual SV selection.
Constellation is SV'S 4, 6, 7, 8. Use
receiver command for C/A acq. / P track.

Data sw. => RCVR
Wypt sw. => 1

Enter, lower display => <u>04</u>

Wypt sw. => 2
Enter, lower display => <u>06</u>

Wypt sw. => 3
Enter, lower display => <u>07</u>

Wypt sw. => 4
Enter, lower display => <u>08</u>

Wypt sw. => 0
Enter, lower display => <u>05</u>

During the acquisition sequence and subsequent tracking process, receiver status information is available in the upper display for Waypoint switch positions 1 through 5, corresponding to the receiver channels. The display shows the SV assigned to that channel, and the status, mode, frequency, and antenna, in the form of a packed, 4-digit number. Table 3.2.5-4 shows the number code definitions for these as well as for the receiver commands.

NOTE

FOR THESE FIVE SWITCH POSITIONS, THE RECEIVER-ASSIGNED SV NUMBER IN THE UPPER DISPLAY BEARS NO NECESSARY RELATION TO THE DESIRED SV NUMBER IN THE LOWER DISPLAY

When the acquisition sequence is complete, i.e., all desired SV'S are being tracked, the upper display, Waypoint switch at 0, changes from CX to FX, where X is the last-entered receiver command number.

TABLE 3.2.5-4 CDU RECEIVER COMMANDS AND STATUS CODES

COMMAND	DESCRIPTION
0	(NO ACTION TAKEN)
1	SOFT CANCEL
2	TOTAL IDLE
3	MTD
4	C/A ACQUISITION/ C/TRACK
5	C/A ACQUISITION/ P TRACK
6	P ACQUISITION/ P TRACK
7	PRECISION

STATUS	DESCRIPTION
0	IDLE
1	VCXO CALIBRATE
2	VCXO SET
3	NOISE CALIBRATE
4	C/A SEARCH
5	CODE CENTER
6	BIT SYNC.
7	P-CODE INITIALIZATION
8	RANGE-RATE MEASUREMENT
9	C/A RANGING
A	C/A WEAK-SIGNAL-HOLD-ON
B	P RANGING
C	P WEAK-SIGNAL-HOLD-ON
D	REACQUISITION

MODE	DESCRIPTION
0	(NOT USED)
1	C/A SEARCH, C/A TRACKING
2	C/A SEARCH, P TRACKING
3	P SEARCH, P TRACKING
4	(NOT USED)
5	MASTER TIME DELAY

FREQ.	DESCRIPTION
0	L1
1	L2

ANTENNA	DESCRIPTION
0	UPPER
1	LOWER

E. **System Alert and Warning Messages**

Alert messages are initiated by the Display software task (and related subtasks) in response to error conditions due to improper CDU operation. The alert message appears in the upper display, and can be cleared using the CLR key.

1. ENT 2SHORT - ENT key was depressed before filling all required input positions.
2. ALPHA ERR - Letter value expected for this digit but something else was entered.
3. NUM ERR - Numeral value expected for this digit but something else was entered.
4. HEX ERR - Hexadecimal value expected but something else was entered.
5. ENT 2 LONG - More input characters were entered than expected.
6. SWITCH RNG - No display available with current Data and Waypoint switch settings.
7. NO FREEZE - Mark key was used before Position Freeze command.
8. NO INPUT - Data values were not preceeded with prefix IN1 or IN2.
9. NO ALMANAC - Almanac does not exist in MSCP memory for this SV; last entry is reset to zero.

Warning messages are initiated by system self-tests in the priority listed below, the first being the top priority. The Caution Lamp will be on as long as the error condition exists. For processor failures, the caution lamp flashes to catch the attention of the operator. The warning message display can be cleared using the CLR key. See

Paragraph 3.4.2, System Error Reporting, for descriptions of the specific processor failure error codes.

1. MCSP FAIL - Master State Control Subsystem failure. Error codes are displayed at ERR setting of Data Switch.

2. NAVP FAIL - Navigation Subsystem Failure. Error codes are displayed at ERR setting of Data Switch.

3. RCVP FAIL - Receiver Subsystem Failure. Error codes are displayed at ERR setting of Data Switch.

4. INIT TIME - Time has not been initialized.

5. INIT POS - Position has not been initialized.

6. TRK FAIL - Communication between the MSCP and RCVP through the STDM Bus has been interrupted.

7. RCVR FAIL - The Receiver Processor has logged a hardware failure in the Receiver LRU.

8. REACQ FAIL - Automatic reacquisition of an SV signal in LOS has failed; concentrated search has begun for that SV.

9. WYP BEHIND - Absolute value of (desired-horiz.-approach-angle minus bearing-to-waypoint) is greater than 90 degrees, i.e., waypoint is being approached from behind desired approach.

10. LAST ENTRY - Last entry was illegal or out of range.

11. SV MESSAGE - An alphanumeric message is available for display at Data Switch setting, MSG.

12. SYSTEM GO - The default message, when no error conditions exist.

3.2.6 Instrumentation Interface Unit Support Function

The IIU Data Blocks are described below with regard to function, timing, word number, word description, value type, and unit of measurement:

A. BLOCK NO. 002 (BASELINE BLOCK)

Function: Measures HDUE motion accuracy and inputs data to EDU, Format 1

Timing: Data in block is valid at 0.1 sec before 3.84 sec boundary. IRIG and FTF are for this instant.

Note: Requires Hewlett-Packard Floating Point Format

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4	IRIG time, upper word	BCD	sec.ms
5	IRIG time, lower word	BCD	hr.min.sec
6- 23	Direction cosine matrix	HPDPFP	na
24- 26	Current user veh. altitude	HPDPFP	meters
27- 32	Current user ENU velocity	HPFP	m/sec
33- 34	Baro altitude (user input)	HPFP	meters

B. BLOCK NO. 006 (BASELINE BLOCK 006 (MODIFIED))

Function: Inputs channel status and satellite vector to EDU status display

Timing: Same timing as BLOCK 002

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4	Almanac/Ephemeris usage flag	I*2	na
5- 7	RCVR 1 - Delay, SV ID, Status	I*2	na
9- 11	RCVR 2 - Delay, SV ID, Status	I*2	na
13- 15	RCVR 3 - Delay, SV ID, Status	I*2	na
17- 19	RCVR 4 - Delay, SV ID, Status	I*2	na
21- 23	RCVR 5 - Delay, SV ID, Status	I*2	na
24- 27	Channel health words	I*2	na
28- 32	(unused)		
33- 36	Satellite vector	I*2	na

C. BLOCK NO. 007 (FILTER ANALYSIS BLOCK 2)

Function: Inputs data to EDU Format 1 and EDU status display, and monitors filter performance

Timing: Same timing as BLOCK 002

Note: Requires Hewlett-Packard Floating Point Format

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4-135	Filter covariance square-root matrix after last covariance	HPFP	na

	propagation		
136-159	(unused)		
160	No. of meas. incorp. on this pass	I*2	na

D. BLOCK NO. 010 (BASELINE BLOCK 010 (MODIFIED))

Function: Inputs pseudo-range residuals to EDU Format 1, and monitors filter performance

Timing: Same timing as BLOCK 002

Note: Requires Hewlett-Packard Floating Point Format

Word No.	Description	Value Type	Units
1	ID and no of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4- 17	(unused)		
18- 27	Pseudo-range residuals by generic SV (set of five, assigned by nav)	HPFP	meters
28- 49	(unused)		
50- 57	Pseudo-range residuals by generic SV (only active nav sources, up to a maximum of four)	HPFP	meters

E. BLOCK NO. 011 (BASELINE BLOCK 011 (MODIFIED))

Function: Inputs range-rate residuals to EDU Format 1, and monitors filter performance

Timing: Same timing as BLOCK 002

Note: Requires Hewlett-Packard Floating Point Format

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4- 17	(unused)		
18- 27	Range-rate residuals by generic SV (set of five, assigned by nav)	HPFP	met/sec
28- 49	(unused)		
50- 57	Range-rate residuals by generic SV (only active nav sources, up to a maximum of four)	HPFP	met/sec

F. BLOCK NO. 018 (VARIABLE)

Function: Allows output of any contiguous set of 85 words in Communications Memory

Timing: 3.84 Sec, not critical

Notes: This is the only block with a variable starting address. The starting address is established by the operator via the CDU Memory-Write function at address, 'D9BC' (hex). M2IIUT transmits this block by loading the standard 3-word preamble into the IIU. M2IIUT then puts the block starting address into word 4, and fills the next word with anything, and finally, loads the next 85 words of contiguous memory starting at the address into the IIU. The starting address is measured from the first word in the MNXXXX Common Block. The EDU can display the first 65 words of this 90-word block. This block will allow the operator to display any part of the Communications Memory on the EDU, except for the eight executive words that precede MNXXXX.

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4	Starting address (relative) of block in communications memory	I*2	na
5	(unused)		
6- 90	Variable data	I*2	na

Q. BLOCK NO. 201 (NAV. FILTER INPUT)

Function: Records corrected pseudo-range and pseudo-range rate at the input to the filter, the SV positions and velocities, and the filter states. This data allows the computation of a fix using the data in BLOCK 202.

Timing: Same timing as BLOCK 002

Notes: This data is the data at the input to the filter. It should be the raw pseudo-range and pseudo-range rate after being corrected for the adjustments made by the NAVP and after being appropriately scaled and biased.

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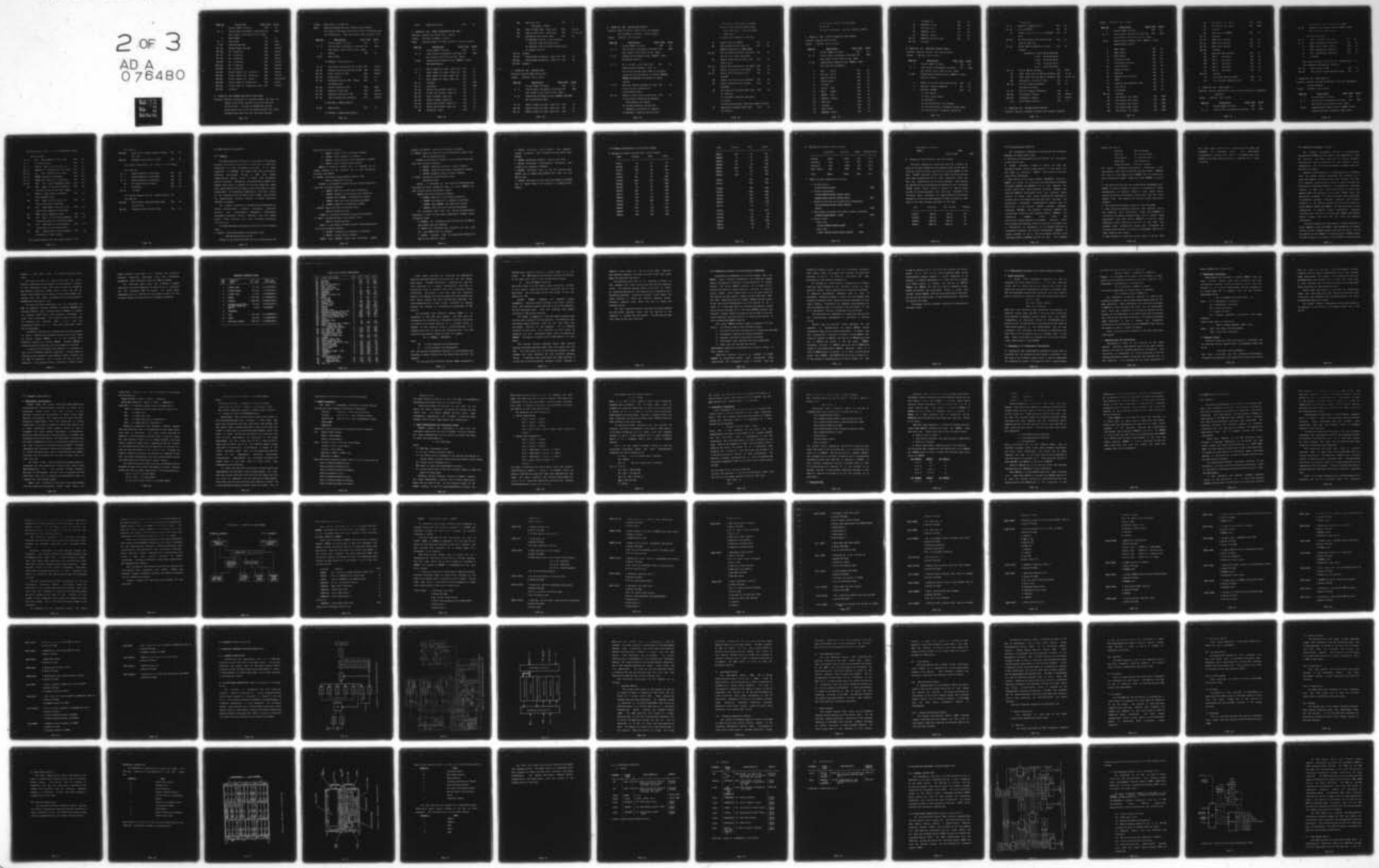


Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4	Week Number	I*2	na
5- 6	Time epoch	I*4	20ms
7- 26	Pseudo-range 5SV	R*8	meters
27- 36	Pseudo-range rate 5SV	R*8	met/sec
39- 58	SV X position	R*8	meters
59- 78	SV Y position	R*8	meters
79- 98	SV Z position	R*8	meters
99-108	SV X velocity	R*4	met/sec
109-118	SV Y velocity	R*4	met/sec
119-128	SV Z velocity	R*4	met/sec
131-142	Filter states 1-3 (position)	R*8	meters
143-148	Filter states 4-6 (velocity)	R*4	met/sec
149-154	Filter states 7-9 (accel)	R*4	met/sec**2
155-158	Filter state 10 (range bias)	R*8	meters
159-160	Filter state 11 (range-bias rate)	R*4	met/sec
149-150	(unused)		

H. BLOCK NO. 202 (CORRECTIONS AND FILTER GAINS)

Function: Records corrections to raw measurements and time, the ranges to the SV'S, and the filter gain matrices of the filter. The data in BLOCKS 201 and 202 would allow a fix to be calculated without the filter, assuming that data from four SV'S were present.

Timing: Same timing as BLOCK 002

Note: Requires Hewlett-Packard Floating Point Format

This data is the data used by the filter in working with the transmitters. Only one option comes down per block.

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4	Option	I*2	na
5-114	Option data		

<* OPTION 1: Corrections *>

Word No.	Description	Value Type	Units
5- 14	Iono/tropo corrections for 5 SV'S	R*4	meters
15- 24	Antenna lever-arm correction 5SV	R*4	meters
25- 34	Clock correction 5SV	R*4	meters
35- 36	Fudge factor	R*4	na
37- 56	Innovation factors 5SV - Range and Range-rate	R*4	na
57- 60	Filter reference time	R*8	20ms
61- 80	Computed ranges 5SV	R*8	meters
81- 90	Computed range-rates 5SV	R*4	met/sec
91- 92	Sum of normalized residuals	R*4	met**2

<* OPTION 2: RANGE GAINS *>

Word No.	Description	Value Type	Units
5-114	Range gains	R*4	na

<* OPTION 3: RANGE RATE GAINS *>

5-114	Range-rate gains	R*4	na

I. BLOCK NO. 206 (INPUT MEASUREMENTS FOR NAVP.)

Function: Records raw inputs from receiver

Timing: 0.64 Sec, boundary critical

Notes: Contains upper and lower buffers of receiver input

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4-109	Communications Memory Array, MNBSIO (1-106), Raw Measurements:		
4- 5	Epoch number at rngng, upper buf	I*4	na
6- 7	Epoch number at rngng, lower buf	I*4	na
8	Week number at rngng, upper buf	I*2	na
9	Week number at rngng, lower buf	I*2	na
10- 11	Latitude	I*4	BAM
12- 13	Longitude	I*4	BAM
14- 23	Pseudo rng by RCVR, upper buf	I*4	na
24- 33	Pseudo rng by RCVR, lower buf	I*4	na
34- 43	Epoch by RCVR, upper buf	I*4	na
44- 53	Epoch by RCVR, lower buf	I*4	na
54- 63	Delta rng by RCVR, upper buf	I*4	na
64- 73	Delta rng by RCVR, lower buf	I*4	na
82	Velocity, north	I*2	*

83	Velocity, east	I*2	*
	* 80 Knots / 32767		
84	Copy of IRIG time - upper word	BCD	sec.ms
85	Copy of IRIG time - lower word	BCD	hr.min.sec
86	Navigation mode status word	I*2	na
	2= degraded 2 SV nav. with altitude hold and time-bias-rate hold		
	3= degraded 3 SV nav with altitude hold,		
	4= normal 4 SV nav,		
87- 96	(unused)		
97-101	Packed RCVR parameters, upper buf.	I*2	na
102-106	Packed RCVR parameters, lower buf.	I*2	na
107-109	(unused)		

J. BLOCK NO. 207 (AIDING DATA)

Function: Records NAVP aiding data

Timing: 3.84 Sec, not critical

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4- 51	Communications Memory Array, MNBSIO (345-392), Bus Input/Output Data:		
4- 19	RCV3 C output bus msg, lower buf	I*2	na
20- 35	RCV3 D output bus msg, upper buf	I*2	na
36- 51	RCV3 E output bus msg, upper buf	I*2	na

K. BLOCK NO. 208 (NAVIGATION CONTROL)

Function: Records SVID'S, RCVR channel assignments, and navigation subsystem control status.

Timing: 3.84 Sec, not critical

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4- 41	Communications Memory Array, MMALRT (1-38), Navigation Control:		
4- 8	SV (1 to 32), or GT (33 to 40) Identification Numbers - This is the set of sources which HDUE is currently using and the information in arrays, MMSTUS, MMRECN and MMFLAG corresponds to these sources.	I*2	na
9- 13	Receiver channel assigned to each source at the completion of concentrated search	I*2	na
14- 18	Status of each source being used: 1= new source, computing polynomials from almanac for aiding 2= aiding available; waiting for ephemeris collection to complete 3= ephemeris complete and precision	I*2	na

	SV position polynomial available 4= outer loop interface data saved from inner loop; ready for gains computation 5= gains with ephemeris available		
19	Update flag for MMSVID	I*2	na
20	Sole access/release flag for MMSVID; argument to X3REQ, X3REL	I*2	na
21- 25	Set of sources desired (selected by user or by auto selection).	I*2	na
26	Number of SV sources with a nav. status of 5	I*2	na
27- 31	Source ID'S scheduled to be added	I*2	na
32	Number of sources to be added	I*2	na
33- 37	Source ID'S scheduled to be deleted	I*2	na
38	Number of sources to be deleted	I*2	na
39	Source selection mode: manual, automatic	I*2	na
40	Altitude hold degraded mode flag: 1= inactive 2= initiated, awaiting new gains 3= active 4= being deactivated, awaiting change of gains	I*2	na
41	Range-bias degraded mode flag: 0= inactive	I*2	na

1= initiated, waiting for new gains

2= active

3= being deactivated, awaiting change of gains

L. BLOCK NO. 209 (FIRST 40 WORDS OF CDU CONTROL)

Function: Records CDU I/O data

Timing: 3.84 Sec, not critical

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4- 43	Communication Memory Array, MNOCDU (1-40), CDU Interface Parameters		
4	Mode switch	I*2	na
5	Display switch	I*2	na
6	Waypoint switch	I*2	na
7	Format switch	I*2	na
8	(unused)	I*2	na
9	Freeze flag	I*2	na
10	MK/FZ number	I*2	na
11	UPDATE flag	I*2	na
12	DISPLAY control	I*2	na
13	LAST row	I*2	na
14	(unused)	I*2	na
15	LAST column	I*2	na
16	WARNING number	I*2	na

17	KEYBOARD row	I*2	na
18	KEYBOARD column	I*2	na
19	KEYBOARD flag	I*2	na
20	WARNING light	I*2	na
21	DISPLAY strobe	I*2	na
22- 41	WORKING displays, ASCII	I*2	na
42- 43	(unused)		

M. BLOCK NO. 210 (RECEIVER CONTROL TABLE)

Function: Records receiver SV control/status

Timing: 3.84 Sec, not critical

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4-148	Communications Memory Array, MNCRCV (1-145), Receiver Control:		
4	Number of sources being used by nav	I*2	na
5	Operator command semaphore	I*2	na
6	Operator command 1= soft cancel 2= idle, total cancel 3= calibrate 4= C/A acquisition, C/A ranging 5= C/A acquisition, P-ranging (normal mode) 6= P-acquisition, P-ranging (direct p)	I*2	na

7= Precision

7- 11	Operator commanded SV'S	I*2	na
12- 16	Copy of MMSVID	I*2	na
17	Update flag for operator commanded SV'S	I*2	na
18- 22	SV ID'S decoded from RCVR 2A msg, used for CDU only	I*2	na
41- 65	Actual RCVR parameters for each channel	I*2	na

parameters= status 38, 43, 48, 53, 58

= xmtr 39, 44, 49, 54, 59

= mode 40, 45, 50, 55, 60

= freq 41, 46, 51, 56, 61

= ant 42, 47, 52, 57, 62

66- 67	FTF at 320 MS boundary	I*2	20ms
68	IRIG, lower word at 320 ms boundary	BCD	sec.ms
69	IRIG, upper word at 320 ms boundary	BCD	hr.min.sec
80	Ionospheric correction flag	I*2	na
86- 90	Set of 5 range-difference availability flags	I*2	na
91- 95	Set of 5 range differences	I*2	na
96-105	Tropospheric delays	I*4	meters
106-115	Ionospheric delays	I*4	meters
116	No. of good receivers	I*2	na

N. BLOCK NO. 211 (SYSTEM STATUS VECTOR)

Function: Records subsystem software and hardware statuses

Timing: 3.84 Sec, not critical

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4-115	Communications Memory Array, MNSTAT (1-112), System Status Vector		
4	MCSP status	I*2	na
5	NAVP status	I*2	na
6	RCVP status	I*2	na
8	Initialize time	I*2	na
9	Initialize position	I*2	na
10	Track failure	I*2	na
11	Number of SV'S	I*2	na
12	Receiver	I*2	na
13	Reacquisition failure	I*2	na
16	STDM	I*2	na
17	Waypoint back-approach flag	I*2	na
18	Last entry	I*2	na
19	SV message	I*2	na
20- 23	(unused)		
24	FTF modulo(16) (peak)	I*2	20ms
25	FTF modulo(32) (peak)	I*2	20ms
26	FTF modulo(64) (peak)	I*2	20ms
27	FTF modulo(192) (peak)	I*2	20ms
28	FTF modulo(5) (peak)	I*2	20ms

29	FTF modulo(8) (peak)	I*2	20ms
30	FTF modulo(32) (peak)	I*2	20ms
31	(unused)		
32	Upper word of NGNRSD	I*2	na
33- 40	(unused)		
41- 54	MCSP error message	I*2	na
55- 68	NAVP error message	I*2	na
69- 82	RCVP error message	I*2	na
83-105	(unused)		
106	Receiver LRU available	I*2	na
107	RCV 1 available	I*2	na
108	RCV 2 available	I*2	na
109	RCV 3 available	I*2	na
110	RCV 4 available	I*2	na
111	RCV 5 available	I*2	na
112-113	(unused)		
114	Init time temporary flag	I*2	na
115	Init position temporary flag	I*2	na

O. BLOCK NO. 212 (DATA BLOCK I)

Function: Records unpacked SV clock correction data for subsequent analysis.

Timing: 3.84 Sec, not critical

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt	I*4	20ms

	was issued (since start of nav. mode)		
4- 53	Communications Memory Array, MTTCDS (1-50), SV or GT Clock Corrections		
	For first SV or GT,		
4- 5	T(OC), reference GPS time	I*4	na
6- 7	A(0), polynomial coefficient	I*4	na
8	AODC, age of data (clock)	I*2	na
9	A(2), polynomial coefficent	I*2	na
10	A(1), polynomial coefficent	I*2	na
11	(unused)		

For second through fifth SV or GT, repeat words 4 - 11;

The remainder of BLOCK 207 contains:

44- 48	Data validity flag	I*2	na
49- 53	Sole access request/release flags	I*2	na

P. BLOCK NO. 213 (DATA BLOCK II)

Function: Records unpacked SV ephemeris data for subsequent ground analysis.

Timing: 3.84 Sec, not critical

Word No.	Description	Value Type	Units
1	ID and number of words	I*2	na
2- 3	Time at which navigation interrupt was issued (since start of nav. mode)	I*4	20ms
4-133	Communications Memory Array, MIEPHM (1-130), Ephemeris/Ground Transmitter Data Array		

For Satellites, words 4 - 133 of BLOCK 213 contain:

For first SV,

4- 5	MO, mean anomaly at ref. time	I*4	na
6- 7	E, eccentricity	I*4	na
8- 9	SQRT(A), SQRT of semi-major axis	I*4	na
10- 11	OMEGAO, rt. ascension at ref. time	I*4	na
12- 13	IO, incl. angle at ref. time.	I*4	na
14- 15	OMEGA, argument of perigee	I*4	na
16- 17	OMEGA dot, rate of rt. ascension	I*4	na
18- 19	TOE, ref. time of ephemeris data	I*4	na
20	CRS, ampl. of the sine harmonic correction term to the orbit radius	I*2	na
21	DELTA n, mean motion difference from computed value	I*2	na
22	CUC, ampl. of the cosine corr. term to the arg. of latitude	I*2	na
23	CUS, amplitude of the sine corr. term to the argument of latitude	I*2	na
24	AODE, age of ephemeris data	I*2	na
25	CIC, ampl. of the cosine harmonic correction term to inclination angle	I*2	na
26	CIS, amplitude of sine harmonic correction to inclination angle	I*2	na
27	CRC, amplitude of cosine harmonic correction to orbit radius	I*2	na

For second through fifth SV, repeat words 4 - 27 for each sv,

124-128	Sole access request/release flag by SV or GT	I*2	na
129-133	Ephemeris data validity flag	I*2	na

For Ground Transmitters (GT), words 4 - 133 contain:

For first GT,

4- 5	Earth-centered x coordinate	I*4	na
6- 7	Earth-centered y coordinate	I*4	na
8- 9	Earth-centered z coordinate	I*4	na
10	GT identification number	I*2	na
11	GT health	I*2	na
12- 27	(unused)		

For second through fifth GT, repeat words 4 - 27 for each GT,

124-128	Sole access request/release flag by SV or GT	I*2	na
129-133	Ephemeris data validity flag	I*2	na

3.3 HDUE NAVIGATION SUBSYSTEM

3.3.1 General

The HDUE Navigation Subsystem is designed to accurately maintain the position and velocity coordinates of a GPS user travelling in a high performance aircraft. It is coded completely in FORTRAN, and communicates with its external operating environment through a 4096 word common communications memory, which it shares with the Master Control Processor. Navigation is accomplished by means of a Kalman filter which is capable of utilizing range and range rate measurements from as many as five satellites or ground transmitters. The Navigation Subystem has exclusive access to the Floating Point Arithmetic Unit (FPAU), and performs its computational function largely in Double Precision (Real*8) arithmetic.

The primary functions of the Navigation Subsystem are system initialization, relative navigation, satellite position and constellation management, measurement adjustment and Master Control interface, and the Kalman filter. These functions are fully discussed in Sections 3.3.3 to 3.3.7.

The HDUE Navigation Subsystem consists of the following tasks:

A. N1MITK, Filter Measurement Incorporation Task,

320 MS Foreground Priority

N1MITK is activated by N1INIT during initialization and calls the following subtasks:

a. N2MCNI, master control interface subtask

b. N2NEQS, state propagation subtask

c. N2HMTR, range and range rate computation subtask

d. N2NVIN, data initialization subtask

N2NVIN is called by N1MITK only in response to an update command by the operator and is not ordinarily executed from N1MITK.

B. N1XFRM, Coordinate Transformation Control Task

640 ms Foreground Priority

N1XFRM is activated by N1INIT during initialization and calls the following subtasks:

a. N2MOLD, WGS 72 to local datum conversion

b. N2GPMG, geodetic to military grid conversion

N2GPMG calls N2OSMG, row identifier offset

c. N2MSLH, mean sea level altitude adjustment

d. N2WPCM, waypoint calculations subtask

C. N1MCNS, Satellite Clock Corrections Task

1280 ms Foreground Task

N1MCNS is activated by N1INIT during initialization.

D. N1NFLT, Navigation Outer Loop Control Task

3840 ms Foreground Task

N1NFLT is activated by N1INIT during initailization and calls the following subtasks:

a. N2IONO, ionospheric-tropospheric correction

b. N2FOTP, filter control subtask

N2FOTP calls N2COVR, gains and covariance update subtask and N2FCPG, covariance propagation subtask.

E. N1SVPN, Satellite Position and Constellation Control Task

120 sec Background Task

N1SVPN is activated by N1INIT during initialization and calls the following subtasks:

a. N2SVSL, satellite selection control subtask

b. N2SVEC, satellite polynomial computation subtask

c. N2CGDG, geometry figure of merit subtask

F. N1INIT, Navigation Initialization Task

Background Task

N1INIT is activated by the Executive Subsystem and activates all other navigation tasks. It calls N2NVIN for data initialization and cancels itself.

N2NVIN calls the following subtasks:

a. N2MOLD, WGS 72 to local datum conversion

b. N2MGGP, military grid to geodetic conversion

N2MGGP calls N2OSMG, row identifier offset

c. N2MSLH, mean sea level altitude adjustment

The following data sets are used by the Navigation Subsystem in order to facilitate communicate between major navigation tasks:

A. NINNER, All variables used primarily by the 320 ms task N1MITK and its subtasks.

B. NOUTER, All variables used primarily by the 3.84 sec. task N1NFLT and its subtasks.

C. NINOUT, Variables used to communicate between the 320 ms and 3.84 sec. tasks.

D. NTRANS, Coordinate transformation and waypoint related variables, used primarily by the 640 ms task N1XFRM.

E. NCONST, Subsystem constants used by all tasks.

F. NELIPS, Coordinate Transformation Constants, used primarily by subtasks of N1XFRM.

G. NSVPOS, Variables used by the SV position task N1SVPN, and to communicate between this task and the 320 ms task.

H. NINTRF, Variables to pass data from N1MITK to N1XFRM and to Master Control IIU function; in commumications memory.

3.3.2 Memory Utilization and Processor Loading

A. Navigation Modules and Data Sets (16 bit words)

Name	Program	Data	Total
N1INIT	55	24	79
N1MCNS	484	65	549
N1MITK	598	48	646
N1NFLT	37	25	62
N1SVPN	376	49	425
N1XFRM	1320	122	1442
N2CGOG	227	53	280
N2COVR	761	167	928
N2FCPG	806	89	895
N2FOTP	554	70	624
N2GPMG	681	162	843
N2HMTR	418	108	526
N2IONO	316	61	377
N2MCNI	1397	68	1465
N2MGGP	613	178	791
N2MOLD	235	100	335

Name	Program	Data	Total
N2MSLH	322	94	416
N2NEQS	67	29	96
N2NVIN	724	74	798
N2OSMG	103	26	129
N2SVEC	1678	241	1919
N2SVSL	776	47	823
N2WPCM	635	110	745
NCONST		203	203
NELIPS		936	936
NINNER		349	349
NINOUT		1286	1286
NTRANS		230	230
NOUTER		556	556
NSVPOS		574	574
WPLOCL		24	24
MNXXXX		1915	1915
MTTCDS		50	50
MIEPHM		130	130
MPALMC		432	432
MMALRT		38	38
NINTRF		49	49

B. Navigation Processor Memory Summary

	Available	Utilized	Spare	Percent used
Program	16896	16544	352	97.9
Constants	1536	1139	397	74.2
Variables	6144	6082	62	99.0
Comm. Memory	4096	3226	870	78.8
Total	28672	26991	1681	94.1

C. Memory by Major Navigation Functions

a. Initialization:

N1INIT, N2NVIN, NCONST — 1080

b. Relative Navigation:

N1XFRM, N2GPMG, N2MGGP, N2MOLD, N2MSLH,
N2OSMG, N2WPCM, NELIPS, NTRANS, WPLOCL — 5891

c. Satellite Position and Constellation Management:

N1SVPN, N2CGOG, N2SVEC, N2SVSL, NSVPOS,
MMALRT — 4059

d. Measurement Adjustment and Master Control Interface:

N1MCNS, N2IONO, N2MCNI, NINTRF — 2440

e. Kalman Filter:

Inner Loop:

N1MITK, N2HMTR, N2NEQS, NINNER — 1617

Outer Loop:

N1NFLT, N2COVR, N2FCPG, N2FOTP, NOUTER — 3065

Inner/Outer Interface:

NINOUT	1286		
		Total Filter:	5968

D. Foreground Task Processor Time Utilization

Processor loading for foreground tasks was studied by means of calling X3TIMM with an argument equal to the task's priority in 20 ms counts just prior to calling X3WAIT in the task. X3TIMM therefore returns the number of 20 ms periods which have transpired prior to task completion since the task was scheduled at its priority boundary. Peak loading was determined by accumulating the maximum of the resulting X3TIMM output values during a period in which a great variety of processing modes was exercised. Therefore the following table represents an approximation to processor loading by giving the peak ammount of time utilized by each task in the time interval allocated for the task.

Task	Priority	Max. Finish	Percent
N1MITK	320 ms	160 ms	50
N1XFRM	640 ms	220 ms	34
N1MCNS	1280 ms	240 ms	19
N1NFLT	3840 ms	2400 ms	63

3.3.3 Initialization Function

For Navigation Subsystem initialization the following sequence of events takes place.

A. The Executive Subsystem activates N1INIT, the navigation initialization task.

B. N1INIT activates X1COMN to enable the FPAU and navigation-master control communications. It then waits for the power up indicator, XQPRUP, to be set to a non-zero value before proceding.

C. Upon receipt of an update command (MNCNAV(2) non-zero), N2NVIN is called to initialize the appropriate subsystem variables. N2NVIN sets MNCNAV(1) to 3, and computes user initial earth fixed, earth centered position (NGACPS) and velocity (NGACVL) coordinates. Since user position inputs consist of either local datum latitude and longitude or military grid coordinates and mean sea level altitude, the appropriate coordinate transformation modules must be exercised. In the process WGS-72 latitude (NGLATD), longitude (NGLNGD), and geodetic altitude (NGALTD) are initialized, as well as the rotation matrix (NGTRO1), for conversion between local level and earth fixed, earth centered coordinates. Velocity inputs are airspeed and heading; vertical velocity is assumed to be 0. Ordinarily, an assumption of 0 airspeed suffices for convergence purposes. The initial acceleration (NGACAC) is always assumed to be 0. All off diagonal entries in the covariance matrix (NGCOVR) are set to zero. The diagonal entries are set to:

Position	100 km squared,
Velocity	100 m/sec squared,
Acceleration	10 m/sec/sec squared,
Range Bias	100 km squared,
Range Bias Rate	50 m/sec squared.

All gains, ionospheric-tropospheric corrections, clock corrections, lever arm corrections and range rates (NGRTCM) are set to 0. The range values (NGRNGC) for all sources are set to 22 million meters. Range bias rate (NGRTBS) is set to 0.

D. The satellite position and constellation managememt task, N1SVPN, is then activated to select a constellation either automatically or manually based on user inputs, and to compute SV position polynomial coefficients from cold start Almanac data. This enables the receiver aiding function to commence.

E. The remaining navigation tasks are then activated.

F. After acquiring ephemeris data on some selected source and computing clock corrections, range bias (NGRBIS) is initialized by summing computed range and a pseudo range measurement from that source. MNCNAV(1) is set to 1 after computing a clock correction, and to 0 at the outer loop boundary after initializing range bias. Throughout the initialization process, the state is propagated, 320 ms at a time, based on user inputs.

G. When ephemeris is acquired from at least 2 sources then the outer loop is exercised to compute gains and update and propagate the covariance matrix. The measurement incorporation process then starts in degraded mode until ephemeris has been gathered and gains computed for at least 4 sources.

3.3.4 Relative Navigation Function

The relative navigation function is accomplished through task N1XFRM and its subtasks, and operates at a 640 ms priority. Its main jobs are to provide waypoint initialization service, make user fix and waypoint output computations, and to provide necessary navigation data for CDU and IIU support.

Waypoint initialization is accomplished by accepting from the Master Control Subsystem the location of a specified waypoint as input by the user through the CDU. This waypoint position may be given in terms of either the Military Grid Reference System or in latitude and longitude relative to some user chosen local datum. In either case waypoint mean sea altitude is also input. N1XFRM calls the appropriate subtasks in order to convert these quantities into waypoint geodetic latitude, longitude and altitude relative to the WGS 72 spheroid and stores the results in arrays NWPLAT, NWPLON and NWPALT. This data may then be used subsequently in waypoint output computations. Waypoint initialization service is provided upon demand, when Master Control signals that the user has input new waypoint coordinates.

The data computed for CDU support is double buffered in array MNNDIS in data set MNXXXX. Both N1XFRM and its Master Control partner, M1ADIS operate every 640 ms. Hence, during any 640 ms period, M1ADIS is processing prior N1XFRM outputs for CDU display in one buffer, while N1XFRM is preparing new outputs in the other buffer for display during the next cycle.

The inputs for user fix computations are the user's state as determined by the measurement incorporation portion of the navigation filter. This data is saved for N1XFRM by task N1MITK in data set NINTRF during every odd 320 ms period. Since N1MITK has a higher priority than N1XFRM, this insures that user state information will be available to N1XFRM each time that it runs.

The user position coordinates x,y,z are converted to WGS 72 geodetic latitude (NGLATD), longitude (NGLNGD) and altitude (NGALTD), and a rotation matrix (NGTRO1) is created for relating earth fixed, earth centered coordinates to local level coordinates. This rotation matrix is then used to transform the velocity state x',y',z' and the acceleration state x'',y'',z'' into local level east, north, and up components.

The WGS 72 latitude and longitude may be then converted to either latitude and longitude relative to a local datum by calling subtask N2MOLD , or to the Military Grid Reference System by calling N2GPMG. Subtask N2MSLH is called to make the mean sea level adjustment to altitude.

A choice of 46 different local datums is provided as well as 11 different reference spheroids. A local datum is defined by the location of the spheroid center relative to the WGS 72 Spheroid, and a choice of one of the 11 spheroids. The spheroid center is defined in Earth Fixed, Earth Centered Coordinates x,y,z whereas the choice of spheroid identifies semi-major axis and flattening parameters, again relative to the base WGS 72 system.

The following table shows the difference between semi-major axis and flattening for each of the 11 spheroids and the reference WGS 72 system. The second table enumerates the x,y,z offsets for the center of each of the 46 local datums from the center of the WGS 72 spheroid.

SPHEROID PARAMETER TABLE

SPH. NO.	SPHEROID NAME	DIFF. IN SM. AXIS	DIFF. IN FLATTENING
1	CLARKE 1880	114.145	0.54781925E-4
2	INTERNATIONAL	253.000	0.14223913E-4
3	CLARKE 1866	71.400	0.37295850E-4
4	BESSEL	-737.845	-0.10006272E-4
5	EVEREST	-858.655	-0.28330158E-4
6	AUSTRALIAN NATIONAL OR SOUTH AMERICAN	25.000	0.00112415E-4
7	WGS-72	0.000	0.00000000
8	KRASOVSKY		
9	AIRY	-571.604	-0.11928812E-4
10	HOUGH	135.000	0.14223913E-4
11	MODIFIED EVEREST	-830.937	-0.28330158E-4

LOCAL DATUM ORIGIN COORDINATES

ID	LOCAL DATUM NAME	SPH.	X(M)	Y(M)	Z(M)
01	ADINDAN	1	152	26	-212
02	ARC 1950	1	129	131	282
03	AUSTRALIAN GEODETIC	6	122	41	-146
04	BUKIT RIMPAH	4	-	-	-
05	CAMP AREA ASTRO	2	103	122	-233
06	CHATHAM OBSV. 1950	2	-	-	-
07	DJAKARTA	4	360	-680	55
08	EUROPEAN	2	84	103	127
09	GEODETIC DATUM 1949	2	- 82	38	-195
10	GHANA	1	-	-	-
11	GUAM 1963	3	89	235	-254
12	G. SEGARA	4	-	-	-
13	HERAT NORTH	2	320	229	-109
14	HJORSEY 1953	2	75	-39	90
15	HU-TZU-SHAN	2	620	542	206
16	INDIAN	5	-189	-746	-259
17	KERTAU	11	12	-857	- 15
18	LIBERIA 1964	1	63	- 12	- 80
19	ASCENSION ISLAND ASTRO 1958	2	214	- 91	- 48
20	CANTON ISLAND ASTRO 1966	2	-294	288	382
21	JOHNSTON ISLAND ASTRO 1961	2	-192	59	211
22	WAKE ISLAND ASTRO 1952	2	-283	44	-141
23	LUZON	3	-	-	-
24	MONTJONG LOWE	4	-	-	-
25	NIGERIA	1	89	112	-124
26	NORTH AMERICAN 1927 -CONUS-	3	22	-157	-176
27	NORTH AMERICAN 1927 - ALASKA AND CANADA -	3	9	-139	-173
28	OLD HAWAIIAN - MAUI	2	-205	215	362
29	OLD HAWAIIAN - OAHU	2	-196	211	352
30	OLD HAWAIIAN - KAUAI	2	-186	214	346
31	ORDINANCE SURVEY OF GREAT BRITIAN 1936	9	-368	120	-425
32	QORNOQ	2	-163	-127	151
33	SIERRA LEONE 1960	1	-	-	-
34	SOUTH AMERICAN 1969	6	77	- 3	45
35	PROVISIONAL SOUTH AM. 1956	2	302	-105	371
36	CORREGO ALEGRE	2	261	-140	24
37	CAMPO INCHAUSPE	2	160	-133	- 75
38	CHUA ASTRO	2	154	-242	40
39	YACARE	2	167	-163	- 33
40	TANANARIVE OBSV. 1925	2	178	254	95
41	TIMBALAI	4	650	-525	76
42	TOYKO	4	140	-516	-673
	WAKE-ENIWETOK 1960				
43	- KWAJALEIN ATOLL -	10	-112	- 68	44
44	- WAKE ISLAND -	10	-121	- 62	22
45	- ENIWETOK ATOLL -	10	-144	- 62	38
46	WGS 72	7	0	0	0

Local datum latitude and longitude are computed by using the Abridged Molodensky formulas and the two tables from above. The WGS 72 altitude is adjusted to a mean sea level altitude by a simple interpolation algorithm in conjunction with a gridded data base of geodetic height corrections. The points in the data base are regularly spaced in 10 degree units and the algorithm interpolates the four points around the local latitude and longitude. The local datum position is then either converted to degrees minutes and seconds or military grid coordinates for CDU display.

The Military Grid Reference System (MGRS) is an extension of the UTM grid system. The UTM grid is a rectangular grid defined by a transverse mercator projection of a point on an oblate spheriod to a cylinder which is tangent to the spheriod along a central meridian. It is normally used over a 6 degree wide longitude zone. The UTM position specification takes the form, for example

36 S 529820.E 3891400.N,

where

36 is the longitude zone designation,

S is the latitude zone designation,

And the position designation consists of a grid Easting and Northing in meters relative to the Central Meridian and the Equator.

The Military Grid Reference System (MGRS) designates a

100,000 meter square by means of a column letter an a row letter. The MGRS Easting and Northing values are relative to the lower left corner of the 100,000 meter square:

ie. 36 S WD 29820. E 91400. N,

Where the letter W is the Column Letter indicating location of the square along the east-west direction, and D is the Row Letter. The zone number 36 and zone letter S are the same as for UTM.

Subtask N2WPCM computes all waypoint output parameters. These are range, bearing, cross track, vertical error, back approach warning and time to go to the waypoint, and are described below. They are computed upon demand according to CDU switch settings.

The Range to Waypoint is the horizontal distance from the the user's position to the waypoint. The bearing is the horizontal angle from grid north to the line from user horizontal position to the waypoint. It is computed relative to true north, and converted to grid north by applying the grid convergence angle, which is computed by N2GPMG. The angle is scaled from 0 to 360 where 0 is Grid North.

The desired vertical approach angle, DVA, and the desired horizontal approach angle, DTK, are inputs from the CDU. The cross track, XT, is the shortest distance in feet between the users position and the horzontal approach vector. A positive cross track means the users position is to the left of the horizontal approach vector, whereas a negative value means the user is to the right. When the back approach warning is on then the sign of the cross track means the opposite from above.

The vertical error, VE, is the shortest distance in feet between the users position and the vertical approach vector. The vertical approach angle is positive to define an ascending approach to the waypoint and is negative for a descending approach. A positive vertical error means the users position is below the vertical approach vector, whereas a negative error means the user is above the approach vector.

The back approach warning indicates the angle between the horizontal approach vector and the bearing to the waypoint is greater than 90 degrees. The CDU warning lamp will flash during this condition.

3.3.5 Satellite Position and Constellation Management

Constellation management is achieved through data set MMALRT, which contains essentially all satellite related status information of interest to Navigation and to Master Control. The array MMSVID contains the ID number of all sources selected at a given time as a function of generic source number, which ranges from 1 to 5. We shall refer to the sources by their generic numbers as SV1, SV2, SV3, SV4, and SV5. Satellites have ID numbers (MMSVID values) from 1 to 24, and ground transmitters have ID's from 33 to 37. A value of 0 indicates that the corresponding generic number has no source assigned to it. The array MMRECN contains the receiver channel numbers assigned to SV1 to SV5. A non zero value indicates that the receiver is tracking the source in the corresponding MMSVID location.

The array MMSTUS contains status information for each source. Its entries take on the following values:

1 The source has been selected but no aiding yet available.

2 Polynomials computed and aiding available.

3 Ephemeris has been successfully collected.

4 Inner/Outer loop interface has been established.

5 Outer loop has executed for source.

Measurements cannot be incorporated for a source unless it has a status of 5.

Satellite position xs, ys, zs is computed in subtask N2HMTR by evaluating second order polynomials whose coefficients are recomputed every 2 minutes. Thus, the difference between current time and polynomial reference time should never be greater than 1 minute. The satellite velocity xs',ys',zs' is found by evaluating the time derivative of the position polynomials.

At navigation initialization polynomials are created from cold start almanac for all selected sources so that receiver aiding can be generated for acquisition purposes. In computing polynomials, ephemeris data is used if available. Otherwise almanac is used, with the almanac most recently processed from a satellite being preferable to cold start almanac. Polynomials are computed using ephemeris as soon as ephemeris data is available, and the status is set to 3. thereafter, they are recomputed every 2 minutes.

The algorithm for computation of satellite position and the interpolating polynomials is described in Section 5.3.21.

Sources may be selected either manually, by the operator, or automatically, by module N2SVSL. Ground transmitters may only be selected manually. In either case the constellation selected is stored in array MMSVCM. This array is compared to MMSVID, and sources in MMSVCM which are not in MMSVID are placed in the add queue, MMADSV. Conversly, sources in MMSVID which are not in MMSVCM are placed in the delete queue, MMDLSV. Whenever, there is a slot in MMSVID which is vacant, i.e. 0, then a source may be moved from MMADSV into MMSVID and be given a status of 1. If the system is navigating with a source (status 5), then it may be deleted only if the other four sources also have a status of 5. This is to avoid degraded mode during constellation changes. However, a source scheduled to be deleted is dropped immediately if it does not have a status of 5. When a source is dropped, its entries in MMSVID, MMRECN and MMSTUS are set to 0, and its ephemeris flags, MIEVFL and MTTVFL, are invalidated. During a single pass through module N2SVSL, additions are made before deletions, and during any single pass, as many additions and deletions as possible are made.

The method used for automatic selection is described in Section 5.3.22.

3.3.6 Measurement Adjustment and Master Control Interface

A. Clock Correction

A second order polynomial expansion is used to represent the drift characteristics of the GPS satellite clocks and to absorb any secular relativistic effect. The satellites and ground transmitters transmit a reference time TOC and polynomial coefficients A0, A1, A2. Let t be a time at which a correction is desired. Then for a particular source:

$$dt = t - TOC$$

$$DC = A0 + dt(A1 + A2\ dt)$$

$$DCR = A1 + 2\ A2\ dt$$

Where DC is the resulting clock correction to be applied to measured pseudo range, and DCR is the clock rate correction to be applied to measured pseudo range rate. For ground transmitters an additional offset of 72.47077224 ms is applied to DC. DC and DCR must be multiplied by the speed of light before applying to the measurements. End of week crossovers are accounted for by adding or subtracting one week from dt if its absolue value is greater than a half week. These corrections are computed for all active sources every 1.28 seconds in task N1MCNS.

B. Ionospheric and Tropospheric Corrections

In processing GPS measurements atmospheric delays must be accounted for. An exponential model based on altitude h and the sine of the elevation angle sin(E) is used to compensate for tropospheric delays. The quantity sin(E) is approximated by using the range R from user to satellite:

$$\sin(E) = (R^{2} - 6.648E14)/(-1.276E7\ R).$$

However, E is assumed to be greater than 5 degrees, so that sin(E) is not allowed to become smaller than 0.087156. The tropospheric correction CT is computed by:

$$CT = 2.175\ EXP(-1.439E-4\ h)/\sin(E).$$

For ground transmitters a simpler model is employed:

$$CT = 3.13E-4\ R\ \exp(-6.936E-5\ h).$$

The ionospheric correction applied is based on the difference between L1 and L2 range measurements made to the same satellite. These differences are recursively averaged in M2STIN in order to reduce the noise due to measurement error. Each new difference is included by setting the new average of the differences to be 63/64 times the old average plus 1/64 of the new range difference. The resulting average range difference is used to compute the ionospheric correction CI by multiplying it by 5.5550564E-10 and then by the speed of light to convert to meters.

These corrections are computed in the Outer Loop every 3.84 seconds.

C. Antenna Lever Arm Corrections

Navigation is based on the location of the lower antenna. Therefore, measurements taken on the upper antenna must be corrected for antenna separation (4.5 meters). This correction is determined to be the projection of the the antenna separation distance along the line from the user to the satellite. It is computed for all active satellites in module N2IONO every 3.84 seconds.

D. Measurement Acceptance

Measurements are accepted in module N2MCNI from all valid, active sources from which ephemeris has been successfully collected. Checks are made to ensure that the receiver is in a valid ranging mode, and the frequency is L1. Pseudo range PR is computed from the raw receiver measurement RM by:

$$PR = (3.5938E-10\ RM + CT + CI - DC)C - CL$$

Where CT = tropospheric correction,

CI = ionospheric correction,

DC = clock correction,

C = speed of light,

CL = antenna separation correction (0 for lower antenna).

Pseudo range rate is computed by:

$$PRR = 0.104067(1232000 - RRM) + CRR,$$

Where RRM = raw range rate measurement,

CRR = clock rate correction.

E. Receiver Aiding

Receiver range and range rate aiding is performed for all selected sources. Range aiding is propagated forward 640 ms by

$$R(t+.64) = R(t)+0.64\ RR(t).$$

The clock correction and the Ionospheric-Tropospheric correction are applied in the opposite direction from which they are taken in adjusting input measurements, thereby creating from the state an approximation to a raw receiver range measurement. This range is then converted to units of 29.30522 meters and rounded to fixed point. The range bias is also forecast 640 ms ahead and sent on as aiding data after converting to 100 nanosecond units.

Pseudo range rate aiding is provided by subtracting range rate from range bias rate, taking out the clock rate correction, and converting the resulting quantity to units of 2000/1920 meters per second.

The Master Control Subsystem provides time aiding to the Receiver in the form of a 1.5 second Z-count, and a 20 ms FTF.

3.3.7 Kalman Filter Function

A. Measurement Incorporation

Pseudo Range and Pseudo Range Rate measurements are incorporated for state estimation purposes by means of a suboptimal Kalman filter. The state consists of user position, velocity and acceleration in Earth Fixed Earth Centered Coordinates, and range bias and range bias rate. Ordinarily, measurements from four satellites or ground transmitters are used to update the state every 320 ms, and a linear exponential state dynamics model is used to propagate the state between measurement incorporations. Gains are computed and the covariance matrix is updated and propagated every 3.84 seconds. The measurement incorporation and state propagation process is collectively referred to as the Inner Loop and is controlled by task N1MITK. The gains computation and covariance update and propagation procedure is called the Outer Loop, and is controlled by task N1NFLT. The Outer Loop is executed once for each 12 times that the Inner Loop runs.

The Earth Fixed, Earth Centered Coordinate System is orthogonal and right handed with origin at the center of the WGS-72 Spheroid. The x axis extends through Greenwich Meridian at the Equator, and the z axis is aligned with the North Pole. The y axis is chosen in the Equatorial plane to complete the right handed system.

Range bias is defined as the sum of the range between user and satellite and measured pseudo range. Hence, the relationship between state and measurements is non-linear and expressed by:

Range Residual = ZR(I) = PR(I) - (RB-R(I))

Range Rate Residual = ZRR(I) = PRR(I) - (RBR-RR(I))

where PR(I) is measured pseudo range for satellite I,

PRR(I) is measured pseudo range rate for satellite I,

RB is range bias,

RBR is range bias rate,

R(I) is range from user to satellite I,

RR(I) is range rate for satellite I.

Range R is computed as the apparent distance between user and satellite, and is the magnitude of the range vector from user to satellite. The range vector from user to satellite is the satellite position vector (xs,ys,zs) minus the user position vector (x,y,z). Range rate RR is the time rate of change of range, and is computed as the dot product of the range vector from user to satellite (x-xs,y-ys,z-zs) with its time derivative (x'-xs',y'-ys',z'-zs') divided by range R. Satellite position and velocity are computed at the time of signal transmission, and user position and velocity are interpreted as at the time of signal receipt.

The satellite position and velocity coordinates must be adjusted to take into account the ammount of earth rotation during the time of signal transmission. These equations are:

xs(I) = xs(I) + ys(I)R(I)WE/C,

ys(I) = ys(I) - xs(I)R(I)WE/C,

xs'(I)= xs'(I)+(ys'(I)R(I) + ys(I)RR(I))WE/C,

$$ys'(I) = ys'(I) + (xs'(I)R(I) + xs(I)RR(I))WE/C,$$

where

(xs(I), ys(I), zs(I)) = satellite I position vector,

(xs'(I), ys'(I), zs'(I)) = satellite I velocity vector,

WE = Earth rotational velocity (7.292115147E-4 rad/sec),

C = speed of light (2.99792458E8 m/sec).

Measurements are incorporated by adding the product of the corresponding gains and residuals to the state. New gains are produced by the outer loop every 3.84 seconds, and the gains data is double buffered so that at any time, one buffer is being used to incorporate measurements while the other is being filled with new gains to be used next. The order in which measurements are processed is the range measurement for SV 1, range rate for SV 1, range for SV 2, range rate for SV 2, and so on. The computed range or range rate used in a particular incorporation is based on the latest available state, that is, the state which was the result of the immediately preceding measurement incorporation. Measurements are processed by generic SV number which is the same order in which outer loop computations are performed.

If there are less than two sources for which gains and measurements are available, then no measurements are used. With two sources then both altitude hold and range bias hold are used to compensate for the shortage of measurements. With three sources then altitude hold remains in effect. The filter operates normally whenever there are either four or five sources from which to incorporate measurements.

B. State Propagation

The state is propagated from time t to time t+dt by solving the state dynamics differential equations:

dP/dt=V, P=(x, y, z), user position vector,

dV/dt=A V=(x', y', z'), user velocity vector,

dA/dt=-A/TA A=(x", y", z"), user acceleration vector,

dRB/dt=RBR

dRBR/dt=0

where TA is the acceleration correlation time (3 seconds).

Let PHIaa = EXP(-dt/TA),

PHIva = TA(1-PHIaa),

PHIpa = TA(dt-PHIva),

then P(t+dt) = P(t) + V(t) dt + A(t) PHIpa,

V(t+dt) = V(t) + A(t) PHIva

A(t+dt) = A(t) PHIaa,

RB(t+dt) = RB(t) + RBR(t) dt,

RBR(t+dt) = RBR(t).

Hence the state transition matrix PHI is 11 by 11 and given by:

PHI(1,1)=PHI(2,2)=PHI(3,3)=1,

PHI(4,4)=PHI(5,5)=PHI(6,6)=1,

PHI(7,7)=PHI(8,8)=PHI(9,9)=PHIaa,

PHI(10,10)=PHI(11,11)=1,

PHI(1,4)=PHI(2,5)=PHI(3,6)=dt,

PHI(1,7)=PHI(2,8)=PHI(3,9)=PHIpa,

PHI(4,7)=PHI(5,8)=PHI(6,9)=PHIva,

PHI(10, 11)=dt.

All other entries of PHI are 0. Thus, the state is propagated by multiplying the state vector by the matrix PHI.

Given an estimate of the state at any time, we can apply the above equations to produce an estimate at some future time. The module N2NEQS performs these state propagation computations with dt=320ms to move the state between times at which measurements are incorporated.

C. Gains Determination and Covariance Update

N2FOTP controls the computation of gains and the covariance update with the help of N2COVR. The basic formula for gains determination for any source and either the range or range rate measurement is:

$$K = PH'/(HPH'+SR),$$

where

I = HPH'+SR = innovation vector,

P = 11 by 11 state covariance matrix,

H = row vector with 11 elements of the partial derivatives of pseudo range or pseudo range rate with respect to the states,

H'= column vector transpose of H,

SR= range or range rate measurement variance,

K = column vector with 11 entries of either range or range rate gains for each state.

Normally, during P ranging, values of 5 meters squared for range measurement variance and 0.5 m/sec squared for range rate are used for SR. For C/A ranging a value of 25 meters squared is used for range measurement variance. The above computational procedure must be repeated for both range and range rate for all active sources. The array H is a function of the user and satellite position and velocity. This data is passed to the outer loop by N1MITK during the last 320 ms of each 3.84 second period.

The equations for the H array are:

a. Range computations

H(1) = (xs(I) - x)/R(I)

H(2) = (ys(I) - y)/R(I)

H(3) = (zs(I) - z)/R(I)

H(4) = H(5) = H(6) = H(7) = H(8) = H(9) = H(11) = 0

H(10)= 1

b. Range rate computations

H(4) = (xs(I) - x)/R(I)

H(5) = (ys(I) - y)/R(I)

H(6) = (zs(I) - z)/R(I)

H(1) = (RR(I)H(4) + xs'(I) - x')/R(I)

H(2) = (RR(I)H(5) + ys'(I) - y')/R(I)

H(3) = (RR(I)H(6) + zs'(I) - z')/R(I)

H(7) = H(8) = H(9) = H(10) = 0

H(11)= 1

The index I identifies the source being used with generic identification number I, where I is between 1 and 5. As before, R and RR are range and range rate computed from the state. The user's position and velocity coordinates are x,y,z,x',y',z', while the satellite's position and velocity are designated by xs,ys,zs,xs',ys',zs'.

The equation for covariance update is:

$$P = (I - KH)P$$

Where I is the 11 by 11 identity matrix with 1 along the diagonal and 0 elsewhere. The covariance matrix must be updated for range and range rate for each active source with a status of 4 or 5, that is, for each source from which measurements are being taken, from which ephemeris data has been collected, and for which Outer Loop interface data has been stuffed by the Inner Loop.

In reality the above equations are not carried out directly but with P decomposed in the form P = UDU' where U is an upper triangular 11 by 11 matrix with all diagonal entries 1, and U' is the transpose of U, a lower triangular matrix. D is a diagonal matrix with positive diagonal entries.

Let n be the number of states, usually 11. Then the equivalent covariance update and gains determination equations for the U-D matrices is:

E = U'H, E is an vector with n entries,

A0 = SR**2,

B0 = 0, B0 is a vector with n entries,

For k = 1 to n,

Ak = Ak-1 + Dkk Ek**2,

Bk = Bk-1 + Uk Dkk Ek,

<u>Uk</u> = Uk - Bk-1 (Ek/Ak-1),

<u>Dkk</u> = Dkk Ak-1/Ak,

K = Bn/An.

The vector Uk represents the k-th column of the matrix U, and Uk and Bk contain zeros below the k-th elements. Uk and Dkk represent the updated values for Uk and Dkk.

D. Covariance Propagation

Time propagation of the covariance matrix between time points t and t + dt is a function of the state transition matrix PHI and process noise covariance matrix Q. Between updates the covariance matrix is propagated dt = 3.84 seconds by the equation:

P(t+dt) = PHI P(t) PHI′ + Q FF,

where PHI′ is the transpose of the matrix PHI. The computational procedure is performed in the subtask N2FCPG and the PHI P PHI′ part is implemented in the U-D formulation. The covariance matrix is then converted to the usual form by the equation P = UDU′, and the matrix Q FF is added to the result. The scalar FF is a multiplier that normally has a value of 1, but which may also become 4, 16 or 64 during turns or periods of high acceleration. The Modified Cholesky Decomposition is used to transform the resulting propagated P back to U-D form, and is described as follows:

For k=n down to k=1, do the following:

Let S be the sum from i = k+1 to n of Uki**2 Dii. Note that for k=n, S is an empty sum and so S=0 for that case.

Dkk = Pkk - S

Ukk=1

For j = 1 to k-1, (skip for k=1) do the following:

Let T be the sum of $U_{ji} U_{ki} D_{ii}$ from i = k+1 to n. Note T = 0 for k = n.

$$U_{jk} = P_{jk} - T$$

The process noise covariance matrix Q consists of constants which are initialized in BLOCK DATA and is:

Q(1,1)=Q(2,2)=Q(3,3)=60.0

Q(1,4)=Q(2,5)=Q(3,6)=Q(4,1)=Q(5,2)=Q(6,3)=16.0

Q(1,7)=Q(2,8)=Q(3,9)=Q(7,1)=Q(8,2)=Q(9,3)=1.9095

Q(4,4)=Q(5,5)=Q(6,6)=5.3921

Q(4,7)=Q(5,8)=Q(6,9)=Q(7,4)=Q(8,5)=Q(9,6)=1.5715

Q(7,7)=Q(8,8)=Q(9,9)=0.9227

Q(10,10)=1.0

Q(10,11)=Q(11,10)=0.1

Q(11,11)=0.01

The process noise adaptation factor FF is chosen at each outer loop pass in the following way. It is initialized to a value of 1 in N2NVIN. During each pass in subtask N2FOTP, the average of all residuals divided by their corresponding innovation vector term, HPH'+SR, is computed in N2FOTP. If this average normalized residual is greater than 1.0, then FF is multiplied by 4. However, FF is not allowed to be greater than 64. If the average normalized residual is less than 0.1, then FF is divided by 4, but not allowed to be less than 1.

E. <u>Degraded Mode</u>

Degraded mode activity is initiated and controlled in the Master Control Subsystem by module M2STIN. Every 160 ms this module counts the number of sources with a valid receiver channel assignment, a status of 4 or 5, and in a valid ranging mode. The result is saved in MMNVSV. If MMNVSV is 4 or 5, then no degraded mode is desired. If MMNVSV is 3 then altitude hold is called for, and for MMNVSV=2 both altitude hold and range bias rate hold should be in effect.

Degraded mode operation is controlled through the four state flags MMALHO, altitude hold flag, and MMRBHO, range bias hold flag. These flags take on the following values:

0 Hold is not in effect,

1 Hold being initiated, and awaiting gains computation,

2 Hold is in effect,

3 Being deactivated; awaiting outer loop execution.

The following table summarizes what M2STIN will do to MMALHO and MMRBHO based on their current value and the newly found value for MMNVSV.

Old MMALHO	MMNVSV	New MMALHO
0 or 1	<4	1
2 or 3	<4	2
0 or 1	4 or 5	0
2 or 3	4 or 5	3

Old MMRBHO	MMNVSV	New MMRBHO
0 or 1	<3	1

2 or 3	<3	2
0 or 1	3, 4 or 5	0
2 or 3	3, 4 or 5	3

Whenever MMALHO is 1 or 2, then the outer loop will compute range gains and update the covariance based on H(1) to H(3) being the unit vector in the up direction, with H(4) to H(11) equal to 0. These gains are used in the inner loop to keep the position state at a specified altitude. Range rate gains are also computed and the covariance matrix updated with H(1) to H(3) and H(7) to H(11) zero and H(4) to H(6) being the unit vector in the up direction. This vector has components:

x = cos(Longitude)cos(Latitude)

y = sin(Longitude)cos(Latitude)

z = sin(Latitude)

which is the third row of the rotation matrix used to transform between earth fixed, earth centered coordinates and local level coordinates. The second set of gains computed are used in the inner loop to try to maintain a time derivative of altitude of 0. These gains are stored in array NALHGN, and MMALHO is set to 2 in N2FOTP.

Whenever MMALHO is 3 or 0, then the outer loop executes normally and sets MMALHO to 0 upon completion.

When MMALHO is 0 then N1MITK saves the state position x, y, z. Later when N1MITK is executed with MMALHO being 2 or 3, then the current position is subtracted from the last saved position when MMALHO was 0. The projection of the difference in the up direction is found and is considered to be a residual to which the altitude hold gains are applied. This enforces the condition that the current state altitude should be the same as the last altitude when the system was navigating with 4 sources. The altitude rate gains are applied to the projection of the current state velocity in the up direction.

When MMRBHO is 1 or 2 then the outer loop executes as if there were no range bias or range bias rate states. Effectively the computations are made for a 9 state filter composed of the position, velocity and acceleration coordinates. Upon completion MMRBHO is set to 2. If MMRBHO is 3 or 0 then the outer loop runs normally and sets MMRBHO to 0. N1MITK does not apply measurements to the last two states whenever MMRBHO is 2 or 3. Therefore, during this mode, range bias rate does not change, and range bias changes only due to propagation.

3.4 HDUE Executive Subsystem

3.4.1 General

The Executive Subsystem is a collection of programs and data sets designed to allow the 'Applications' software in the various processors to operate as real-time, concurrent processes. The Applications (or Operational) software is that portion of the GPS real-time software which executes the GPS mission-oriented functions and algorithms. The Executive provides the interface between (1) processor interrupts and the applications software, (2) between the applications tasks, and (3) between calling and called subprograms.

Three major features of the GPS Executive are as follows: (1) Maximum commonality of procedures and data blocks among the three Local Executives, i.e., RCVP, MSCP, NAVP; (2) High degree of modularity in each Local Executive; (3) Simplicity and security of interfaces among individual modules of the Executive, as well as between the Executive and Applications software.

All operational software (including portions of the Executive) is divided into the following heirarchies, listed in the order of decreasing execution control levels: Tasks, and Subprograms.

A Task represents the smallest software component visible to the Executive, i.e., a task is the smallest software entity which the Executive will explicitly schedule and dispatch for execution. At any time during the real-time process, a task is considered as being in one of several possible, well-defined states. Futhermore, a task is the smallest software element which is allowed to communicate to the Executive Control via Executive Service Routines and thus explicitly influence the future course of the computational process.

A Subprogram (or Subroutine) is the software component which is below a task in the Executive control hierarchy structure. Since subprograms may call (invoke) other subprograms, they may form several levels of software modules in this structure.

The Executive activates the tasks in all the processor subsystems and subsequently controls the necessary sharing of processor time that must occur in a real-time system. For this purpose, the tasks are divided into two large categories, foreground and background.

The foreground priorities each have a required execution rate, in that they must be executed once in a certain time period. The tasks are ordered into priority classes according to their execution rates. The background priorities use processor time as it is made available by the completion of the foreground. They are ordered according to the desirability that they receive this left-over processor time.

Since it is often necessary for a program module to be available for use by concurrent tasks, the Executive provides a means by which reentrancy may be accomplished without loss of data integrity. Each concurrent use of a routine accesses its own data area for the routine. The executive's role is to allocate this area and provide the base address to the calling routine.

The Executive performs the processor self-test functions and logs errors arising both from these and other hardware and software conditions, such as memory parity errors.

Processor interrupts are also handled through the Executive. The primary interrupt in the HDUE system is the Fundamental Time Frame (FTF), a 20-millisecond counter. There are other timer interrupts, also occuring at a fixed rate, which perform scheduling and synchronization. These transfer control to the process dispatcher. Additional interrupts are generally involved in error reporting and return to whichever task was executing when the interrupt occurred.

The major scheduling functions are handled in the 20 millisecond interrupt handler. Priorities ready for execution in the upcoming time period are marked, and each task that was supposed to finish in the preceding 20-ms period is checked to see that it did. Control is then passed to the dispatcher, which starts the highest priority task thus marked. This is the key functional element in the Executive.

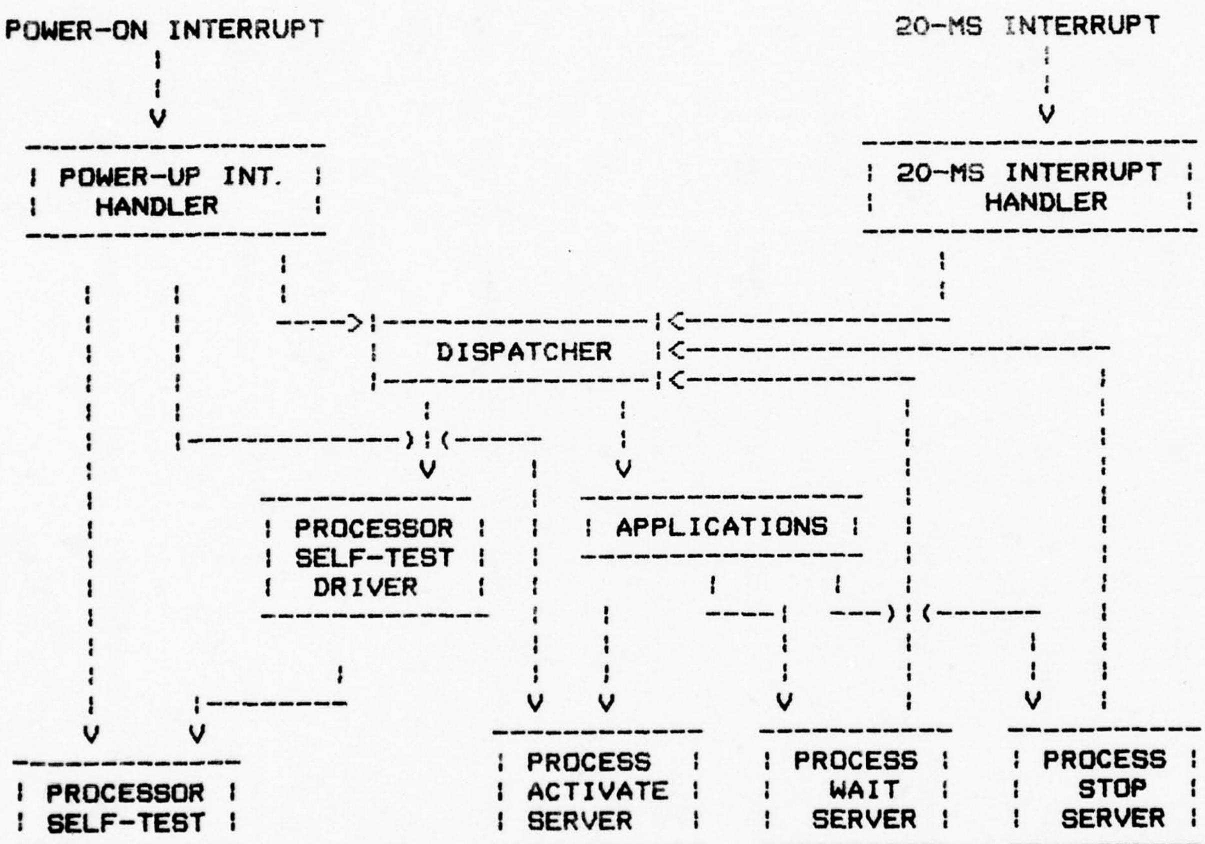
In addition to its scheduling duties, the 20-ms interrupt handler also carries out the synchronization of the three processors. This is accomplished by responding to update commands before incrementing the 20-ms count. If, upon receiving an update command that is not the first since power-up, the update count and 20-ms count do not agree, the processors are not synchronized and an error is logged.

There are utilities called Executive Service Routines which perform oft-repeated scheduling and other functions for the applications processes. Process activation, stop (deactivation), and waiting are the scheduling functions. Other functions include granting and relinquishing sole access to data sets, passing arguments to called subprograms, providing reentrant linkage where appropriate, and logging error reports.

Also included in the Executive are service routines for the Floating Point Arithmetic Unit (FPAU), integer and extended integer arithmetic packages, and memory allocation for the different processors.

Figure 1 contains the high-level flow diagram for the executive.

FIGURE 3.4.1-1 EXECUTIVE FLOW DIAGRAM



3.4.2 System Error Reporting

This section describes the error recording data set, XERROR, the format of errors recorded, and contains a list of all the HDUE errors which are reported to the executive programs X3ERR and X3ERRA.

Errors are recorded in XERROR starting in the location labeled XEBUFS. The first word of each error message is the number of words to follow. That is, if there are three error descriptors, then the first word will contain the number 5. The second word contains the Error Code word (ECW), and third word contains the 20-ms FTF count. The remaining words contain the applicable error descriptors. This is a 28 word circular buffer.

Location	Contents	Word
XEDROP	No. of errors dropped because buffer full	1
XEPTRF	Word in XEBUFS to be filled next	2
XEPTRE	Word in XEBUFS to be emptied next	3
XEBUFS+0	N, No. of words to follow	4
XEBUFS+1	ECW, Error Code Word	5
XEBUFS+2	20-ms FTF count	6
XEBUFS+3	Error Descriptor 1	7
XEBUFS+4	Error Descriptor 2	8

and so on,

XEBUFS+N	Error Descriptor N-2	4+N

Other error messages follow up to:

XEBUFE   Follows last word in XEBUFS

To determine the current contents, the information to consider starts with the location contained in XEPTRE and continues through the word which precedes the location contained in XEPTRF.

The Error Code Word and the descriptors are sent to either X3ERR or X3ERRA as arguments. The first two bits of the Error Code Word are supplied by the error handler, and they indicate the subsystem: 01 is master state; 10 is navigation; 11 is receiver.

When there is not enough room to record all of a reported error, then none of the error is recorded. However, the fact that there was an error dropped is indicated in XEDROP. The contents of XEDROP is incremented by 1 for each error dropped.

A listing of the errors which may be reported follows. The Error Code Word (ECW) is listed first, followed by the name of the module which initiated the error report. On the right hand side a description of the arguments is listed with a description of the error listed first.

0101 X1IPOW
1 Processor self test
2 20-ms FTF(LSW)
3 No. useful words follow
4 Error code generated from X2TST/X2TFP
5 Descriptor 1
6 Descriptor 2

		7 Descriptor 3
		8 Descriptor 4
0102	X1IM	1 Memory parity error
		2 20-ms FTF(LSW)
		3 PC when parity trap occurred
0103	X1II	1 I-bus time out
		2 20-ms FTF(LSW)
		3 PC when time-out occurred
0105	X1IFS	1 FPAU returned an error status
		2 20-ms FTF(LSW)
		3 FPAU status word; bits 0 and 4 to 15 unused
		bit 1 on, overflow
		bit 2 on, underflow
		bit 3 on, invalid operand
		4 PC of interrupted module
0106	X1IT01	1 No active process in 1-ms priority
		2 20-ms FTF(LSW)
0107	X1IT05	1 5-ms prior overrun incomplete last period
		2 20-ms FTF(LSW)
		3 Ptr to priority of overrun task
		4 PC of overrun task
0207	X1IT05	1 5-ms seq. out of order, 5-ms not eq 3 from 20-ms
		2 20-ms FTF(LSW)
		3 5-ms count

0307	X1IT05	1 5-ms count > 3. count/int. seq. out of sync.
		2 20-ms FTF(LSW)
		3 5-ms count
0208	X1IT20	1 20-ms update count not = XC0020 (sys out of sync)
		2 20-ms FTF(LSW)
		3 Update 20-ms count
0308	X1IT20	1 20-ms prior overrun, incomplete last period
		2 20-ms FTF(LSW)
		3 Ptr to priority(XLEVEL block) of overrun proc.
		4 PC of overrun proc
0408	X1IT20	1 Background prior. overrun, incomplete last period
		2 20-ms FTF(LSW)
		3 Ptr to priority(XLEVEL block) of overrun proc.
		4 PC of overrun proc
0109	X1INT2	1 Unwanted interrupt level 2
		2 20-ms FTF(LSW)
		3 PC of interrupted module
010C	X1TST	1 Processor self-test error
		2 20-ms FTF(LSW)
		3 No. of useful words follow
		4 Error code generated from X2TST/X2TFP
		5 Descriptor 1
		6 Descriptor 2
		7 Descriptor 3

8 Descriptor 4

010D X2TST	1 ROM checksum test failure
	2 20-ms FTF(LSW)
	3 No. of useful words following
	4 Error code
	5 ROM block start address
	6 ROM block end address
	7 Expected checksum value
	8 Computed checksum value
020D X2TST	1 RAM memory test failure
	2 20-ms FTF(LSW)
	3 No. of useful words following
	4 Error code
	5 RAM block start address
	6 RAM block end address
	7 Bad RAM location
	8 Bad RAM value
030D X2TST	1 Basic arithmetic failure
	2 20-ms FTF(LSW)
	3 No. of useful words following
	4 Error code
	5 CZC mask for arith/logic test
	6 Value on which CZC applied
	7 (ignore)
	8 (ignore)

010E	X2IPOW	1 Processor self test error
		2 20-ms FTF(LSW)
		3 No. of useful words follow
		4 Error code generated from X2TST/X2TFP
		5 Descriptor 1
		6 Descriptor 2
		7 Descriptor 3
		8 Descriptor 4
0111	X3ACT	1 More than two args passed
		2 20-ms FTF(LSW)
		3 PC of activating task
0211	X3ACT	1 Receiver no. > max receiver no.
		2 20-ms FTF(LSW)
		3 Receiver number
		4 PC of activating task
0311	X3ACT	1 Task already activated
		2 20-ms FTF(LSW)
		3 pointer to process in XPROC
		4 PC of activating task
0113	X3CANC	1 More than two args passed
		2 20-ms FTF(LSW)
0213	X3CANC	1 No. receivers greater than max allowed
		2 20-ms FTF(LSW)
0115	X3REQ	1 Time out on gaining sole access to common

2 20-ms FTF(LSW)

0215	X3REQ	1 No. args not = 1
		2 20-ms FTF(LSW)
0116	X3REL	1 No. args not = 1
		2 20-ms FTF(LSW)
011A	F$RGMY	1 No. of arguments does not agree with caller
		2 20-ms FTF(LSW)
		3 Calling program PC
		4 Called program PC
		5 No. of arguments expected
011D	X3TIMM	1 No. args not = 1
		2 20-ms FTF(LSW)
021D	X3TIMM	1 Modulus not positive value for time request
		2 20-ms FTF(LSW)
011E	IASHFT	1 Overflow when shifting left, sign bit changed
		2 20-ms FTF(LSW)
021E	IASHFT	1 Absolute value of shift count greater than 15
		2 20-ms FTF(LSW)
0120	X3ERRA	1 Error reports have been dropped
		2 20-ms FTF(LSW)
		3 No. of errors dropped
0121	EASHFT	1 Overflow when shifting left, sign bit changed

		2 20-ms FTF(LSW)
0221	EASHFT	1 Absolute value of shift count greater than 15
		2 20-ms FTF(LSW)
0126	EXINT	1 Divisor greater than or equal to 2**16
		2 20-ms FTF(LSW)
		3 (ignore)
		4 MSW of arg
		5 LSW of arg
		6 EXINT WP
		7 (ignore)
		8 (ignore)
		9 User WP
		10 User return PC
012C	X1INT7	1 Unwanted interrupt level 7
		2 20-ms FTF(LSW)
012E	X2TFP	1 FPAU add/subtract error
		2 20-ms FTF(LSW)
		3 No. of useful words following
		4 Error code
		5 Computed wrong value
		6 Expected correct value
		7 (ignore)
		8 (ignore)
022E	X2TFP	1 FPAU mult/div error

2 20-ms FTF(LSW)

3 No. of useful words following

4 Error code

5 Computed wrong value

6 Expected correct value

7 (ignore)

8 (ignore)

0140 M1CMSC	1 SBIM error from master	
	2 20-ms FTF(LSW)	
	3 Error code:	>FFFB(-5) - FIFO empty
	3 Error code:	>FFF9(-7) - parity error
	3 Error code:	>FFF7(-9) - timing error
	3 Error code:	>FFF5(-11)- no reply
0194 R1MRC	1 R1SRC failure to respond	
	2 20-ms FTF(LSW)	
	3 RMSRCD word	
0294 R1MRC	1 Illegal RMSRCR value during initialization	
	2 20-ms FTF(LSW)	
	3 RMSRCR word	
0394 R1MRC	1 Duplicated R1SRC response	
	2 20-ms FTF(LSW)	
	3 CMPFLG	
0494 R1MRC	1 Initialization time-out limit	
	2 20-ms FTF(LSW)	

0594	R1MRC	1 Illegal step 0 R1SRC response during initializatio
		2 20-ms FTF(LSW)
		3 RMSRCR word
0694	R1MRC	1 Illegal initialization response
		2 20-ms FTF(LSW)
		3 RMSRCR word
0794	R1MRC	1 Illegal comd in RCV3B3 during TTDC
		2 20-ms FTF(LSW)
		3 Value of RCV3B3
0894	R1MRC	1 Illegal RMSRCR during concentrated search
		2 20-ms FTF(LSW)
		3 Value of RMSRCR+17
		4 Reentrant index value
0994	R1MRC	1 Unexpected R1SRC response in concentrated search
		2 20-ms FTF(LSW)
		3 RMSRCR value
		4 Reentrant index value
0A94	R1MRC	1 Illegal comd in RCV3B3 during conc search
		2 20-ms FTF(LSW)
		3 RCV3B3 value
0C94	R1MRC	1 Illegal sv status at msg reporting time
		2 20-ms FTF(LSW)
		3 SV status word

0D94	R1MRC	1 Illegal comd in RCV3B3 during precision mode
		2 20-ms FTF(LSW)
		3 RCV3B3 value
0E94	R1MRC	1 Unexpected response in precision
		2 20-ms FTF(LSW)
		3 RMSRCR value
		4 Reentrant index value
1094	R1MRC	1 Illegal comd in RCV3B3 during Idle/Track
		2 20-ms FTF(LSW)
		3 RCV3B3 value
1194	R1MRC	1 Unexpected response in Idle/Track
		2 20-ms FTF(LSW)
		3 RMSRCR value
		4 Reentrant index value
1294	R1MRC	1 Conc. search: No. of svs tracking >5 or <0
		2 20-ms FTF(LSW)
		3 Number of svs tracking
0196	R1PCK	1 RSCOMM not OK for receiving new data
		2 20-ms FTF(LSW)
0197	R1PIN	1 Overflow on calculating MOD 75 count
		2 20-ms FTF(LSW)
0297	R1PIN	1 Overflow on calculating MOD 75 count
		2 20-ms FTF(LSW)

0397	R1PIN	1 Overflow on calculating MOD 75 count
		2 20-ms FTF(LSW)
0497	R1PIN	1 OVERFLOW on calculating MOD 75 count
		2 20-ms FTF(LSW)
049A	R1SCH	1 DWELL*390 >65536
		2 20-ms FTF(LSW)
039B	R1SRC	1 Unexpected C/A epoch drift
		2 20-ms FTF(LSW)
049B	R1SRC	1 R1DDT/R1PCK data communications failure
		2 20-ms FTF(LSW)
01C7	DEXP	1 Input argument to DEXP more than 174.673
		2 20-ms FTF(LSW)
		3 Argument passed to DEXP
01C8	DSIN	1 Abs. value of input argument to DSIN more than 16
		2 20-ms FTF(LSW)
		3 Argument passed to DSIN
01C9	DATAN2	1 Pair of input arguments to DATAN2 was (0,0).
		2 20-ms FTF(LSW)
		3 First argument passed to DATAN2.
		4 Second argument passed to DATAN2.
01CA	DSQRT	1 Negative input argument to DSQRT
		2 20-ms FTF(LSW)
		3 Argument passed to DSQRT.

01CB	DCOS	1 Abs. value of input argument to DCOS more than 16
		2 20-ms FTF(LSW)
		3 Argument passed to DCOS
01F1	B1SLIO	1 SBIM did not reply to a select word
		2 20-ms FTF(LSW)
02F1	B1SLIO	1 SBIM timing error
		2 20-ms FTF(LSW)
03F1	B1SLIO	1 Parity error on the data received by the SBIM
		2 20-ms FTF(LSW)

4.0 HARDWARE SYSTEM DESCRIPTION

4.1 RECEIVER PROCESSOR LINE REPLACEABLE UNIT

4.1.1 GENERAL DESCRIPTION

The Receiver Line Replaceable Unit No 1 (RCVR-LRU) functions as the front end of the HDUE system. The receiver processes the signal from the GPS space vehicles (SV's) received through the GFE antenna and Preamp/PPDS to obtain: 1) Pseudo Range, 2) Pseudo Range Rate, and 3) data contained in the downlink signal.

4.1.2 FUNCTIONAL DESCRIPTION (refer to Figures 4.1-1 through 4.1-3)

The receiver is configured with five identical channels. (Refer to Figure 4.1-1). A block diagram showing one of these channels is presented in Figures 4.1-2 and 4.1-3. Each channel contains a Wideband, two Narrowbands, a Frequency Synthesizer, a Code Generator, and an Output Module. Each receiver has a single Master Oscillator, Clock Module, Built-In Test Module, Signal Distribution Module and Receiver Control Processor Unit (RCU), as well as a DC-to-DC to convert the input 28 VDC to the operating voltages.

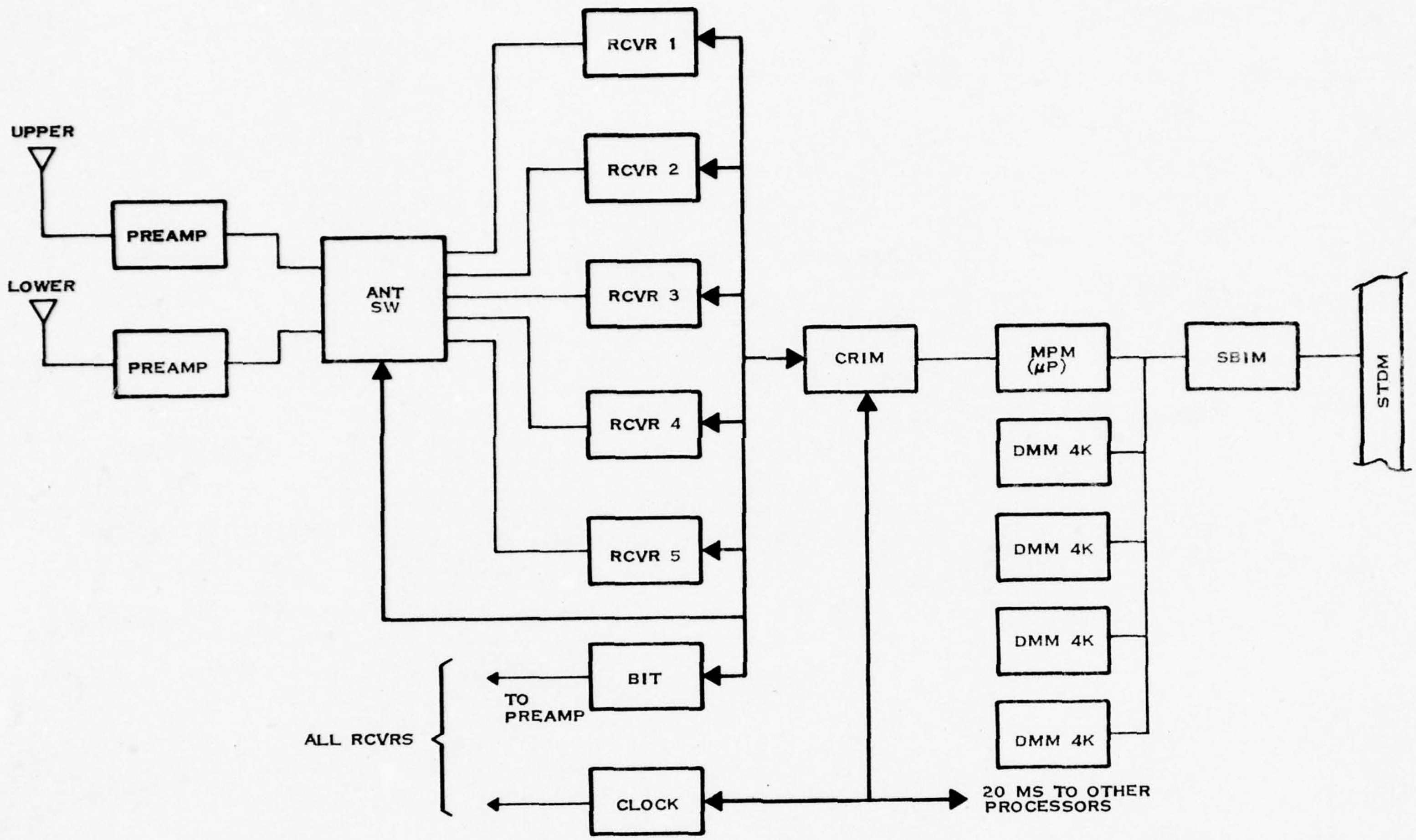


Figure 4.1-1. Functional Block Diagram Receiver LRU

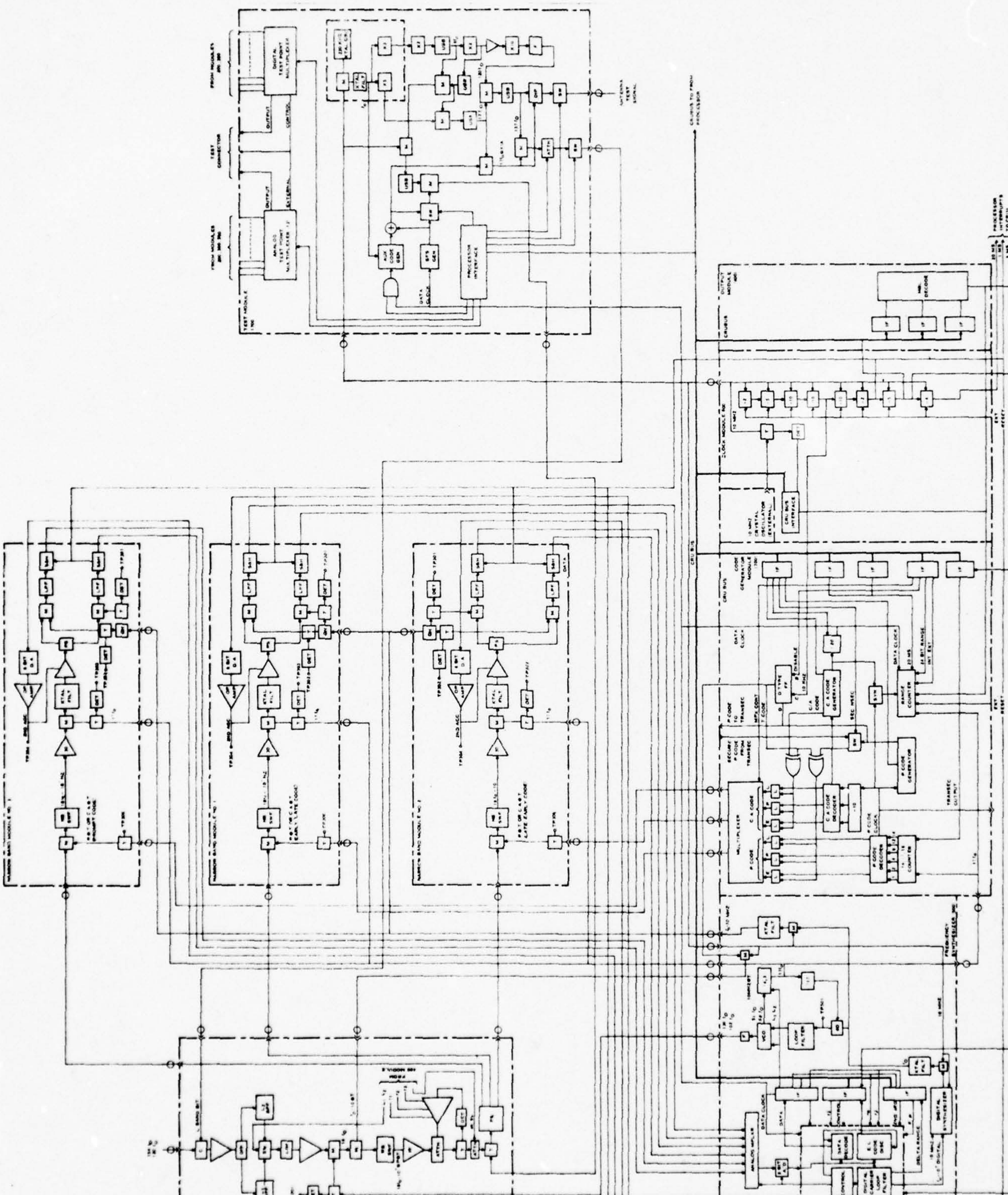


Figure 4.1-2. Detailed Functional Block Diagram Receiver LRU

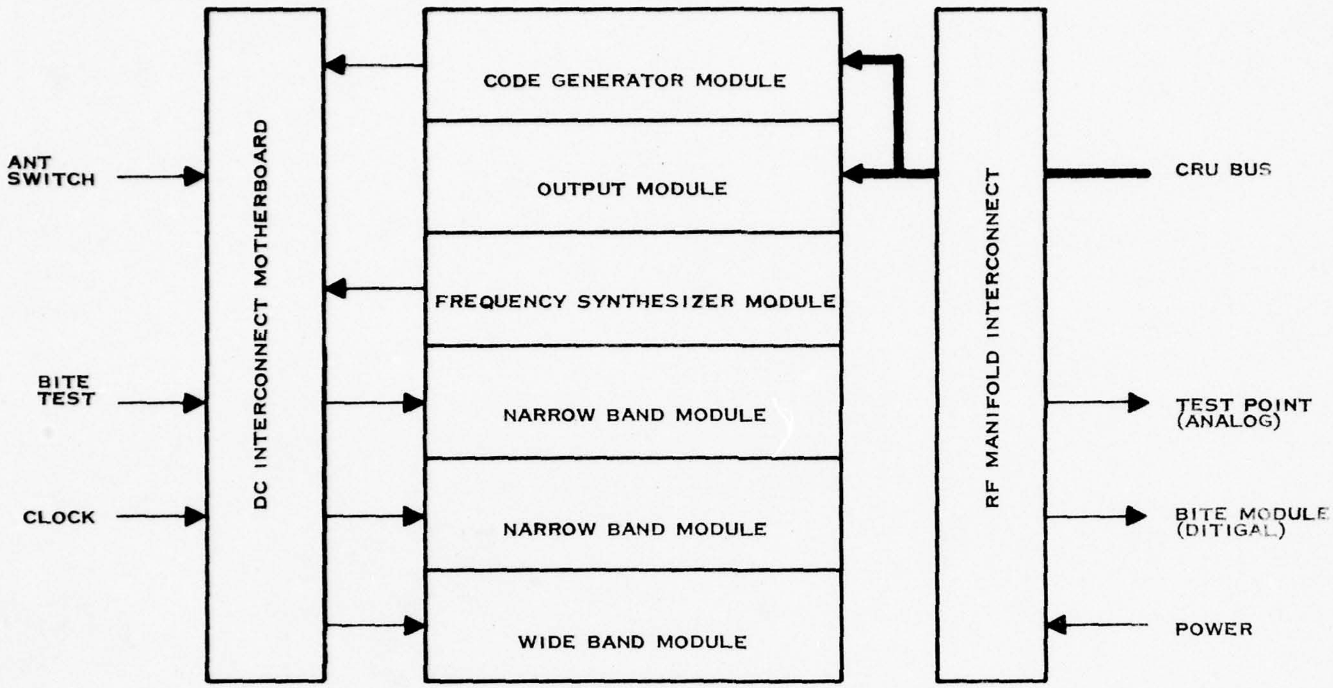


Figure 4.1-3. Functional Block Diagram, One Receiver Channel

Both code and carrier loops are contained in each RF channel. The code tracking is implemented in the Narrowband Modules (code correlation), the Output Module and Receiver Control Processor Unit (offset detection), and the Code Module (code generation and adjustment). The carrier tracking loop is implemented in the Wideband and Narrowband Modules (RF down-conversion and phase/frequency detection) and in the Frequency Synthesizer Module (loop filter and L.O. generation). The clock for the Code Generator Module is tuned by the carrier tracking loop; thus, the code loop tracking is aided by the carrier tracking loop.

The functional allocations to the modules are as follows:

I. Wideband Module

The L-band input signal to the antenna (L1 and L2) is doppler shifted in frequency to 154 Fo and 120 Fo, where Fo = 10.23 (1+V/C) MHz. These contain the biphase code and data modulation. The antenna signal is amplified in the GFE Preamp/PPDS, then fed to the RCVR-LRU where it is further amplified in a low-noise preamplifier before reaching the Wideband Module (WBM). The WBM amplifies the signal at L-band, down-converts to the first intermediate frequency (IF) of 18 Fo, and amplifies further at the IF. The IF bandwidth is 15 MHz to allow the code spectrum to pass. The doppler is scaled in all down-conversions in the receiver. When the carrier is locked, all local oscillator frequencies tune and track with the signal doppler offset in a coherent manner. The WBM contains an AGC to control its gain and a pulse blanker to minimize the effects of pulse jamming. The output of this module offsets the IF by 10 MHz and introduces a receiver internal code (T-code) to enhance rejection of CW jammers. The WBM output is split to feed two Narrowband Modules.

II. Narrowband Module

The Narrowband Module (NBM) has a second down-conversion and an IF at Fo + 10MHz. Final IF amplification and filtering occur before conversion to baseband in a Costas phase detector. The code is correlated or removed at this module's input, so the IF bandwidths are reduced to 50 kHz and eventually to 4 KHz to prevent noise power saturation in the IF amplifiers. Baseband circuitry in this module includes phase detection, frequency detection, envelope detection of the input signal, signal-to-noise ratio detection, and a second AGC circuit.

III. Frequency Synthesizer Module

The phase or frequency detector output of the NBM is used to drive the carrier tracking network in the Frequency Synthesizer Module (FSM). The network or loop filter output tunes a voltage-controlled crystal oscillator (VCXO) which tunes the frequency of all the local oscillators (LO's) used throughout the reciver. All LO's and the tracking network are in the FSM.

IV. Code Generator Module

The Code Generator Module (CGM) generates the receiver's replica of the input signal code. Early, late, and prompt code versions are generated and output to the NBM's for code correlation and alignment. As described earlier, the code tracking is aided by the carrier tracking loop to remove the doppler. This is accomplished by providing 17 Fo as a reference to the CGM which is used as the code clock after division by 17. In addition, the code can be slewed by division by 16 or 18 to allow code alignment. A code discriminator is formed in the RCU and is used to drive the code centering circuitry in the CGM. The CGM also contains the pseudo range measurement circuitry that measures the code state at a reference time mark.

V. Output Module

The Output Module (OM) serves as an interface between the RF hardware and the digital RCU. The OM provides analog-to-digital conversion of the envelope detectors in the NBM's and processor command decoding to control functions in other hardware modules. The 50-Hz signal data is also detected in this module.

Finally, a range rate counter is included in this module to count the frequency of the VCXO in the FSM. When the receiver is locked to the input signal, the output of this counter is the pseudo range rate used in navigation computations.

VI. Clock Module

The Clock Module uses a 10-MHz Master Oscillator clock signal as a reference to provide timing marks needed in the receiver. Both hardware counters and processor interrupts are obtained from this module.

VII. Built-In-Test Module

A separate Built-In Test Module (BITM) provides a coded L1 and L2 test signal and an 18 Fo test signal for testing the reveiver. It allows calibration of time delays in this multi-channel system and provides health checks for all receiver channels. In the HDUE only the time delay calibration feature is implemented.

VIII. Signal Distribution Module

The Signal Distribution Module (SDM) receives signals from both the clock module and the built in test module, amplifies them and distributes them to the five receiver channels.

The Receiver Control software subsystem resident in the RCU is partitioned into a high level control, called Multi-Receiver Control (MRC), and an individual channel control, called Single Receiver Control (SRC). Under direction of the Master Control Subsystem resident in the Navigation Processor LRU. The MRC controls the individual channel of SRC in order to calibrate the differential delays (called master time delay) in the receiver hardware, inject navigation aiding during SV search or reacquisition, measure L1/L2 differences, and extract (and send to Master Control) the SV measurement and message data. The SRC is implemented as a set of reentrant programs each of which (under MRC control) measures the noise seen by a receiver to determine detection threshold, and performs C/A-code or P-code search and P-code initialization, which is followed by the steady-state condition of tracking. The SRC also performs the SV data extraction functions associated with tracking, such as data detection bit synchronization, and parity checking.

The basic RCVR-LRU sequences and operations are:

I. Normal Acquisition

The functions of each step of the normal acquisition sequence are given below.

II. VCXO Cal

This step calibrates the VCXO frequency response in the CAL or open carrier loop configuration. Range rate measurements are made at each of several voltage input settings in order to derive a voltage vs. frequency calibration.

III. VCXO Set

The VCXO frequency is set to the computed value of the input frequency including doppler. An initial level of AGC is established during this step.

IV. C/A Noise

This is a step wherein the noise level is measured as a reference for code search. C/A-CODE for a SV that is out of receiving range is selected from the CGM during this measurement.

V. C/A Search

The C/A-CODE for the desired SV is inserted and a search made in a sequence of 1 chip steps for detection of the SV signal. The outputs of both the early (+38/170 chip) and late (-38/170 chip) channels are summed and compared to the noise level in order to establish signal detections. The basic signal intergration period during search is 5 milliseconds. Search is terminated after successful signal detection.

VI. C/A Coarse Center

After signal detection, a code phase centering to within 1/4 chip is performed.

VII. C/A Acquisition

An acquisition sequence of first frequency lock and then phase lock is performed during this step. Frequency lock is maintained for a fixed time interval before activating phase lock. The success of this step is verified by the lock detector status.

VIII C/A Fine Center

Code centering to within 1/17 chip is performed during this step.

IX. Bit Sync

The proper bit sync position is determined by quantizing the analog level of the data signal on every 1-ms C/A epoch. Phase lock to the carrier is maintained with the C/A-CODE inserted in the prompt position.

X. Frame Sync

This is a SV data recovery step which is continued until frame sync and reading of the SV Hand Over Word (HOW).

XI. P-Code Initiate

The desired P-code and phase (P-code generator state) are initiated in the CGM during this step. The P-code generator is started on the next bit clock epoch such that both the C/A-code and P-code are synchronized. However, the P-code will be off center by 10 times the C/A error in chips, a maximum of 10/17 (.588) P-code chips.

XII. P-Code Center

This step centers the P-code using a tau dither approach in one narrowband channel. The other narrowband channel is used to maintain track with the C/A-code.

XIII. P Acquisition

The same acquisition sequence of first frequency lock and then phase lock as used for C/A-code acquisition is performed during this step.

XIV. Ranging

The ranging step is the normal continous tracking, data reading, range and range rate measurement state for the receiver. In this step AGC time constants are selected to respond to signal level changes caused by aircraft dynamics.

XV. Weak Signal Hold On

The *weak signal hold on* step is activated in the event of insufficient signal-to-noise ratio to maintain normal ranging. The carrier loop is switched to frequency lock and the code loop is switched to the prompt code position used for tracking. Degraded ranging is continued; however, SV data reading is stopped during this step.

XVI. Direct P Acquisition

The receiver functional sequence control settings for direct P acquisition steps are defined similarly to those previously given for normal acquisition except that the system does not go through C/A acquisition.

MECHANICAL DESCRIPTION

The RCVR-LRU is contained in a single full lenth, 1 1/2 ATR case. There are 13 sub-assemblies in the LRU. These are:

Quantity	Name
1	Master Oscillator
2	Preamplifier
1	Antenna Switch
5	Single Channel Receiver with RF and DC Interconnect Boards
1	RCU and Clock Module with Interconnect Board
1	BITE Module
1	Signal Distribution Module
1	Power Supply Unit

See Figures 4.1-4 and 4.1-5 for top and bottom views of the RCVR-LRU, indicating placement of subassemblies.

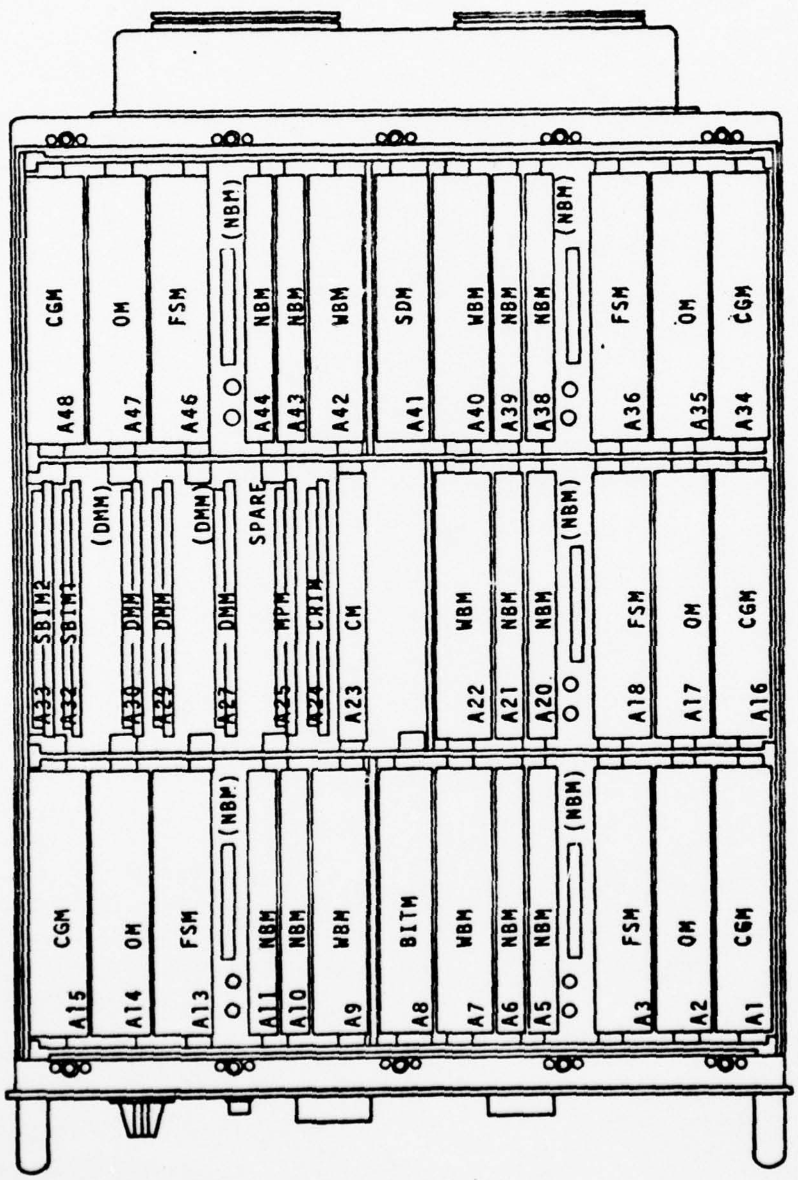


Figure 4.1-4. HDUE Receiver - Top View W/O Cover

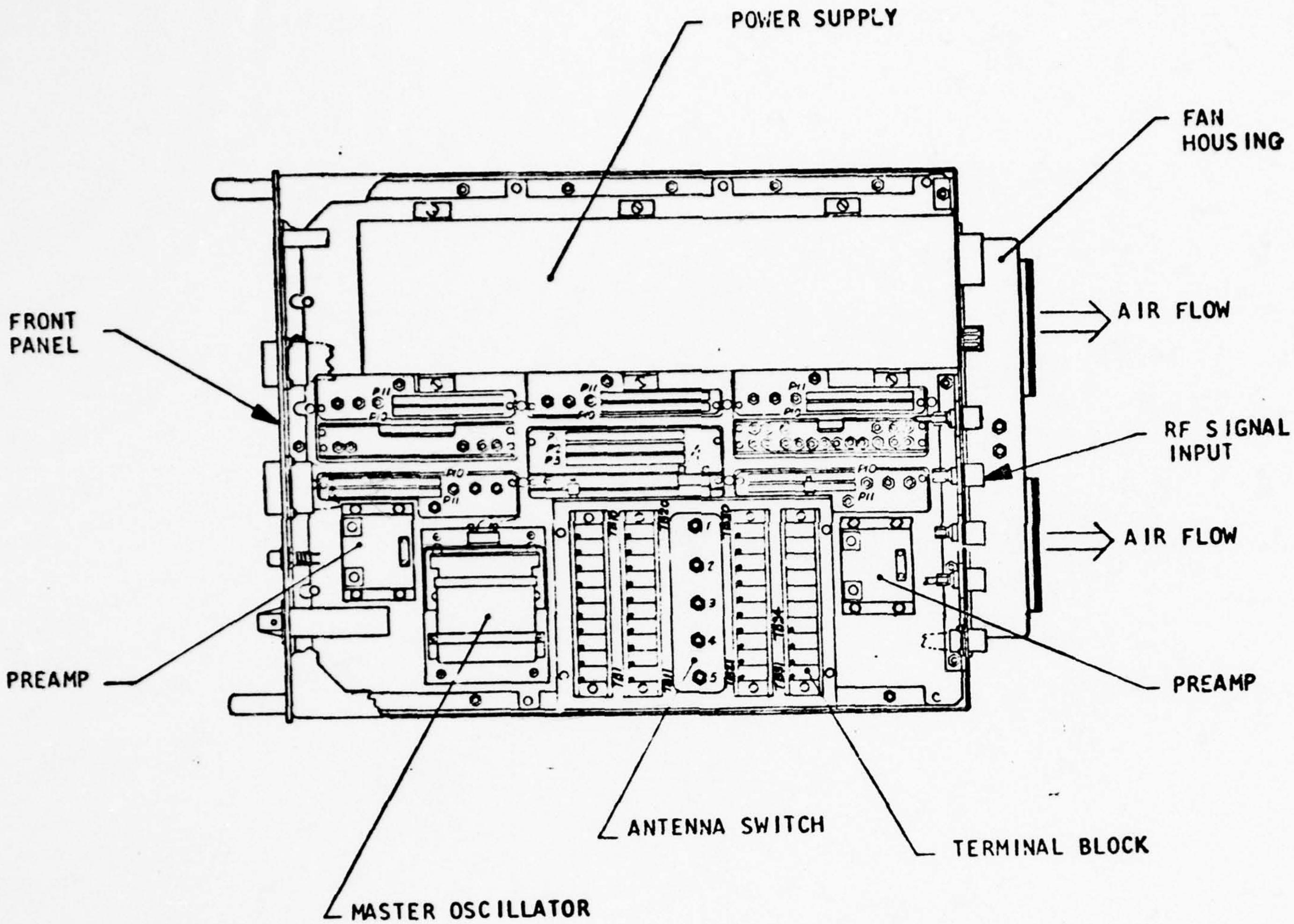


Figure 4.1-5. HDUE Receiver - Bottom View W/O Cover

Each single channel receiver is made up of the following modules.

Quantity	Name
1	Wideband Module
2	Narrowband Module
1	Output Module
1	Frequency Synthesizer Module
1	Code Generator Module
1	DC Logic Distribution Board
1	RF and Signal Distribution Board
1	Capacitor Module

The RCU and CM's are located on a interconnect board. There are 3 spare spaces located in the RCU to allow expansion. The following is a list of these modules:

Quantity	Name
1	SBIM-1
1	SBIM-2
1	MPM
1	CRIM
4	DMM

The BITE and Signal Distribution Modules are plugged into internal wiring. The power supply is a removable unit, well shielded to protect the LRU from converter oscillator interference. The Master Oscillator, Antenna Switch, Preamplifiers, and Power Supply Unit are located in the bottom section of the LRU.

4.1.3 ELECTRICAL INTERFACE

I. Inputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	SOURCE
RF	Lower ant	SV signal (L1 and L2 carriers modulated with P-code, C/A-code, and data)	external preamp
RF	Upper ant	SV signal (L1 and L2 carriers modulated with P-code, C/A-code, and data)	external preamp
Power	28VDC	6.3 a	AC/DC CONV
Power	115VAC	115VAC, 400Hz, 81 w	AC/DC CONV
Logic	UPCRUINZ	TTL (*CRU data input)	maint panel
Logic	/MPRSTZ	TTL (Maintenance panel reset)	maint panel
Logic	/MPLOADZ	TTL (Maintenance panel load)	maint panel

* CRU = Communications Register Unit

II. Outputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	DESTIN.
RF	Ant 1 and Ant 2	1575.42 MHz and 1227.6 MHz modulated with X1 portion of P-code at -15 dBm	external preamp
Analog	UPVCCSAM	5VDC (VCC sample indicates that power is applied to the MPM)	maint panel
Clock	INT-20MSOUTZ and INT-20MSOUTRZ	**TTL DR (20-msec fundamental time frame)	NAV-LRU
Logic	/UPMEMENZ	TTL (memory enable)	maint panel
Logic	/UPENDCYZ	TTL (end of memory cycle)	maint panel
Logic	UPIAQZ	TTL (instruction acquisition)	maint panel
Logic	/UPRSTZ	TTL (Maintenance Panel reset)	maint panel
Logic	UPCRUOUTZ	TTL (CRU data output)	maint panel
Logic	UPCRUCLKZ	TTL (CRU clock)	maint panel
Data	UPA(00-14)Z and /UPA(00-14)Z	TTL DR (processor address)	maint panel

**TTL DR = output of a SN54265J or equivalent

III. Bi-directional

CATEGORY	SIGNAL NAME	CHARACTERISTIC	SOURCE/ DESTIN.
Clock	SBCLKZ and SBCLKRZ	***TR DR (clock for transferring data between RCVR and NAV LRU's)	NAV-LRU
Data	SBDATAZ and SBDATARZ	TR DR (communication data between RCVR and NAV LRU's)	NAV-LRU

***TR DR = Transformer Drive

4.2 NAVIGATION PROCESSOR LINE REPLACEABLE UNIT

4.2.1 GENERAL DESCRIPTION

The Navigation Processor Line Replaceable Unit No. 2 (NAV-LRU) is the basic computational and control component of the HDUE system. The NAV-LRU is divided into two processing systems, both having access to a common hardware Floating Point Arithmetic Unit (FPAU). The first processing system is the Master Control Subsystem Processor (MCSP) which controls the flow of data between the processing components and controls the mode of operation. The second processing system is the Navigation Processor (NAVP) which performs the navigation computations.

4.2.2 FUNCTIONAL DESCRIPTION (refer to Figure 4.2-1)

The Microprocessor Module (MPM) provides computational and functional control capability. Each MPM interfaces with Data Memory Modules (DMM's), a Communication Register Interface Module (CRIM), and the FPAU on its local memory bus. Each MPM also interfaces with the common memory and the Data Bus Extender Module (DBEM) through an Internal Bus Interface Module (IBIM). The MCSP communicates with the RCVR-LRU through the Serial Bus Interface Module (SBIM) and with the CDU-LRU through the Driver/Receiver Interface Module (DRIM).

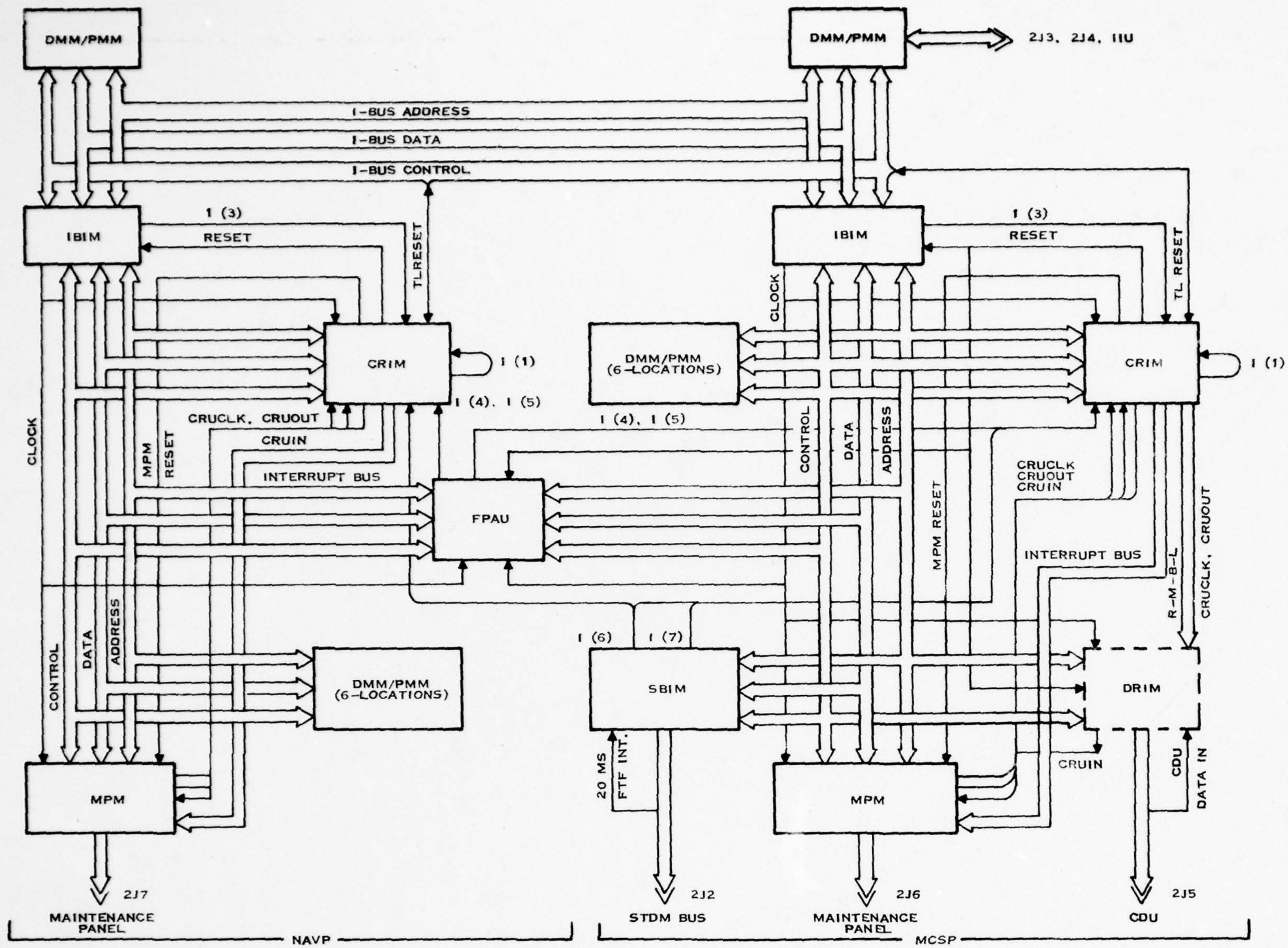


Figure 4.2-1. Functional Block Diagram of Navigation LRU

A more detailed functional allocation to these modules is as follows:

I. Microprocessor Module (refer to Figure 4.2-2)

The components of the MPM, as shown in Figure 4.2-2, are the microprocessor unit, address decode logic, programmable read-only memory (PROM), PROM power switching circuitry, random-access memory (RAM), clock circuitry, and buffer logic.

The basic functional component of the MPM is the single chip, 16-bit, Integrated-Injection-Logic, sbp9900 microprocessor unit.

The SBP9900 is software compatible with the TI 990 minicomputer family. General operational characteristics the microprocessor unit exhibits are:

(A) 16-bit instruction word

(B) 3-MHz basic clock

(C) Memory-to-memory architecture

(D) Memory address capability for up to 32,768 sixteen-bit words or 65,536 eight-bit bytes

(E) Separate memory, I/O, and interrupt bus structure

(F) Use of 16 work-space registers in memory

(G) Up to 16 prioritized interrupts

(H) Instruction-driven communication register unit (CRU) and direct memory address (DMA) I/O capability

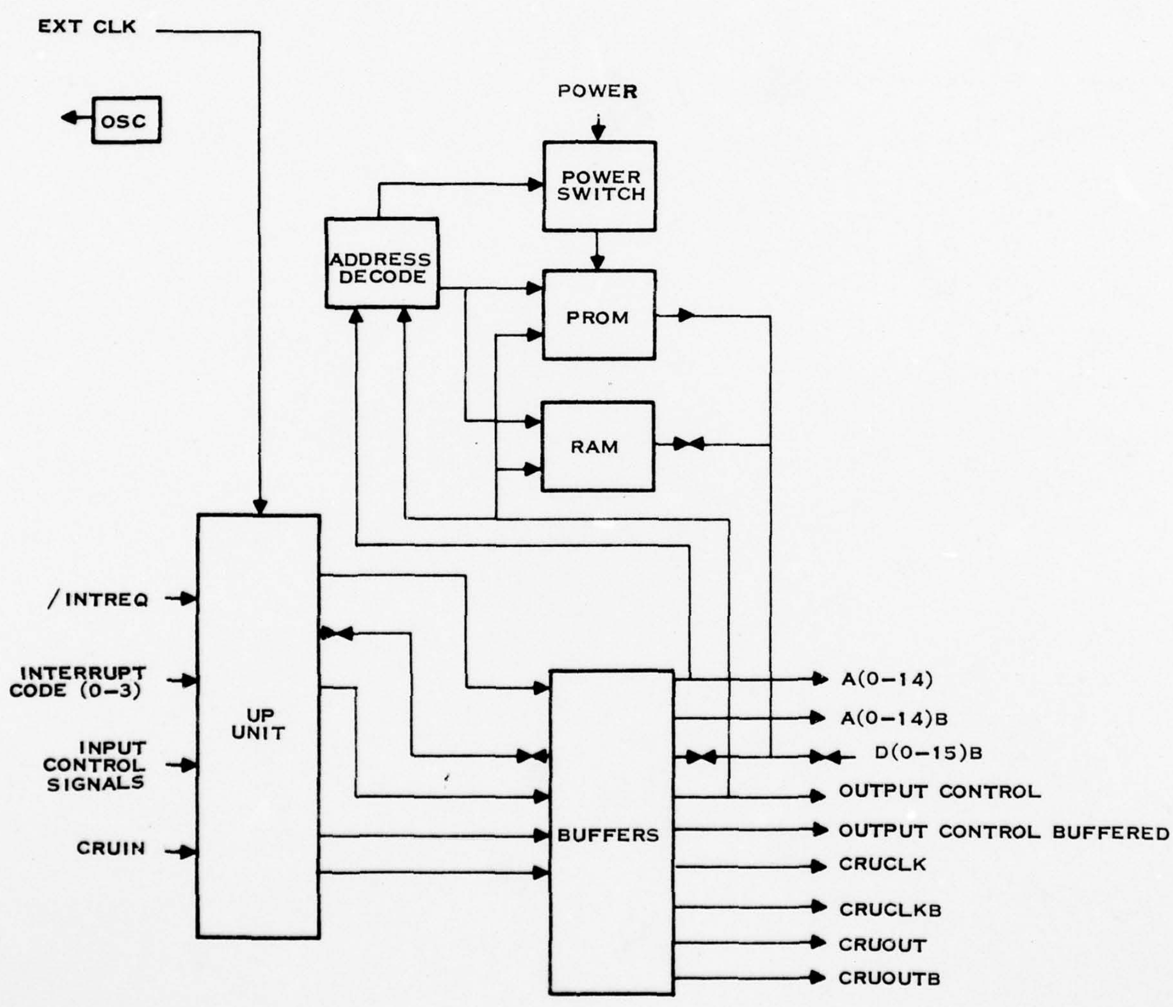


Figure 4.2-2. Functional Block Diagram Microprocessor Module

The MPM address decode logic performs memory address recognition and decode for the memory (PROM or RAM) contained within the MPM. The PROM on the MPM provides the microprocessor unit with 512 words of nonvolatile storage for program instruction and data constants. The PROM switching circuitry minimizes MPM power by disabling the power source from all MPM PROM devices not being addressed. The RAM on the MPM provides the microprocessor unit with 256 words of high-speed read/write memory for allocation as work-space memory. The optional MPM clock circuitry provided for use as a system clock has been bypassed to enable utilization of an external clock located on the MPM's associated IBIM. The buffer logic on the MPM provides the necessary buffering for the microprocessor unit memory bus and CRU bus signals.

The MPM memory bus provides the mechanism for information transfer between the MPM and memory for instruction fetch operations and storage/data retrieval operations. The instruction-driven CRU bus, along with the microprocessor unit DMA I/O feature, provides the MPM with input/output capabilities.

II. Data Memory Module

Each DMM provides the system with 4,096 words of random-access read/write memory for temporary storage of 17-bit data words (16 bits for data and 1 bit for

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parity). Each DMM contains a single-port data and address bus compatible with the MPM local memory bus.

III. Communications Register Interface Module

The CRIM consists of:

(A) Communication register unit decoder and buffers

(B) Interrupt circuitry

(C) Parity generator/checker

(D) Reset circuitry

The CRIM decodes bits 3 through 5 of the address bus into eight register select lines for use by any CRU device. The other address and CRU control lines are also buffered for use by CRU devices. The interrupt circuitry synchronizes the interrupt stimuli, provides interrupt masking/clearing capability, and generates the interrupt request and code signals for the MPM, (refer to Table 4.2-1 for the Interrupt priorities). The parity generator/checker performs parity checks on read operations and generates the parity bit for storage during operations to read/write memory. Parity errors are signalled to the user as interrupts. The reset circuitry receives the various system reset stimuli (e.g., from power supply) and provides corresponding reset signals to the other processor modules.

TABLE 4.2-1. NAV-LRU INTERRUPT PRIORITY RANKING

Interrupt Level	MCSP	NAVP	COMMENTS
0	Power On	Power On	Non-maskable interrupt invoked by power good from power supply
1	Parity Error	Parity Error	CRIM generates checks parity on all RAM read/write cycles
2	--	--	Spare
3	Memory Time-out	Memory Time-out	Local bus time out is generated by CRIM anytime more than 4 wait states occur on local bus
			IBIM generated error when non-existent I-Bus memory is addressed and read/write cycle not complete within 10 uS
4	FPAU PC +	FPAU PC +	FPAU increment
5	FPAU Status	FPAU Status	FPAU status
6	20 MS FTF RCVR LRU	20 MS FTF RCVR LRU	20 MS Fundamental Time Frame (FTF) interrupt
7	SBIM OP Terminate	--	Generated by SBIM to indicate OP complete or error encountered

IV. Internal-Bus Interface Module

In Figure 4.2-1, communication between the processors in the multiple processor configuration is accomplished via the internal bus (I-bus). The I-bus is a high-speed, 16-bit parallel data bus. The transfer of data between processors is accomplished through an intermediate DMM interface to the I-bus. Each MPM interfaces to the I-bus through its associated IBIM. The IBIM controls access onto the I-bus and provides for the bidirectional passage of data between the MPM and the I-bus.

V. Floating Point Arithmetic Unit

The FPAU provides floating-point arithmetic and conversion capability. The FPAU is a dual-port, highspeed, auxiliary arithmetic unit that performs single and double precision arithmetic operations. The FPAU can be interfaced to a maximum of two processors via their local memory buses. In the HDUE system where the FPAU is interfaced to two processors, a software calling sequence has been established to avoid usage conflicts.

VI. Data Bus Extender Module

Additional input/output capability is provided by the DBEM which extends the I-bus to external devices. Specific external devices in the HDUE system include the Instrumentation Interface Unit LRU and the TI 990/10 Software Development Facility.

VII. Serial Bus Interface Module

The SBIM converts clock signals and data to the format required by the STDM bus for interface between the MCSP and the RCVR-LRU.

VIII. Driver/Receiver Interface Module

The DRIM provides drivers for long cables to the CDU-LRU for passing CRU control information between the MCSP and the CDU-LRU.

4.2.3 FUNCTIONAL INTERFACE

The microprocessor unit on each MPM executes a full minicomputer instruction set containing 69 instructions. The arithmetic instructions include add, subtract, compare, negate, absolute value, increment, decrement, shift left/right arithmetic, clear, multiply, and divide. A variety of logical instructions is also provided. Included are set 1's/0's corresponding, compare 1's/0's corresponding, exclusive OR, invert, AND, OR, and shift logical/circular. The set of program control instructions includes jump (13 conditions), load, store, move, swap byte, branch, and return (from interrupt/subroutine). Seven addressing modes are available for operand derivation. Instruction execution times range from 8 (store) to 124 (divide) clocks. Most instructions require 10 to 20 clocks to execute, with variations dependent on the instruction function and the specified operand derivation cycle. Table 4.2-2 lists the various processor instruction execution times assuming a 3-MHz system clock.

TABLE 4.2-2. INSTRUCTION TIME

Instruction Type	Execution Times (microseconds)	
	Minimum	Maximum
Arithmetic		
Add/subtract	4.67	10.00
Multiply	17.33	20.00
Divide	30.67	44.00
Compare	4.67	10.00
Shift (left/right arithmetic)	4.67	17.33
Absolute value	4.00	7.33
Increment/decrement	3.33	6.00
Clear	3.33	6.00
Logical		
Set 1's/0's corresponding	4.67	10.00
Compare 1's/0's corresponding	4.67	7.33
Exclusive OR	4.67	7.33
OR/AND (immediate)	4.67	4.67
Shift (logical/circular)	4.67	17.33
Swap bytes	3.33	6.00
Program control		
Move	4.67	10.00
Jump	3.33	3.00
Branch	2.67	5.33
Return	4.67	4.67
Load	4.00	4.00
Store	2.67	2.67
Input/output		
Single bit	4.00	4.00
Multiple bit	7.33	22.67

4.2.4 MECHANICAL DESCRIPTION (refer to Figures 4.2-3 and 4.2-4)

The NAV-LRU is contained in a single case and contains 5 subassemblies. These are: 1) NAVP, 2) MCSP, 3) DBEM, 4) Common memory, and 5) FPAU.

I. The NAVP contains the following modules:

Qty	Name
1	MPM
1	CRIM
1	IBIM
6	DMM

II. The MCSP contains the following modules:

Qty	Name
1	MPM
1	CRIM
1	IBIM
6	DMM
1	SBIM 1
1	SBIM 2
1	DRIM

III. The Common memory consists of one DMM.

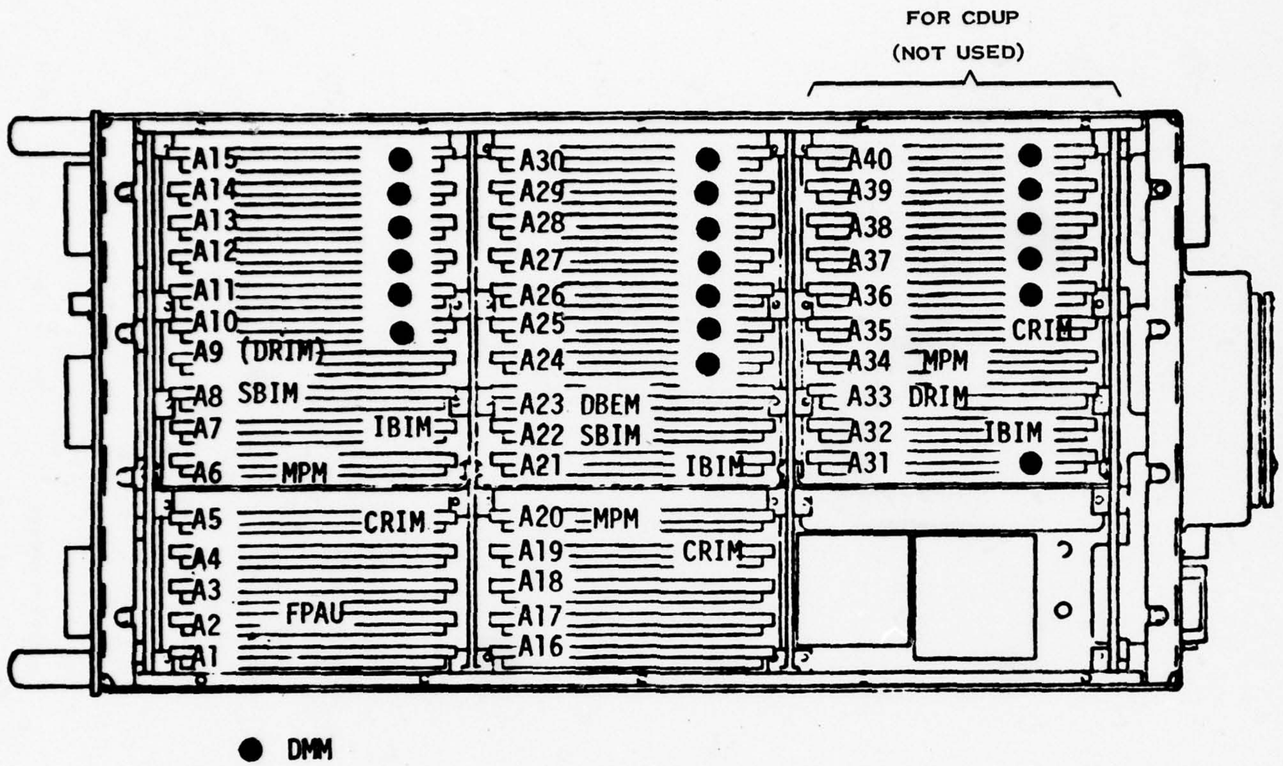


Figure 4.2-3. NAV LRU Top View W/O Cover

		> FFFE
512 Words PROM (MPM) A6	512 Words PROM (MPM) A20	> FE00
Not Used	Not Used	> FC00
256 Words RAM (MPM) A6	256 Words RAM (MPM) A20	> FA00
3 Words SBIM A8 & A22	3 Words Not Used	> F9FA
Words Not Used	Words Not Used	> F900
1 Word FPAU	1 Word FPAU	> F8FE
Not Used	Not Used	> F800
DBEM	A23	> F200
512 Words Instrumentation Interface Unit DBEM	A23	> F000
4K Words DMM (Global) A24		> D000
Not Use		> C000
4K Words DMM/PMM (Local) A15	4K Words DMM/PMM (Local) A30	> A000
4K Words DMM/PMM (Local) A14	4K Words DMM/PMM (Local) A29	> 8000
4K Words DMM/PMM (Local) A13	4K Words DMM/PMM (Local) A28	> 6000
4K Words DMM/PMM (Local) A12	4K Words DMM/PMM (Local) A27	> 4000
4K Words DMM/PMM (Local) A11	4K Words DMM/PMM (Local) A26	> 2000
4K Words DMM/PMM (Local A10	4K Words DMM/PMM Local A25	0

Figure 4.2-4. NAV-LRU Memory Map

IV. The FPAU consists of the following modules:

Qty	Name
1	FPAU Interface
1	FPAU Processor
1	FPAU Control 1
1	FPAU Control 2
1	FPAU Shift Register
2	FPAU Bit Slice

The NAV-LRU also has provisions for a third processing system located at the rear of the LRU. Interconnect cabling exists; however, connectors are not installed on the motherboard. The LRU is cooled by a fan at the rear of the LRU which draws air across the modules for cooling. The DC power supply is located on the underside of the unit and is removeable.

The memory mapping versus the hardware module is shown in Figure 4.2-4.

4.2.5 ELECTRICAL INTERFACE

I. Inputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	SOURCE
Power	28VDC	5.8 a	AC/DC Conv
Power	115VAC	115VAC, 400Hz, 41 w	AC/DC Conv
Data	UPCRUINZ	TTL (CRU data input)	*MP, CDU-LRU
Logic	UPBINZ	TTL (data bus input)	MP
Logic	/MPRSTZ	TTL (Maintenance panel reset)	MP
Logic	/MPLOADZ	TTL (Load command)	MP
Logic	/DEMERIZ	TTL (memory error for data read)	IIU-LRU
Logic	/DESTRTIZ	TTL (to indicate that the DBEM is to initiate a memory cycle on the local I-Bus)	IIU-LRU
Logic	DEREADIZ	TTL (read/write)	IIU-LRU
Logic	/DEHOLDIZ	TTL (to indicate that the I-Bus access is to be retained once acquired)	IIU-LRU
Logic	/DERESIZ	TTL (250-nsec(min) asynchronous low reset pulse)	IIU-LRU
Logic	/DECOMPIZ	TTL (to indicate that the memory cycle initiated by DBEM is complete)	IIU-LRU
Clock	INT-20MSOUTZ and INT-20MSOUTRZ	**TTL DR (20-msec FTF)	RCVR-LRU

*MP = Maintenance Panel
**TTL DR = output of a SN54265 or equivalent

II. Outputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	DESTIN.
Analog	UPVCCSAM	5VDC (VCC sample to indicate that power is applied to the MPM)	MP
Data	UPA(00-14)Z and /UPA(00-14)Z	TTL DR (processor address)	MP
Logic	/UPMEMENZ	TTL (memory enable)	MP
Logic	/UPENDCYZ	TTL (end of memory cycle)	MP
Logic	UPIAQZ	TTL (instruction acquisition)	MP
Logic	UPCRUOUTZ	TTL (CRU data output)	MP
Logic	UPCRUCLKZ	TTL (CRU clock)	MP
Logic	/DEMOROZ	TTL (to indicate parity error was detected for the data read from the local I-Bus)	IIU-LRU
Logic	/DECOMPOZ	TTL (to indicate that the memory cycle initiated by the remote device is complete)	IIU-LRU
Logic	/DERESOZ	TTL (250-nsec(min) asynchronous low reset pulse)	IIU-LRU
Logic	/DESTRTOZ	TTL (to indicate that the remote device is to initiate a memory cycle on the remote bus)	IIU-LRU
Logic	/DEREADOZ	TTL (read/write control)	IIU-LRU
Logic	/DEHOLDOZ	TTL (to indicate that the remote bus is to be retained once acquired)	IIU-LRU
Logic	/DRCRUOTZ	TTL DR (CRU data)	CDU-LRU

	and DRCRUOTZ		
Logic	/DRSTRCKZ and DRSTRCKZ	TTL DR (CRU output strobe)	CDU-LRU
Logic	/DRBZ(0-2) and DRBZ(0-2)	TTL DR (Byte address code UPA(9-11))	CDU-LRU
Logic	/DRLZ(0-2) and DRLZ(0-2)	TTL DR (Latch address code UPA(12-14))	CDU-LRU
Logic	/DRRZ(6) and DRRZ(6)	TTL DR (REGISTER enable line representing CRU addresses hex 1800 through 1BFE)	CDU-LRU

III. Bi-directional

CATEGORY	SIGNAL NAME	CHARACTERISTIC	SOURCE/ DESTIN.
Clock	SBCLKZ and SBCLKRZ	*TR DR (clock for transferring data between RCVR and NAV LRU's)	RCVR-LRU
Data	SBDATAZ and SBDATARZ	TR DR (communication data between RCVR and NAV LRU's)	RCVR-LRU
Data	DEDZ(00 -15)	Tri-state TTL (data)	IIU-LRU
Data	DEAZ(05 -19)	Tri-state TTL (address)	IIU-LRU

*TR DR = Transformer Drive

4.3 CONTROL DISPLAY LINE REPLACEABLE UNIT

4.3.1 GENERAL DESCRIPTION

The Control Display Line Replaceable Unit No. 3 (CDU) is the man/machine interface for the HDUE system. This Line Replaceable Unit (LRU) accepts commands from the operator via a keyboard and transmits them to the Master Control Subsystem Processor (MCSP). The MCSP transmits information to the CDU which then displays the information on two 10-character alphanumeric displays. The type of information transmitted or received is determined, via operator control, by the position of the data mode and format switches.

4.3.2 FUNCTIONAL DESCRIPTION (refer to Figure 4.3-1)

The CDU-LRU contains the following elements:

1) CRU driver/receiver
2) CDU electronic interface unit
3) Alphanumeric display
4) Input/Output controls
5) Integrally lighted panel
6) Power supply

The inter-relation of these elements is illustrated in Figure 4.3-1. The functional allocation to these elements is as follows:

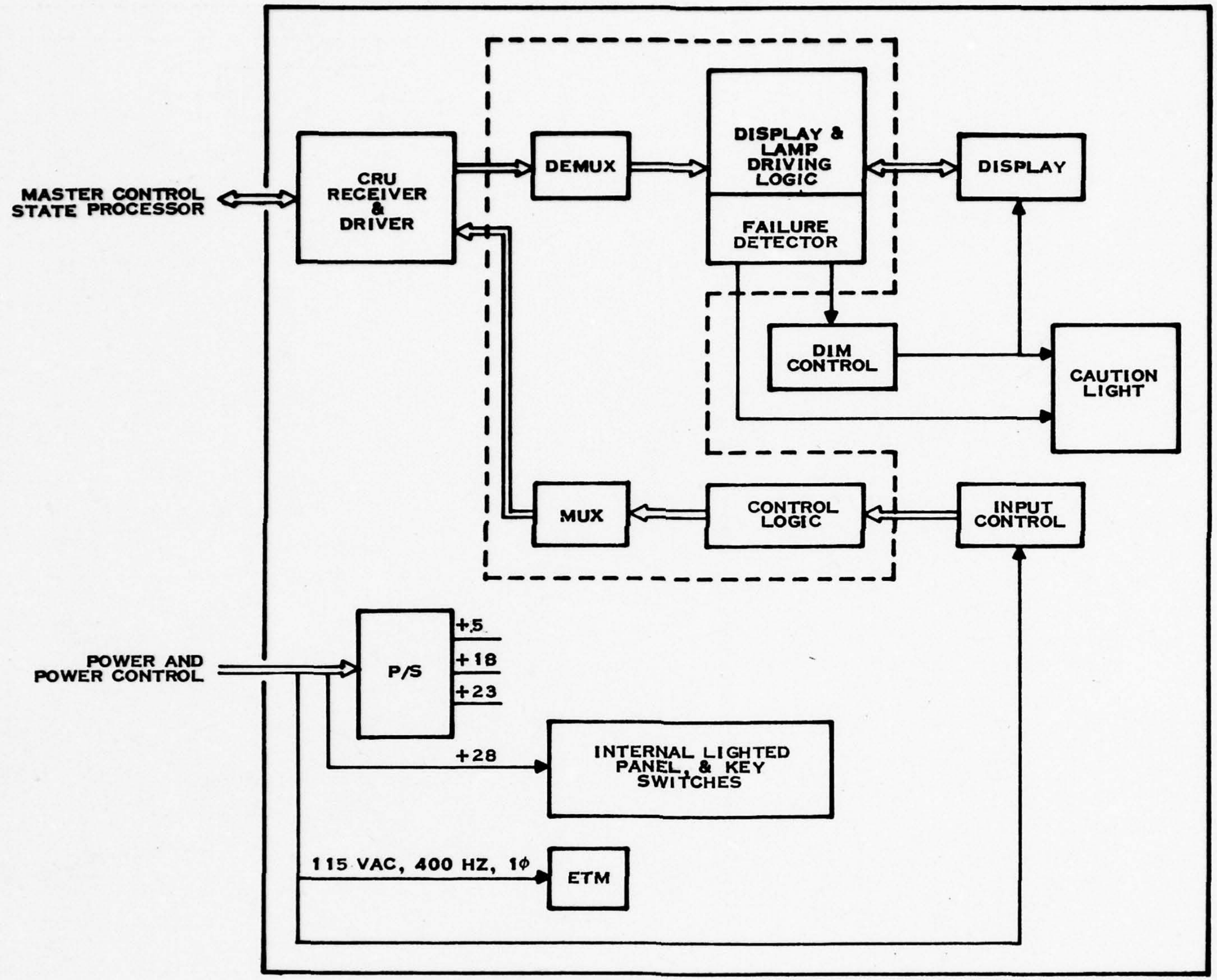


Figure 4.3-1. Functional Block Diagram Control Display Unit

I. CRU driver/receiver

This is the interface circuit which converts CRU information on balanced line driver inputs from the Driver Receiver Interface Module (DRIM) within the Navigation Processor LRU to single ended TTL levels for use within the CDU. Transfers from the CDU to the NAV-LRU are converted from single ended TTL levels to balanced driver outputs to be transmitted to the DRIM in the NAV-LRU.

II. CDU electronic interface unit

This unit serves as an interface between the MCSP and the control panel through the CRU driver/receiver.

The CDU Electronic Interface Unit (CDUEIN) consists of 1) CDU display driving logic, 2) CDU control pick-up logic, 3) CDU lamp driving logic, and 4) failure detector for the MCSP.

(A) CDU display driving logic

The CDU display driving logic consists of circuitry to accept inputs from the MCSP and drive the alphanumeric displays. The core of the CDU display driving logic is a 64 X 8 random access memory (RAM). Data to be displayed is transmitted from the MCSP and stored in the RAM. The CDU display driving logic then strobes the displays using the contents of this RAM. The strobing process is continuous, pausing only long enough to allow new data to be read into the RAM. Data is read into the RAM in an 8-bits (one byte) parallel format.

(B) CDU pick-up logic

The CDU control pick-up logic monitors operator commands input via the input controls and sends the commands to the MCSP.

(C) CDU lamp driving logic

The CDU CAUTION lamp driving logic accepts inputs from the MCSP. This lamp is controlled by the MCSP software.

(D) Failure detector for the MCSP.

The failure detector for the MCSP monitors a signal from the MCSP to detect a malfunction or enable status.

III. Alphanumeric display

The alphanumeric display consists of two rows of 10 characters each. The characters are 16-segment incandescent units, located as shown in Figure 4.3-2. The display is strobed by the CDU display driving logic in sets of 10 at a rate greater than 60 complete refreshes per second; thus, the top and bottom rows are

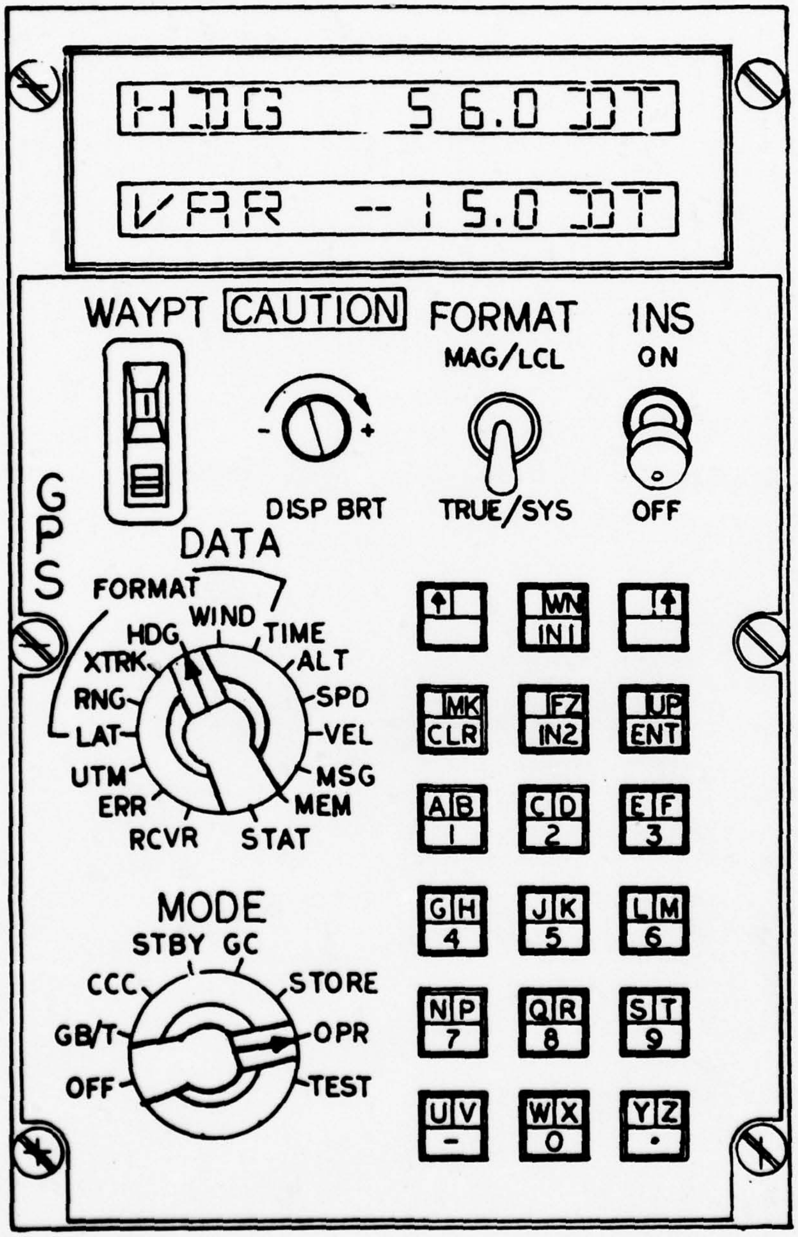


Figure 4.3-2. CDU Control Panel

strobed in parallel at a rate greater than 60Hz. The displays are covered with a red density filter.

IV. Input/Output controls

The Input/Output controls allow the operator to issue commands to the HDUE, interrogate the system for information, and input data. The Input/Output controls are illustrated in Figure 4.3-2.

V. Integrally lighted panel

The front panel is an integrally lighted panel. The intensity of the integral lighting is adjustable through a control installed on the Instrumentation Interface Unit (LRU No. 5) to simulate the normal cockpit panel intensity control.

A lamp with the advisory legend "CAUTION" is illuminated independently. The on-off switching of this lamp is controlled by software in the MCSP. The legend "CAUTION" is in translucent letters colored aviation yellow. When not energized, the legend is not readable.

VI. Power supply (refer to Figure 4.3-3)

The power supply consists of five sections: 1) switching regulator, 2) DC-TO-DC converter, 3) voltage monitor, and 4) temperature monitor.

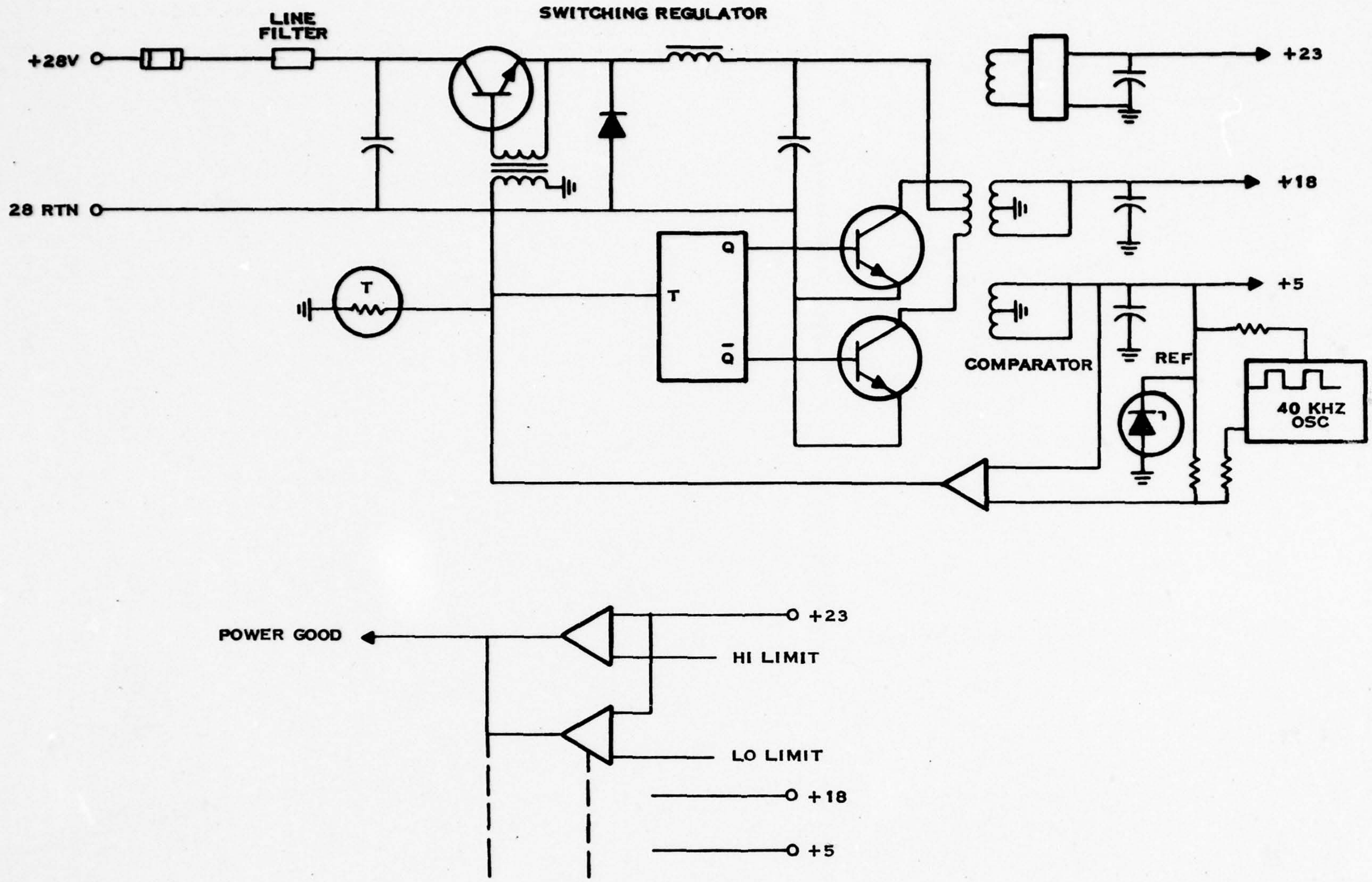


Figure 4.3-3. Power Supply Diagram Control Display Unit

A) Switching regulator

Power supplied to the CDU is regulated by a switching regulator operating at 40 KHz.

B) DC-to-DC converter

The output of the regulator is supplied to the primary of a DC-to-DC converter operating at 20 KHz. The DC-to-DC converter transformer has three secondaries which are rectified and filtered to provide +5, +18, and +23 volts as required by the CDU. The +18 volt supply powers a precision regulator which serves as a reference. In addition, a 40-KHz sawtooth is generated from this reference which modulates a 5.0-volt reference. By comparing the 5-volt sawtooth modulated reference with the 5-volt output, a duty cycle modulated 40-KHz pulse train is produced which has an "on" time proportional to the relative error between the reference and the output voltage. This pulse train is coupled back to the switching regulator drive circuitry and thereby adjusts the transformer primary voltage providing closed loop regulation.

C) Voltage monitor

A voltage monitor consisting of window comparators set to the upper and lower limits of acceptable regulation is provided to detect out-of-tolerance operation on each voltage. This output provides the "power good" signal which initializes the logic in the CDU whenever the power is turned on.

D) Temperature monitor

Excessive temperature rise in the CDU, for whatever reason, is sensed by a thermistor. When a preset threshold is exceeded, the supply is turned off until the temperature returns to an acceptable level to prevent damage to the components.

4.3.3 FUNCTIONAL INTERFACE

I. Power turn on

When the operator moves the MODE select switch to a non-off position, a relay is energized in the AC/DC Converter LRU which allows battery-buffered 28 VDC to be supplied to all HDUE LRUs.

II. Operator displays

The alphanumeric display lamps which convey data and status to the operator are software controlled.

ALERT and WARNING messages are displayed on the upper row of the display. The messages that can be displayed are as follows, listed in order of priority:

ALERT Messages

ENT 2 SHORT
ALPHA ERR
NUM ERR
HEX ERR
ENT 2LONG
SWITCH RNG
NO FREEZE
NO INPUT
NO ALMANAC

WARNING Message

MCSP FAIL
NAVP FAIL
RCVP FAIL
INIT TIME
INIT POS
TRK FAIL
RCVR FAIL
REACQ FAIL
WYP BEHIND
LAST ENTRY
SV MESSAGE
SYSTEM GO

For a description of these messages refer to paragraph 3.2.5.

The MCSP interrogates the operator inputs at a rate of 10 Hz. The CDUEIM has the watch-dog circuit which monitors this consistent signal from the MCSP. Constantly the operational status of the processor is checked and the CDUEIM shows a specific indication in the display if the interrogations are missing. The "CAUTION" lamp is also controlled by the MCSP software.

III. Operator inputs

The operator may make entries as described in Tables 4.3-1 and 4.3-2.

The data entry keyboard is encoded using 3 column switches and 6 row switches, which requires five discrete bits to determine which momentary contact switch the operator has depressed. The format toggle switch is used to change display formats via the software.

4.3.4 MECHANICAL DESCRIPTION

The configuration of the CDU is as shown on Figure 4.3-4. The front panel was discussed above in the FUNCTIONAL INTERFACE section. The circuit boards are located behind the front panel and slide out vertically. The connectors and fusing for the 28 VDC are located on the rear panel. The higher heat dissipation portions of the DC-to-DC Converter are located on the inside of the rear panel.

TABLE 4.3-1
FUNCTIONS OF KEY SWITCHES

Symbol	Description
MK	MARK, stores vehicle present position in waypoint.
FZ	FREEZE, stores vehicle present position as determined by the NAVP in a temporary register.
UP	UPDATE, updates NAVP with contents of waypoint, altitude, true air speed, heading, and time.
IN 1	INPUT ROW 1, puts display into input mode.
IN 2	INPUT ROW 2, puts display into input mode.
CLR	CLEAR, clears contents of any display in the input or input error modes and puts display into output mode without affecting the processor memory contents.
ENT	ENTER, enters contents of any display in input mode into the processor memory and puts display into output mode.
WN	WARNING Request, allows warning message to be observed when a CAUTION indicator is illuminated.
¦ ^ ¦ ¦ ¦ ¦ ¦	Causes the upper left portion of the keys to activate.
¦ ¦ ^ ¦ ¦ ¦ ¦	Causes the upper right portion of the keys to activate.
.	DECIMAL, controls memory address increment.
-	MINUS, controls memory address decrement. Also causes entry values to be negative.
A to Z 0 to 9	Values entered as depressed.

TABLE 4.3-2

FUNCTIONS OF CONTROL SWITCHES

Symbol	Description
MODE	Power on-off
DATA	Controls the display and directs inputs
WAYPT	Controls the input of the DATA switch
FORMAT	Selects magnetic or true reference
INS	Not presently used
DISP BRT	Controls brightness of alphanumeric display

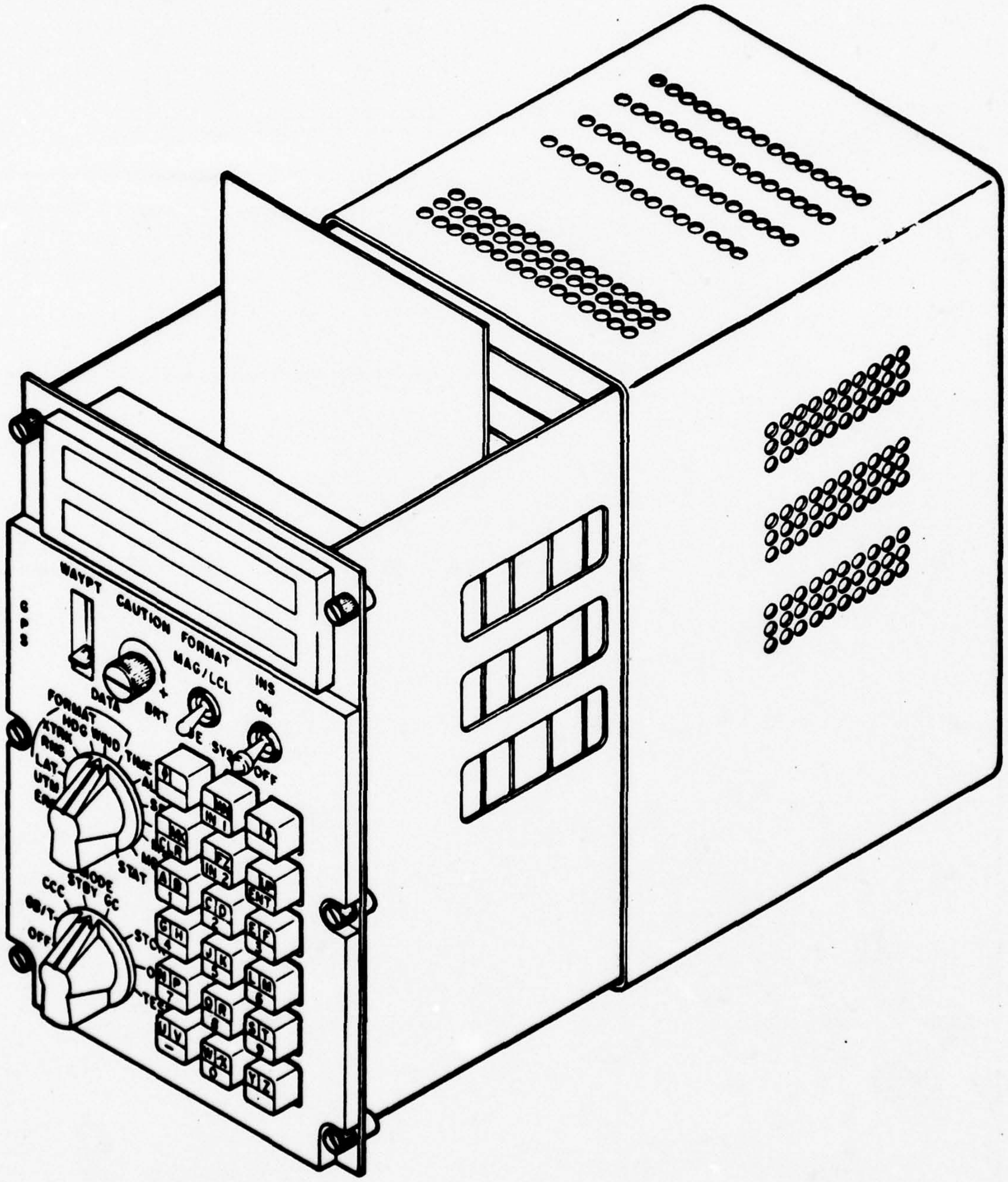


Figure 4.3-4. HDUE Control/Display LRU

4.3.5 ELECTRICAL INTERFACE

I. Inputs

CATEGORY TYPE	SIGNAL NAME	CHARACTERISTIC	SOURCE
Power	28VDC	2.1 a	AC/DC Conv
Power	115 VAC	1 w (400 Hz, 1-phase)	AC/DC Conv
Power	28VDC Panel	Variable 0-28VDC Integral panel lighting	IIU
Logic	/DRCRUOTZ DRCRUOTZ	*TTL DR (CRU data)	NAV-LRU
Logic	/DRSTRCKZ DRSTRCKZ	TTL DR (CRU output strobe)	NAV-LRU
Logic	/DRBZ(0-2) DRBZ(0-2)	TTL DR (BYTE address code UPA (9-11))	NAV-LRU
Logic	/DRLZ(0-2) DRLZ(0-2)	TTL DR (LATCH address code UPA (12-14))	NAV-LRU
Logic	/DRRZ (6) and DRRZ(6)	TTL DR (register enable line)	NAV-LRU

*TTL DR = From a dual line driver type SN55114 or equivalent.

II. Outputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	DESTIN.
Data	/CDUCRUINZ CDUCRUINZ	TTL DR (CRU serial output Data)	NAV-LRU

4.4 AC/DC CONVERTER LINE REPLACEABLE UNIT

4.4.1 GENERAL DESCRIPTION (refer to Figure 4.4-1)

The AC/DC CONVERTER contains the circuitry necessary to: 1) accept 115 VAC 400 Hz, convert it to 28 VDC, and distribute it to the other LRU's, 2) accept 28 VDC and distribute it to the other LRU's, and 3) provide continuous 28 VDC to the other LRU's during momentary primary power interruptions lasting for up to seven seconds. The other LRU's contain DC-TO-DC converters to provide the necessary operating voltages. Refer to Figure 4.4-4 for HDUE 28 VDC distribution.

4.4.2 FUNCTIONAL DESCRIPTION (refer to Figures 4.4-1 and 4.4-2)

The AC/DC Converter Unit provides 28 VDC input power to the individual HDUE LRU's. When three phase, 400 Hz primary power is available it may be selected with a switch on the unit to be converted and provided as an alternate to the 28 VDC aircraft source. When 28 VDC primary power is selected the AC/DC Converter provides protection from transient surges appearing on the input power line. Also included in this LRU is a battery pack which is automatically switched onto the HDUE 28 VDC during momentary outages in the primary power. This back-up support is provided for both the 115 VAC and 28 VDC operation.

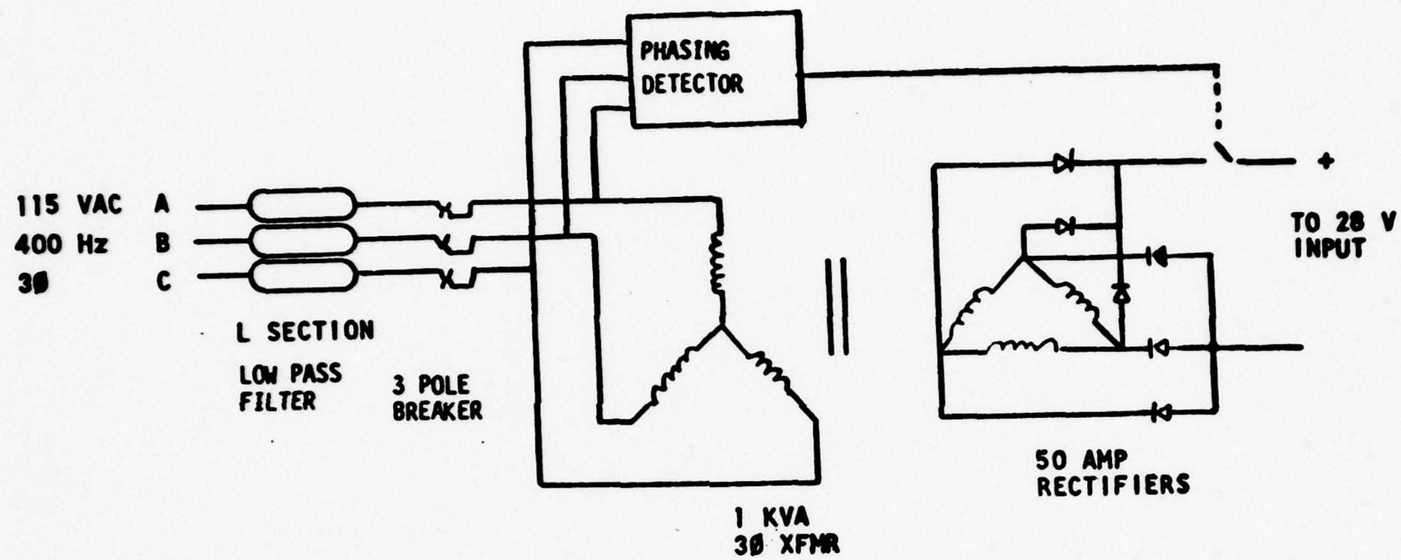


Figure 4.4-1. Functional Diagram AC/DC Converter

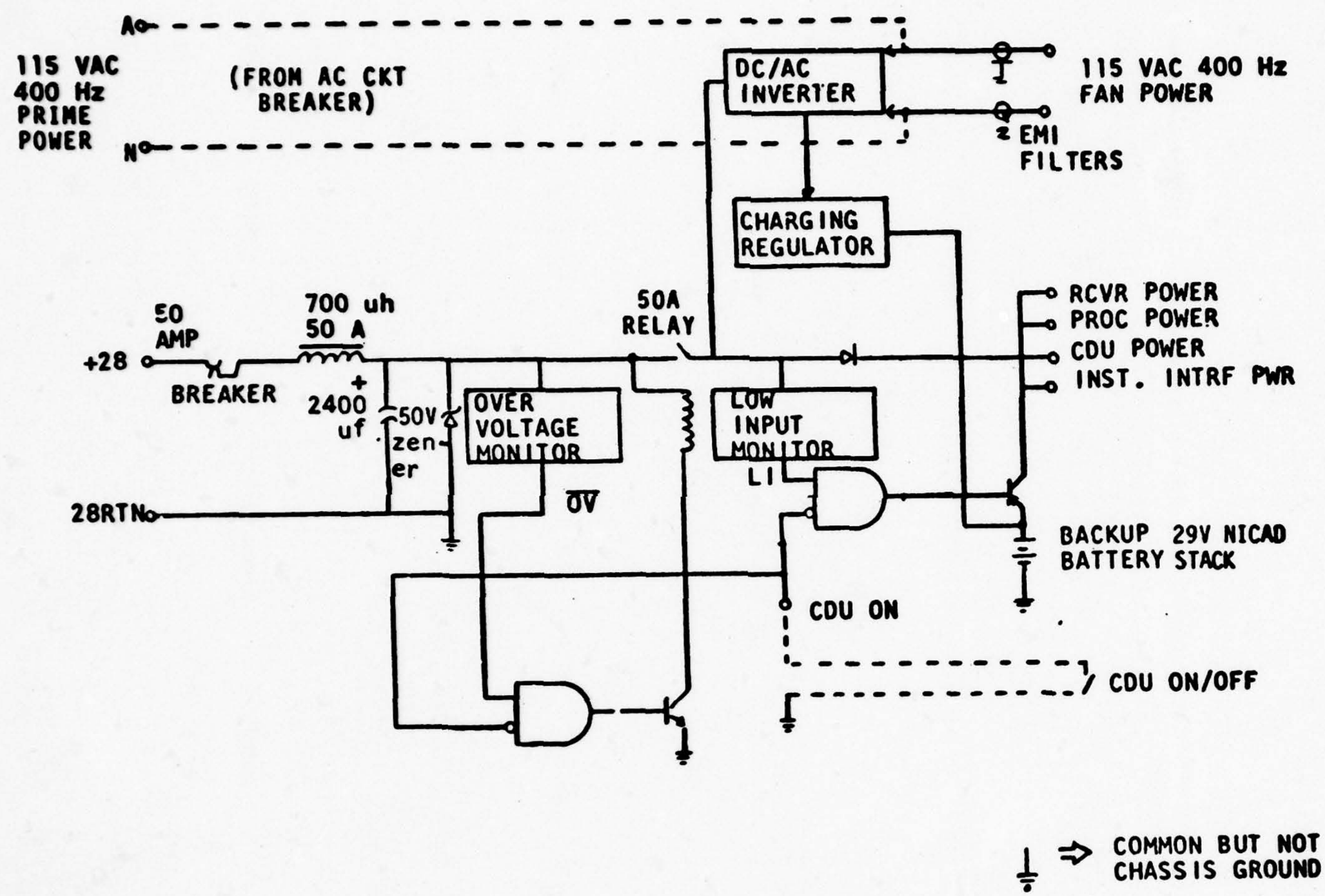


Figure 4.4-2. Functional Diagram Surge Protection, Battery Back-up, DC/AC Inverter

When operating from the 28 VDC, the AC/DC Converter generates 115 VAC, single phase, 400 Hz power for the LRU cooling fans and run time totalizing meters and for the internal battery charging circuit.

I. AC-TO-DC Converter section

A diagram of the AC/DC Converter section is shown in Figure 4.4-1. The 3-phase EMI line filter removes high frequency ripple and spikes on the primary power input. A single-phase detector monitors improper phasing of input power. In the event of a failure of one or more phases of the primary power, the 3-pole relay breaks the circuit until normal phasing is restored. The 28 VDC is provided by the step down transformer followed by rectifiers.

II. 28 VDC surge protection

The ouput of the rectifiers, or alternatively, the aircraft 28 VDC primary power is supplied to the input filter network in Figure 4.4-2. This choke and capacitor bank protect the HDUE from transient surges on the aircraft power and provide the ripple filtering required on the rectified 28 VDC from the AC/DC Converter.

III. Battery back-up supply

The back-up battery provides continuous 28 VDC power to the HDUE LRU's in the event of primary power dropouts. In addition, turn on and arming for the HDUE system from the CDU is provided. This unit also generates 115 VAC, 400 Hz, single phase power for the HDUE cooling fans and time totalizing meters, as well as auxiliary charging voltage for the battery pack. The charging regulator profiles the rate of charge with temperature to prevent damage to the battery pack. An overvoltage monitor contained in the unit disconnects primary power during periods of sustained, abnormally high voltage which might damage subsequent circuits, and an undervoltage monitor connects the battery pack in the event primary input power drops to the point that the distributed voltage is below 20 VDC.

4.4.3 MECHANICAL DESCRIPTION

The configuration and component location is given in Figure 4.4-3. Fuses are provided for 115 VAC to each of the three LRU's --Receiver, Nav Processor (and IIU), and CDU--, 115 VAC to the internal battery charging circuit, 28 VDC to the CDU, and 28 VDC to the internal 400 Hz inverter. Circuit breakers are provided for the input 3-phase 115 VAC and input 28 VDC.

The voltage distribution is shown in Figure 4.4-4.

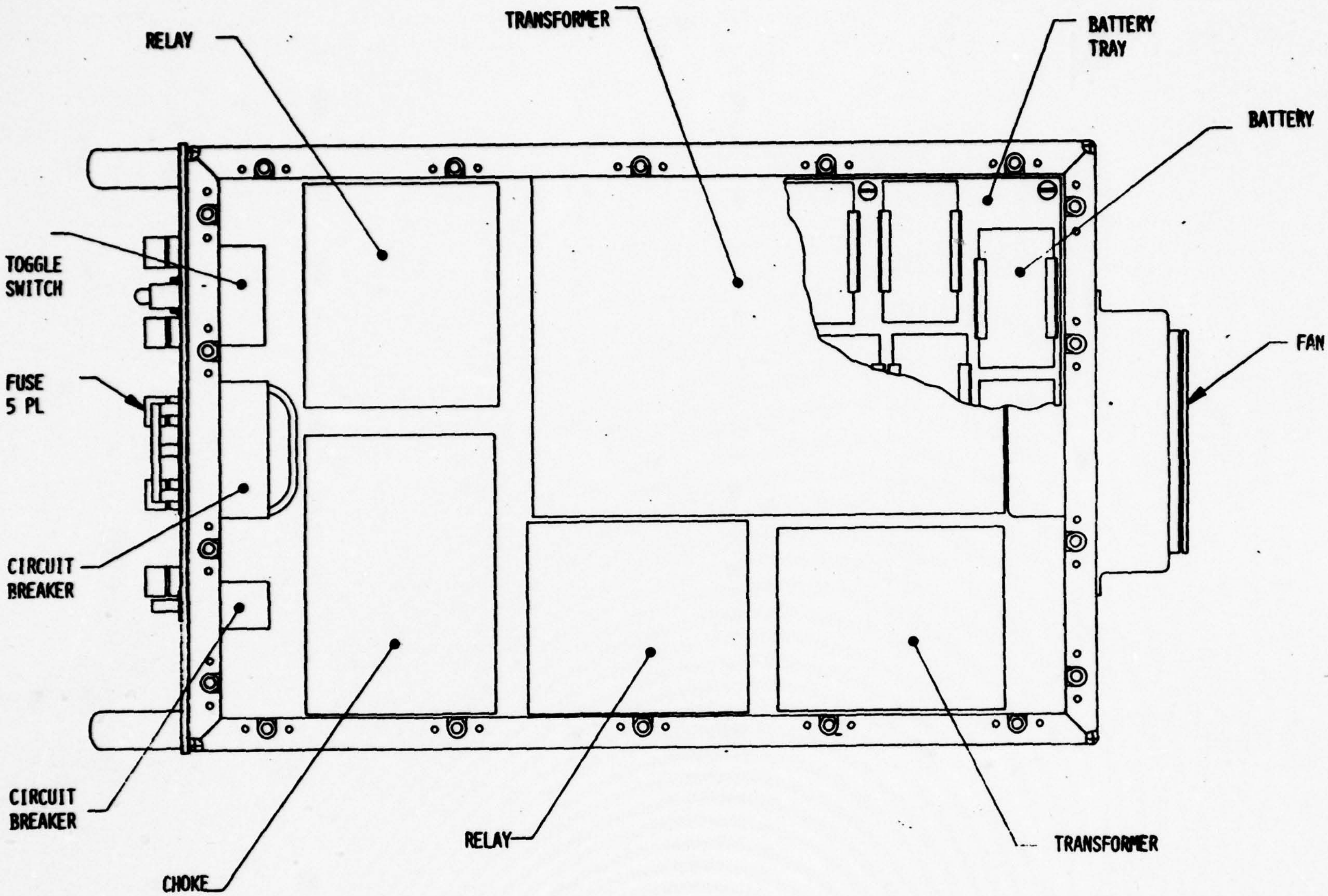


Figure 4.4-3. AC/DC Converter W/O Cover

4.4.4 ELECTRICAL INTERFACE

I. Inputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	SOURCE
Power	28V	26 a (22 to 30 VDC (steady state) MIL-STD-704, Category B; limits 2 and 3)	prime pwr
Power	PH A-C and NEUT	754 w (100 to 130 VAC, 3 phase 380 to 420 Hz)	prime pwr
Logic	CDU ON	Level (GND switches system power on)	CDU-LRU

II. Outputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	DESTIN.
Power	28V	16 a (20 to 30 VDC)	RCVR-LRU, NAV-LRU, CDU-LRU
Power	115 VAC	200 w (115 ± 15% VAC, 1 phase 380 to 420 Hz)	RCVR-LRU, NAV-LRU, CDU-LRU

The distribution of the output voltages and their respective loads are listed in Table 4.4-1.

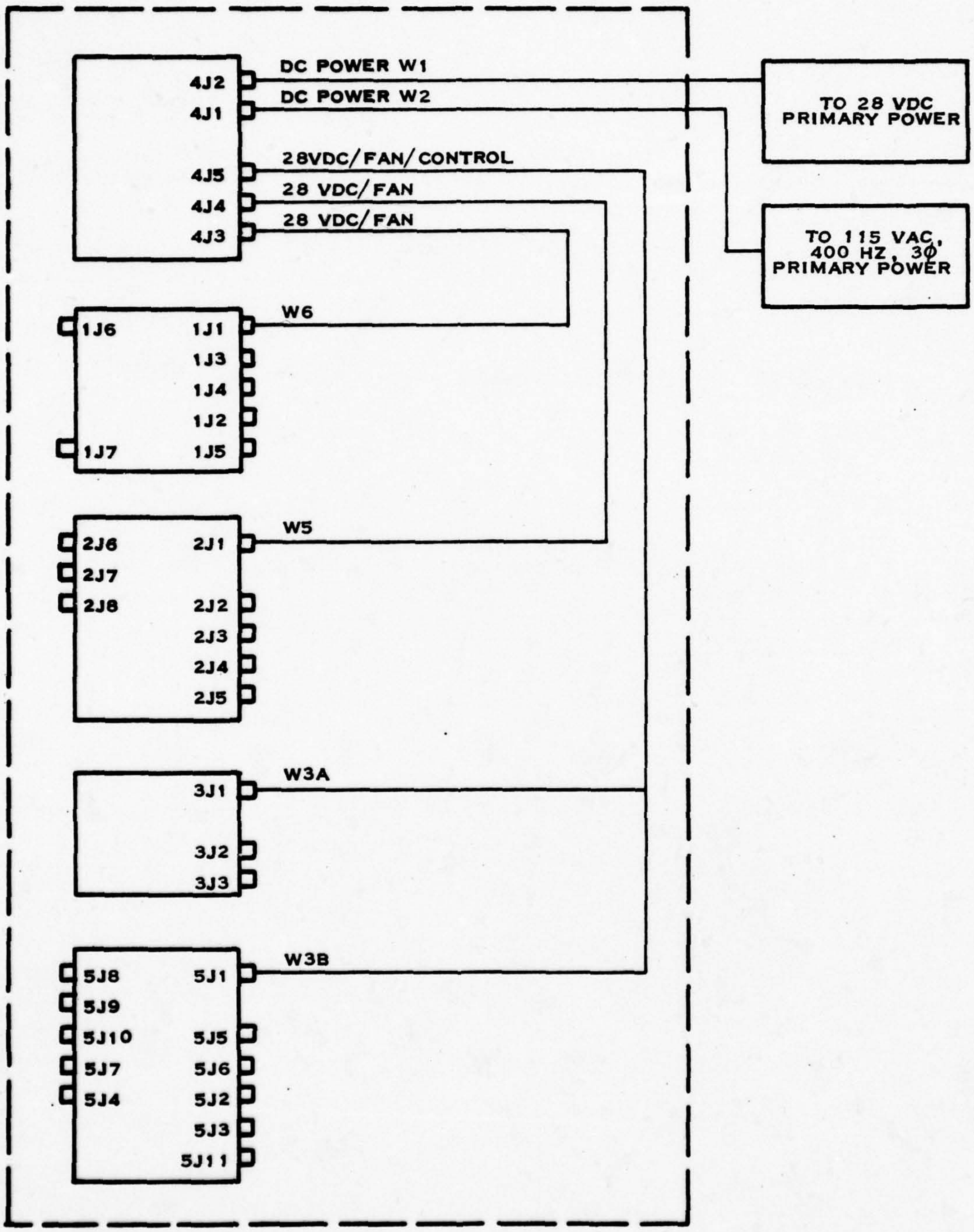


Figure 4.4-4. Power Distribution

TABLE 4.4-1. LRU POWER REQUIREMENTS

NOMINAL POWER IN WATTS

	RCVR	Processor	CDU	Instrumentation	AC/DC Converter On 28 VDC Primary Power	AC/DC Converter On 115 400 Hz Primary Power
28V Power Input	177	162	60	60	171	0
AC Power	81	41	1	1	0	171
	258	203	61	61	171	171

	TYPICAL
Total System Power*	754

4.5 INSTRUMENTATION INTERFACE LINE REPLACEABLE UNIT

4.5.1 GENERAL DESCRIPTION

The Instrumentation Interface Unit (IIU) is support equipment normally used with the HDUE. The IIU (LRU 5) provides: 1) interface with the pallet HP2100 Instrumentation Processor, 2) HDUE program cassette loading, and 3) HDUE microprocessor maintenance panel interface. In addition to the above interface functions the IIU provides panel edge light intensity control for the CDU.

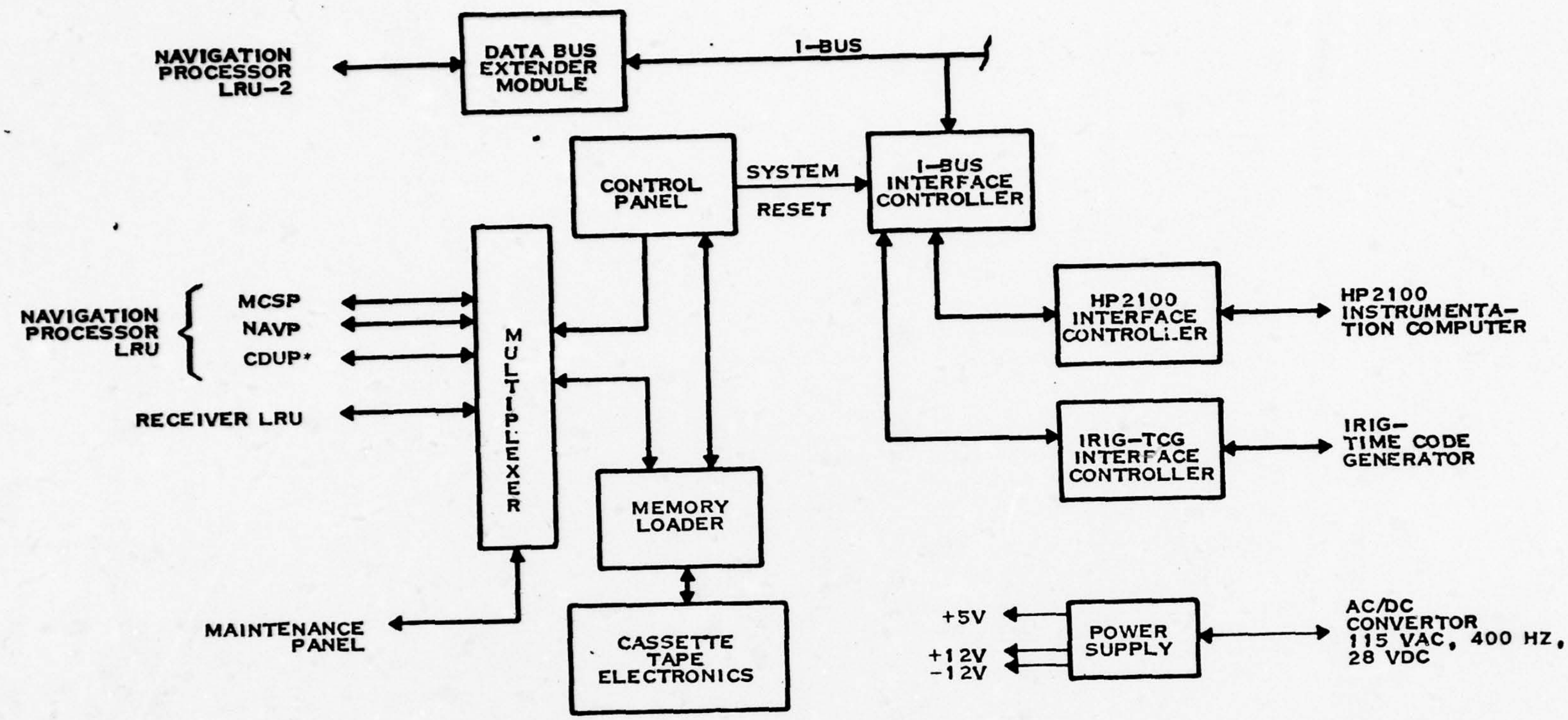
4.5.2 FUNCTIONAL DESCRIPTION (refer to Figure 4.5-1)

I. Data Bus Extender Module

The interface between the IIU and the NAV-LRU for data to be delivered to the instrumentation processor is accomplished via a Data Bus Extender Module (DBEM). This module functions as an extension of the NAV-LRU I-Bus.

II. HP2100 Data Buffer Controller

The HP2100 Data Buffer provides the functional interface between the HP2100 Instrumentation Processor and the NAV-LRU, via the IIU. Handshake signals CCDF, CCDC, DCDF, and DCDC are utilized for transfer of data blocks consisting of up to 256, 16-bit words from the HDUE to the HP2100.



*NOT USED

Figure 4.5-1. Functional Block Diagram Instrumentation Interface Unit

This transfer is discussed below in the FUNCTIONAL INTERFACE section.

III. Time Code Generator Interface

The Time Code Generator (TCG) Interface provides interface between the HDUE and the TCG. The two 16-bit words of IRIG time are transferred via handshake and logic signals /DATA 0, /DATA 1, /DATA 2, /STROBE, and /DATA READY FLAG from the TCG. This transfer also is discussed in the FUNCTIONAL INTERFACE section.

IV. Memory Loader

The Memory Loader interfaces with the maintenance panel multiplexer as shown in Figure 4.5-1. It enables any one of the Microprocessor Modules (MPM's) in the NAV-LRU or the RCVR-LRU, as selected on the IIU front panel, to read data from the loader. Data is transfered at a rate of 665 words per second.

V. Maintenance Panel Multiplexer

The maintenance panel multiplexer allows the maintenance panel to enter data or to read data from any memory location in the NAV-LRU or the RCVR-LRU for basic diagnostic testing of the HDUE system. The multiplexer also contains the memory loader interface.

VI. Power Supply

The internal power supply is a commercial unit that converts 115 VAC 400 Hz from the AC/DC Converter, via the NAV-LRU, to +5 VDC, +12 VDC, and -12 VDC for use within the IIU.

VII. CDU Panel Edge Light Control

The CDU lighting is controlled with a variable voltage adjustable in the IIU to 28 VDC. The 28 VDC is supplied by the AC/DC Converter, through the NAV-LRU.

4.5.3 FUNCTIONAL INTERFACE

I. HP2100 Interface Controller (refer to Figures 4.5-2 through 4.5-4)

The I-Bus interface is a slave device. In this configuration the buffer memory appears as an extension of the NAV-LRU communication memory. The address space of the buffer is hex address F000 to F1FE. The buffer is a multiported device with high speed memory components functionally configured to enable block data transfers (read cycles) at rates determined by the HP2100 DMA.

Refer to Figure 4.5-3 for the functional flow and to Figure 4.5-4 for the handshake timing.

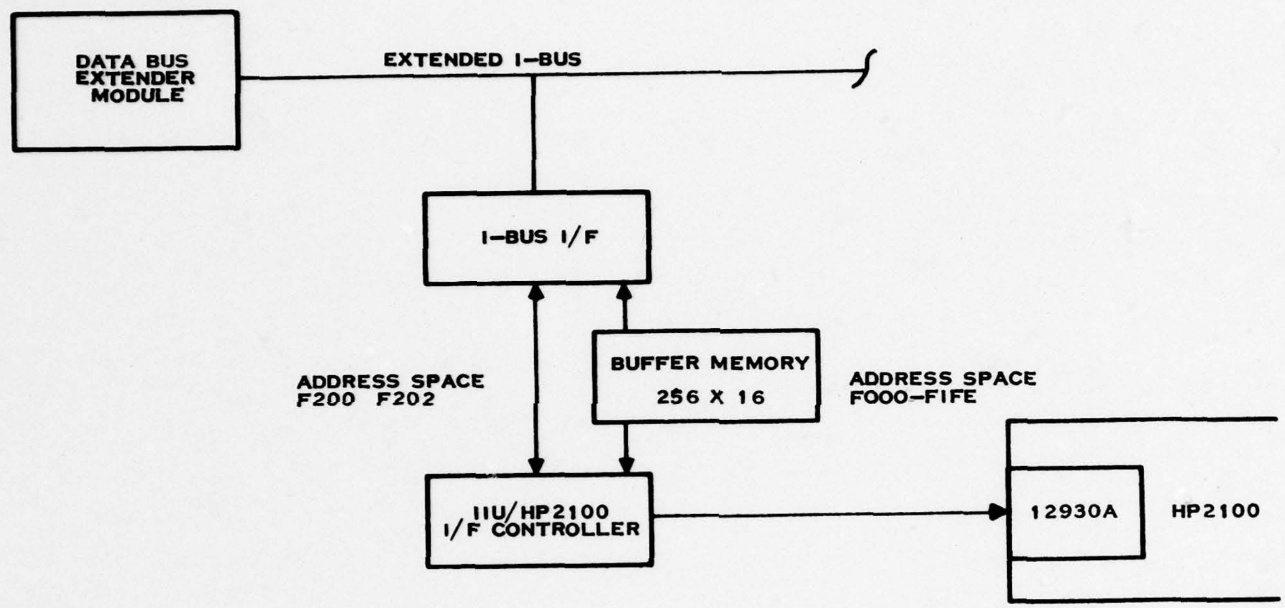


Figure 4.5-2. Functional Block Diagram HP2100 Interface

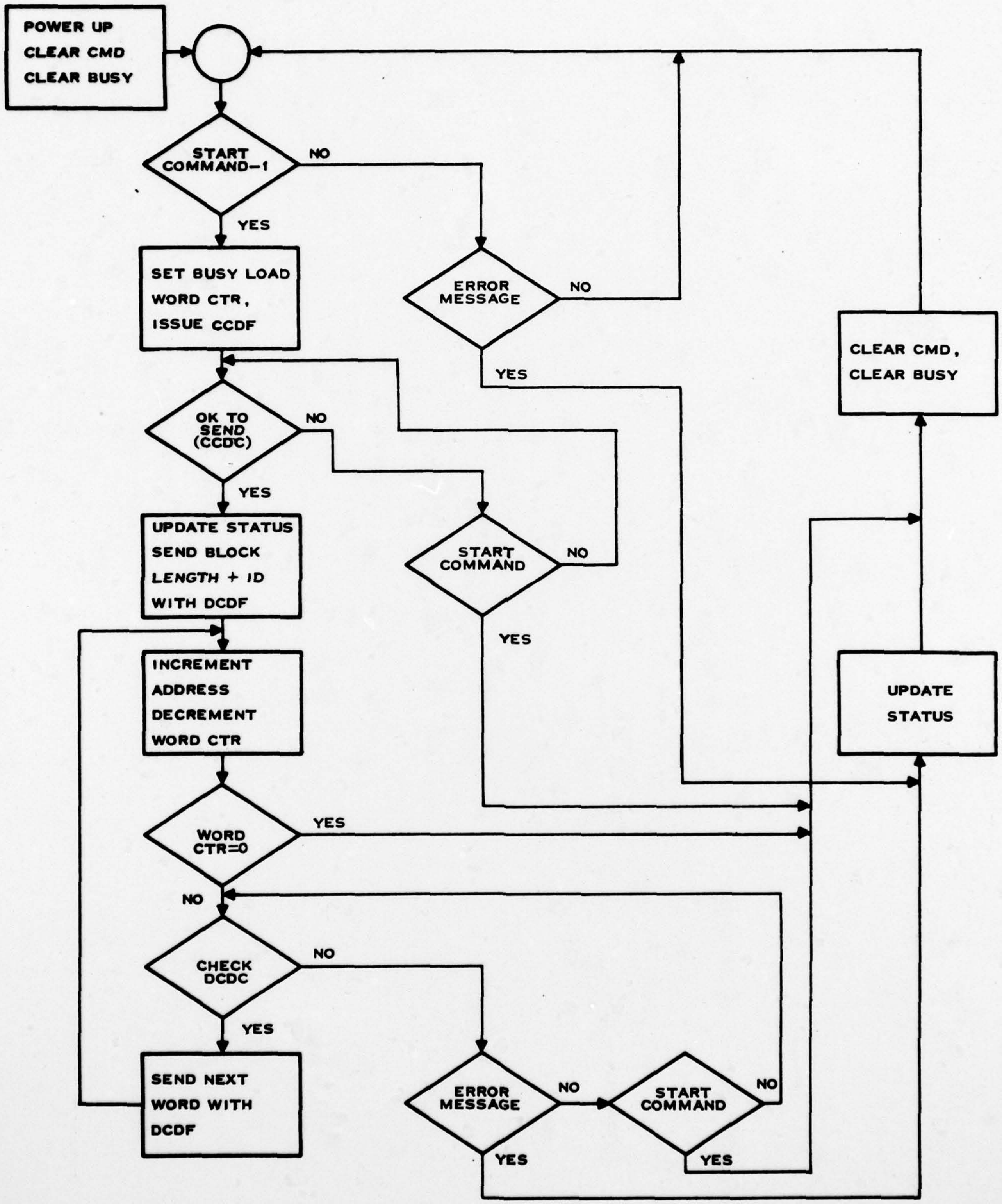


Figure 4.5-3. Flow Diagram HP2100 Control

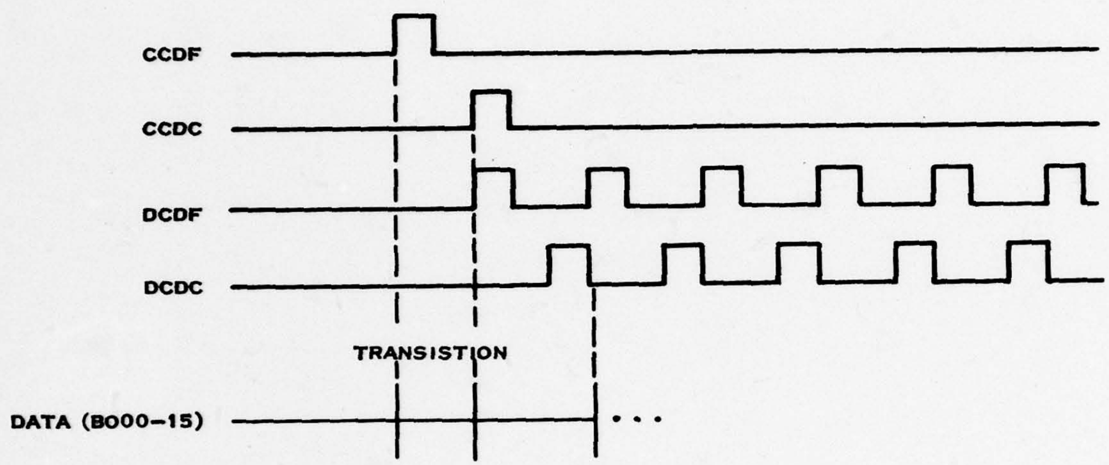


Figure 4.5-4. Signal Timing HP2100 Control

Upon power up, the controller begins interrogating the COMMAND word looking for a logic 1. Upon detection of the COMMAND word, the Controller enters the initialization sequence which accomplishes the following:

(A) set BUSY = 1

(B) set COMMAND = 1

(C) read memory location F000 (block ID/word length)

(D) set word counter to number of words

(E) enter transfer sequence

The transfer sequence starts with making the first word in the data block available in the buffer and the transmittal of a Command Channel Data Flag (CCDF) to the HP2100. The HP2100 observes the first word of the data block and sets up its respective counters, then returns a Command Channel Control Command (CCDC) when it is ready to receive data. With the reception of the CCDC the Controller leaves the first data word available on the buffer and transmits a Data Channel Data Flag (DCDF). The HP2100 reads the first word of the data block and increments its counters, then returns a Data Channel Control Command (DCDC). In response to the DCDC the Controller places the second word in the buffer and transmits another DCDF. This process continues until the entire data block is cycled through the buffer.

The above sequence terminates if there is either a non-zero error message or the next data block is loaded into the buffer.

(A) Non-zero Error Message

In the case of a non-zero error message from the HP2100 the transfer sequence terminates. After 20 msec another CCDF is issued and the sequence starts again for the same data block. In the case of three failures of this type the sequence is not attempted again until the next data block is loaded in the memory buffer.

(B) Time-out

The system assumes a good transfer of the data block with a zero error message and loads the next data block when it is ready. This occurs in a minimum of 160 msec from the last CCDF.

II. IRIG TCG Interface (refer to Figure 4.5-5)

IRIG time is available to the IIU via a 16-bit data bus and 5 control lines. When it is necessary to read the TCG, a "freeze" is sent to the TCG. This "freeze" command holds the time in the output buffer of the TCG at the instant that it was issued.

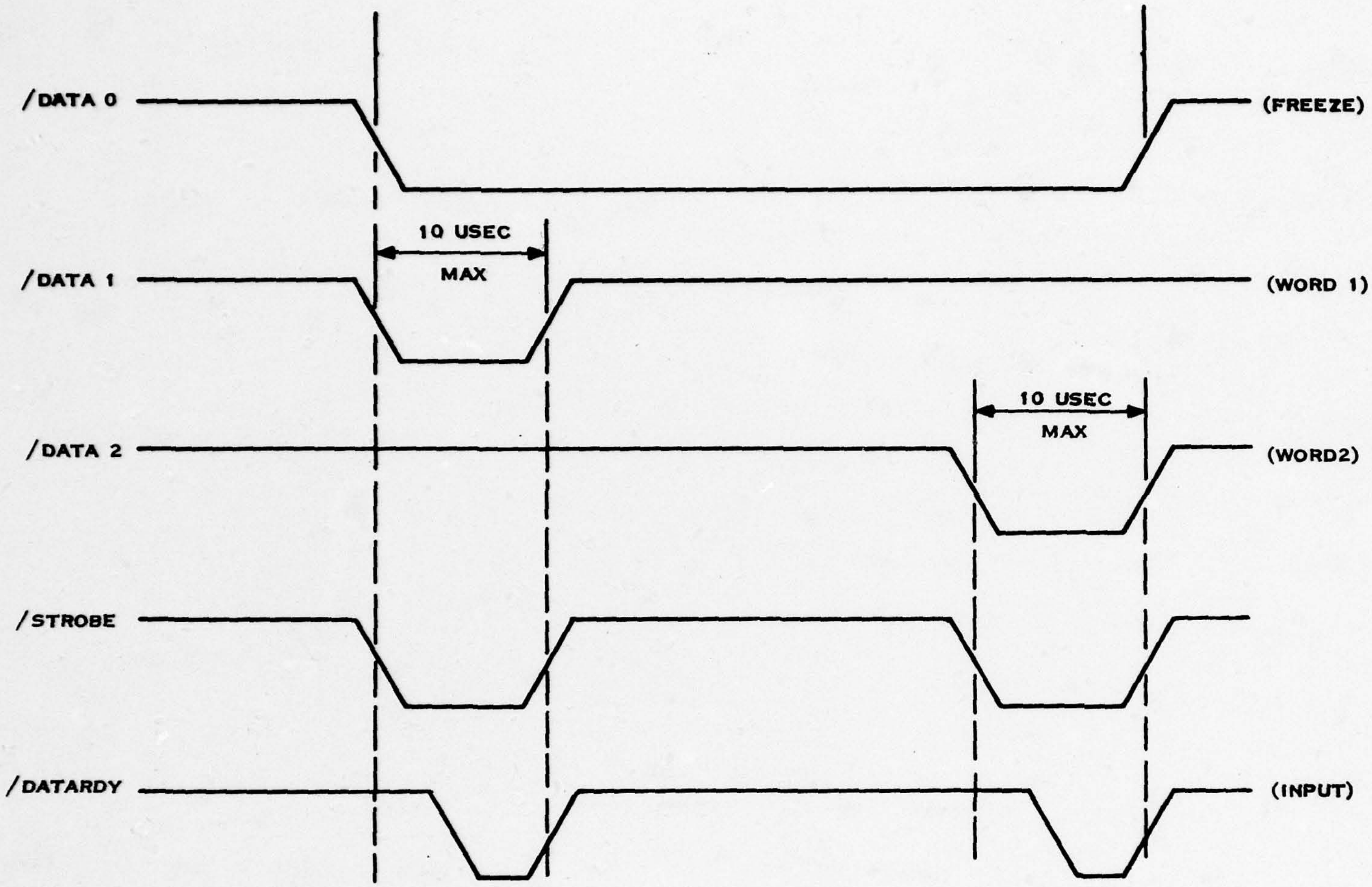


Figure 4.5-5. Signal Timing IRIG Time Code Generator Interface

/DATA 0 functions as the "freeze" command and is low when time is desired. /DATA 1 is for the least significant word and /DATA 2 is for the most significant word. The /STROBE is low when the data is to be read. The response flag from the TCG is /DATARDY.

Signal timing is shown in Figure 4.5-5.

4.5.4 MECHANICAL INTERFACE

The IIU is configured shown in Figures 4.5-6 and 4.5-7.

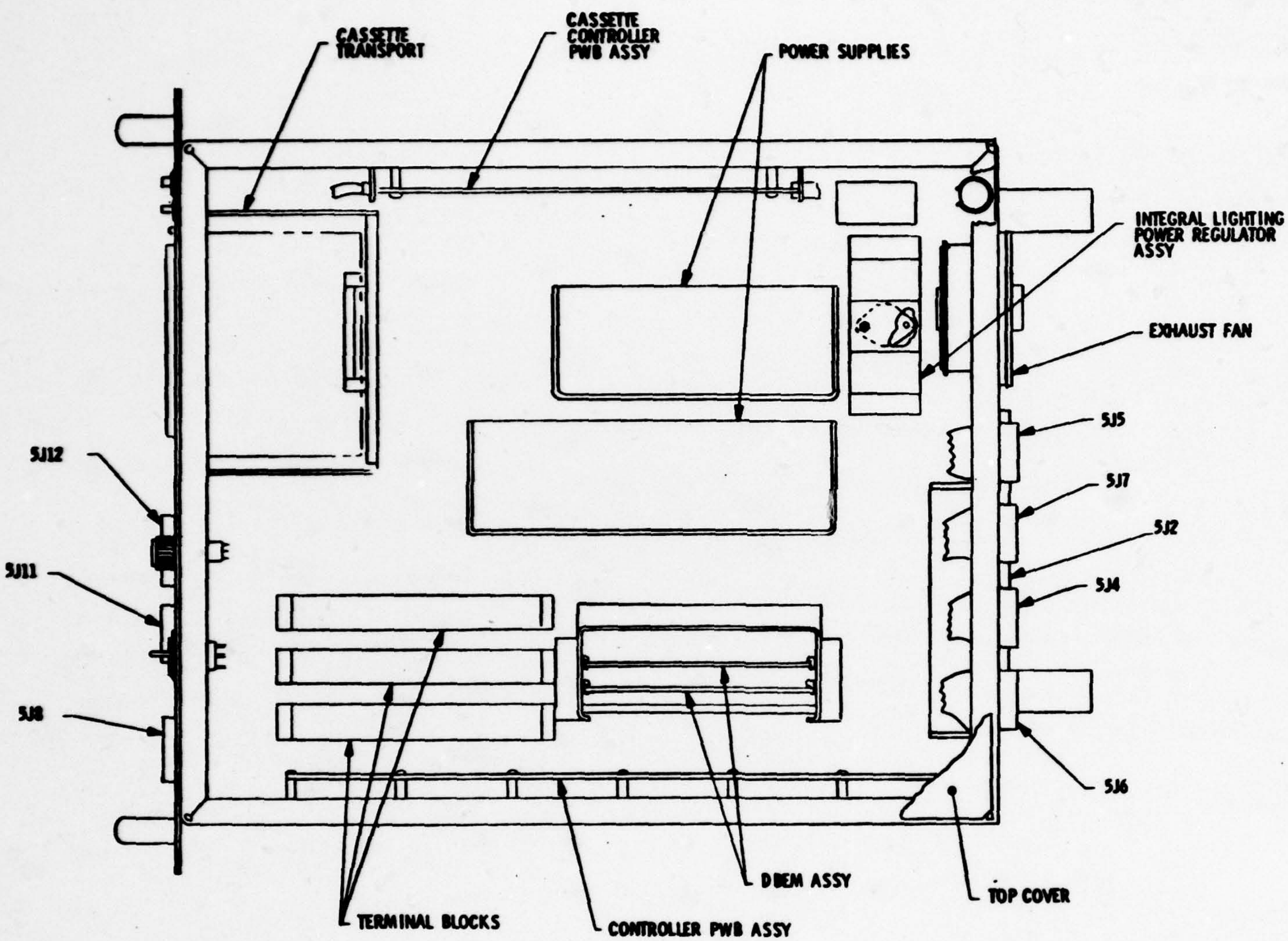


Figure 4.5.6. Top View Instrumental Interface Unit (without cover)

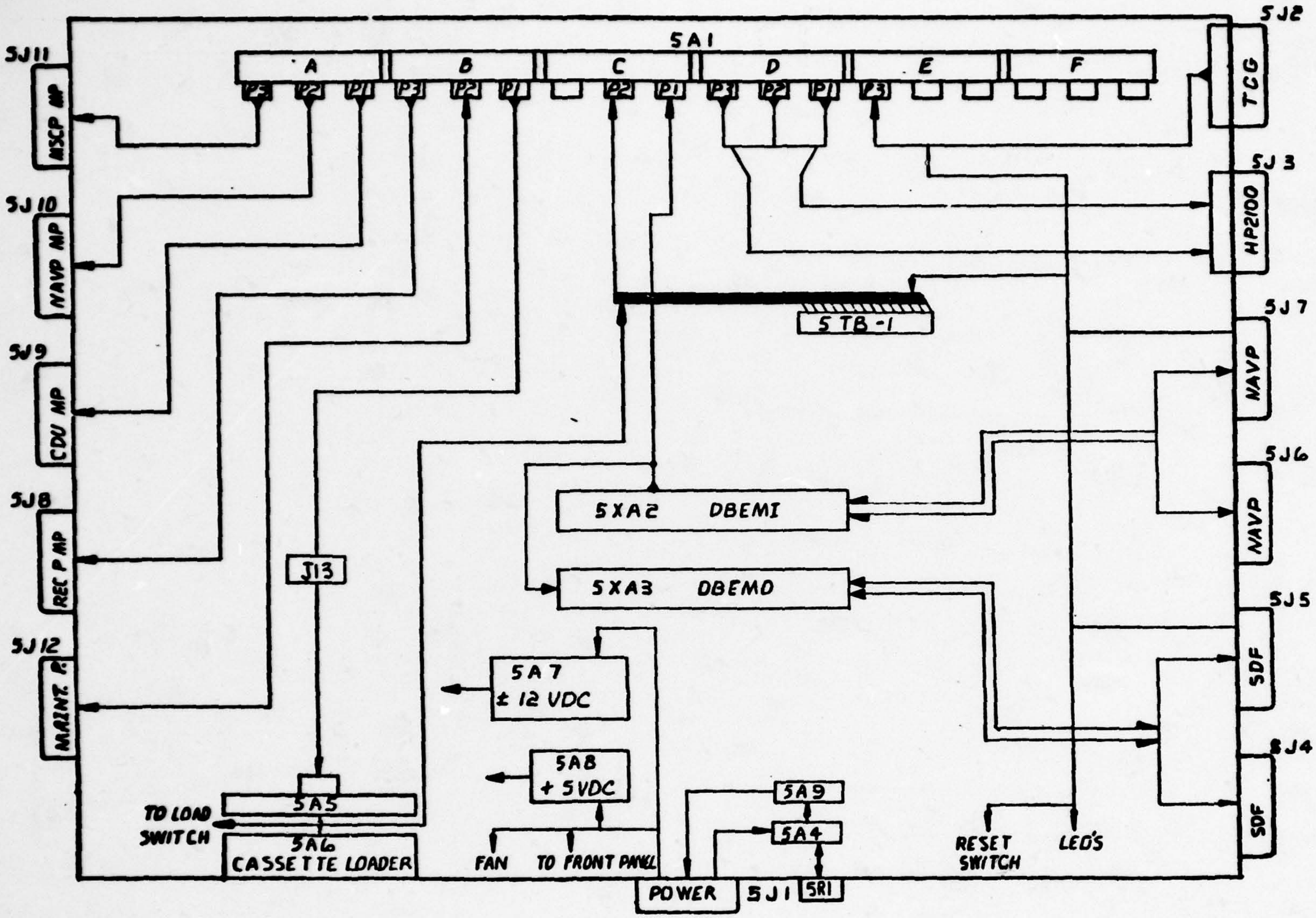


Figure 4.5.7. Instrumentation Interface Unit Layout

4.5.5 ELECTRICAL INTERFACE

I. Inputs

CATEGORY TYPE	SIGNAL NAME	CHARACTERISTIC	SOURCE
Power	115 VAC	400 Hz, 1-phase, 1 w	NAV-LRU
Power	28 VDC	2.1 a	NAV-LRU
Data	CW(10-15)	*TTL DR (status word)	HP2100
Data	DA(00-15)	TTL (IRIG time)	TCG
Logic	/DEMERIZ	TTL (to indicate memory error for data read)	NAV-LRU
Logic	/DESTRTIZ	TTL (to indicate that the DBEM is to initiate a memory cycle on the local I-Bus)	NAV-LRU
Logic	DEREADIZ	TTL (read/write command)	NAV-LRU,
Logic	/DEHOLDIZ	TTL (to indicate that the I-Bus access is to be retained once acquired)	NAV-LRU,
Logic	/DERESIZ	TTL (250nsec(min.) asynchronous low reset pulse)	NAV-LRU,
Logic	/DECOMPIZ	TTL (to indicate that the memory cycle initiated by DBEM is complete)	NAV-LRU,
Logic	/DATARDY	TTL (to indicate that the IRIG time is ready)	TCG
Logic	CCDF	TTL DR (to indicate that the next data block is ready to be read by the external instrumentation)	HP2100
Logic	DCDF	TTL DR (to indicate that the next data word is ready to be read by the external instrumentation)	HP2100
Logic	UPCRUINZ	TTL (CRU data input)	**MP(5)

Logic	/MPRSTZ	TTL (Maintenance panel reset)	MP(5)
Logic	/MPLOADZ	TTL (Load will be generated by the Maintenance Panel to cause the MPM to execute a non-maskable interrupt with memory address hex FFFC containing the trap vector)	MP(5)

*TTL DR = output of a SN54265J or equivalent

**MP(5) = NAV, RCVR, MSC, CDU(not used) and MP ports. The MP port is selectable to the other processor ports.

II. Outputs

CATEGORY	SIGNAL NAME	CHARACTERISTIC	DESTIN.
Data	BO(00-15)	TTL DR (data words of data block)	HP2100
Data	STS(1-6)	TTL DR (status-true tied high, complement tied low)	HP2100
Data	UPA(00-14)Z and /UPA(00-14)Z	TTL DR (processor address)	MP(5)
Logic	/DEMOROZ	TTL (to indicate parity error was detected for the data read from the local I-Bus)	NAV-LRU
Logic	/DECOMPOZ	TTL (to indicate that the memory cycle initiated by the remote device is complete)	NAV-LRU
Logic	/DERESOZ	TTL (250-nsec(min) asynchronous low reset pulse)	NAV-LRU

Logic	/DESTRTOZ	TTL (to indicate that the remote device is to initiate a memory cycle on the remote bus)	NAV-LRU
Logic	/DEREADOZ	TTL (read/write command)	NAV-LRU
Logic	/DEHOLDOZ	TTL (to indicate that the remote bus is to be retained once acquired)	NAV-LRU
Logic	/DATA 0	Tri-state (to freeze data in TCG)	TCG
Logic	/DATA 1	Tri-state (to select IRIG word 1)	TCG
Logic	/DATA 2	Tri-state (to select IRIG word 2)	TCG
Logic	/STROBE	Tri-state (to transfer IRIG time data)	TCG
Logic	CCDC	TTL DR (to indicate that the external instrumentation is ready to read the data block)	HP2100
Logic	DCDC	TTL DR (to indicate that the external instrumentation is ready to read the next data word)	HP2100
Logic	/UPMEMENZ	TTL (memory enable)	MP(5)
Logic	/UPENDCYZ	TTL (end of memory cycle)	MP(5)
Logic	UPIAGZ	TTL (instruction acquisition)	MP(5)
Logic	/UPRSTZ	TTL (Maintenance Panel reset)	MP(5)
Logic	UPCRUOUTZ	TTL (CRU data output)	MP(5)
Logic	UPCRUCLKZ	TTL (CRU clock)	MP(5)

III. Bi-directional

CATEGORY	SIGNAL NAME	CHARACTERISTIC	SOURCE/ DESTIN.
Data	DEDZ(00-15)	Tri-state TTL (data)	NAV-LRU
Data	DEAZ(05-19)	Tri-state TTL (address)	NAV-LRU

DAT

ILM