Array E System Description

This ATM describes the ALSEP Array E System. Its main purpose is to convey an understanding of the Power and Data Subsystems operation to a depth just above the circuit schematic level.

Written by:

A. Bedford
A. Bedford

Joe Kasser
J. Kasser

B C McLeod
B. MacLeod

D. J. Thomas
D. Thomas

Approved by:

D. Fithian
D. Fithian

ARRAY E SYSTEM DESCRIPTION

TABLE OF CONTENTS

ARRAY E SYSTEM DESCRIPTION

TABLE OF CONTENTS (CONT)

TABLE OF FIGURES

TABLE OF FIGURES (CONT)

TABLE OF FIGURES (CONT)

1.0 GENERAL

1.1 INTRODUCTION - ALSEP Array E

1.1.1 Purpose

The Apollo Lunar Surface Experiments Package (ALSEP) will gather scientific data on the physical properties of the lunar surface and environment. The ALSEP system is deployed on the lunar surface by the Apollo Astronauts and remains on the moon, sensing the lunar surface environment and transmitting the information gathered to earth for study.

1.1.2 Organization

The ALSEP System consists of a set of scientific instruments which measure the quantities of interest, a Central Station which communicates with earth to relay commands and data, and a thermoelectric generator powered by a radioactive thermal energy source.

1.1.3 Configuration - Stowed and Deployed

The ALSEP is ferried to the moon inside the Lunar Module, in the form of two subpackages as shown in Figures 1-1 and 1.2.

ARRAY E SUBPACKAGE NO. 1

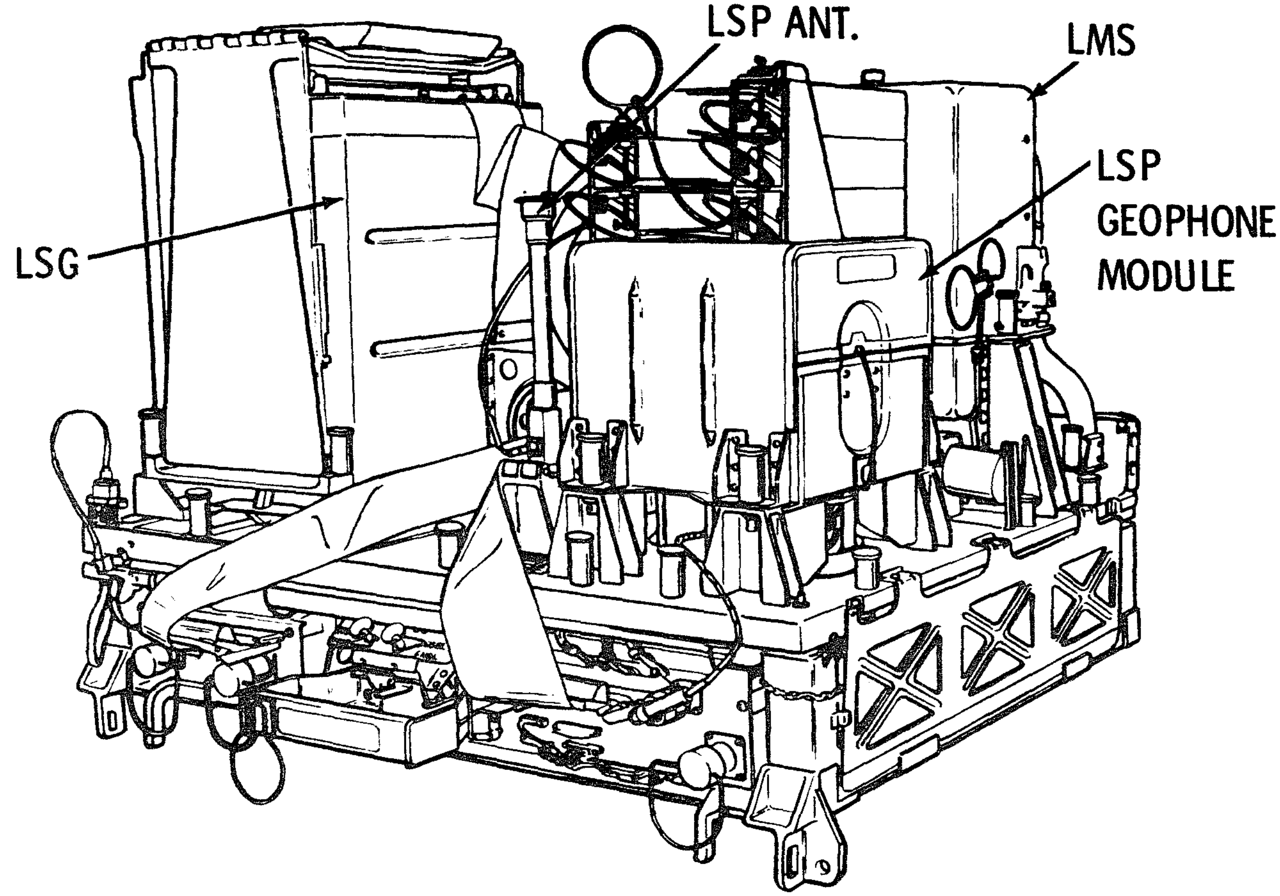
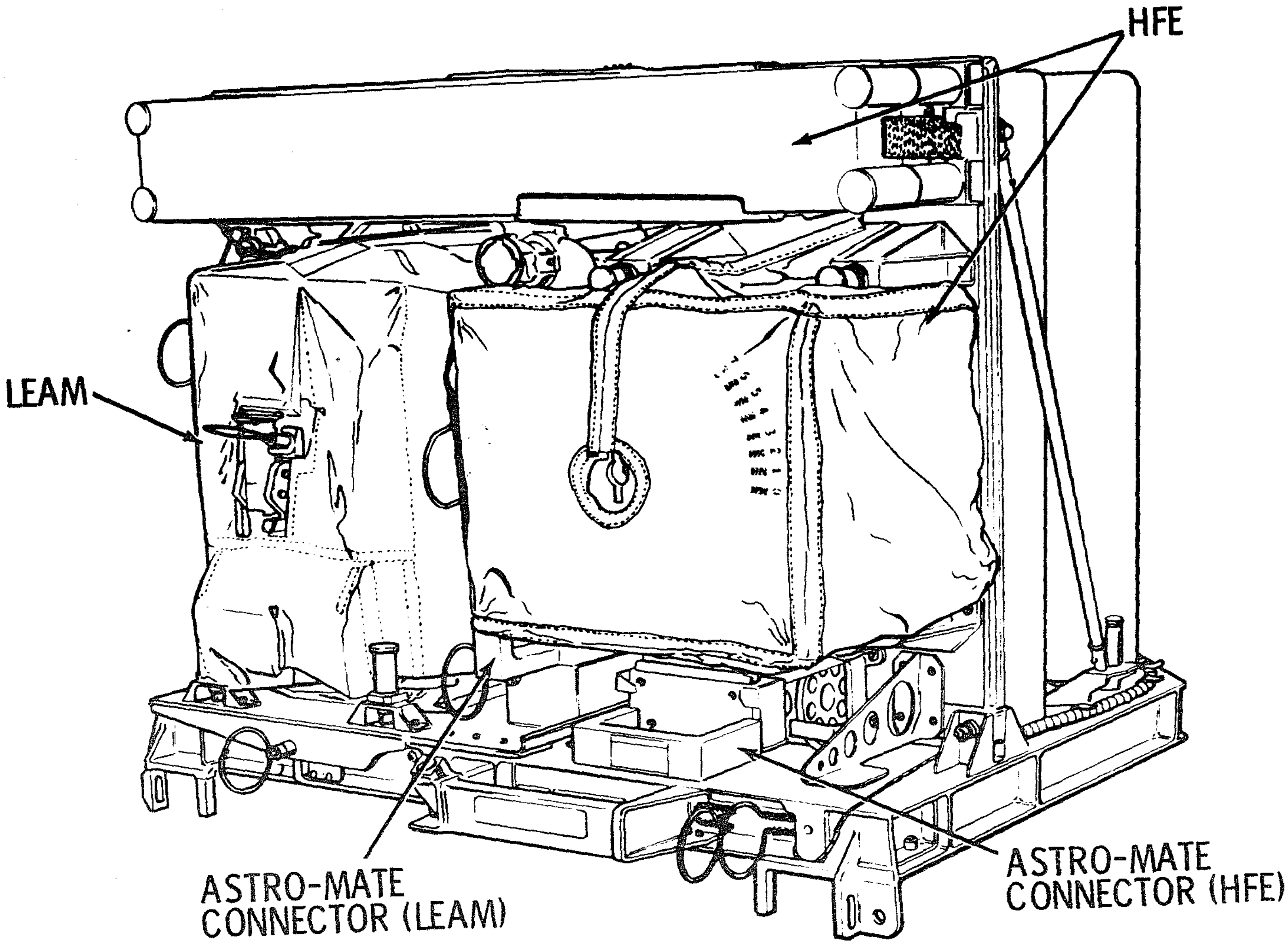


Figure 1-1

APR. 72 3270.1.9

ARRAY E SUBPACKAGE NO. 2



APR. 72 3270.1.11

Figure 1-2

1.1.3 (Cont)

As stowed for transport, subpackage No. 1 contains three of the experiment subsystems and the central station, while subpackage No. 2 contains the other two experiment subsystems and the Radioactive Thermoelectric Generator (RTG).

After the Astronauts have landed on the moon, the individual units are deployed on the lunar surface in a predetermined manner so that each unit causes a minimum of interference to any other unit. Each experiment subsystem is connected to the Central Station by means of flat cables, through which electrical power, control signals and information are conducted. The power source (RTG) is also separated from the Central Station and connected to it by power cables. In the case of the RTG, the physical separation is necessary to reduce the effect of the waste heat on the Central Station.

Two of the experiment subsystems have external sensors and signal generators. The probes for the Heat Flow Experiment (HFE) are located close to the HFE electronics package and connected by cables. The Lunar Seismic Profiling Experiment (LSPE) uses remotely located explosive packages as signal generators and several geophones as signal detectors. Most of the LSPE electronics is in a package located in the Central Station. The geophones are connected by cables to the LSPE Central Station Electronics package (LSPE CSE). The explosive packages are distant from ALSEP and activation by radio is required.

A resulting array is shown diagrammatically in Figure 1-3. The base of subpackage #1 contains the Data Subsystem. During deployment the experiment packages are removed and the screens and reflectors which control the Central Station temperature during the lunar day are erected. The antenna used to communicate with earth is installed on the fixed antenna mast. The Data Subsystem used to relay commands and data between earth and experiments is located within a thermal bag in the base. The LSPE CSE is also located within this thermal bag. The base of subpackage No. 2 serves as a mounting surface for the RTG.

1.2 FUNCTIONS OF THE MAJOR SUBSYSTEMS

1.2.1 Protection from the Lunar Environment

The electronic equipment used in ALSEP would not survive if it were required to experience the full range of lunar temperatures. The Central Station and each of the experiment subsystems has a carefully designed thermal control system. During the lunar day passive thermal control is achieved by sets of screens and reflectors which shade the thermal plates from the sun and allow them to radiate heat into deep space.

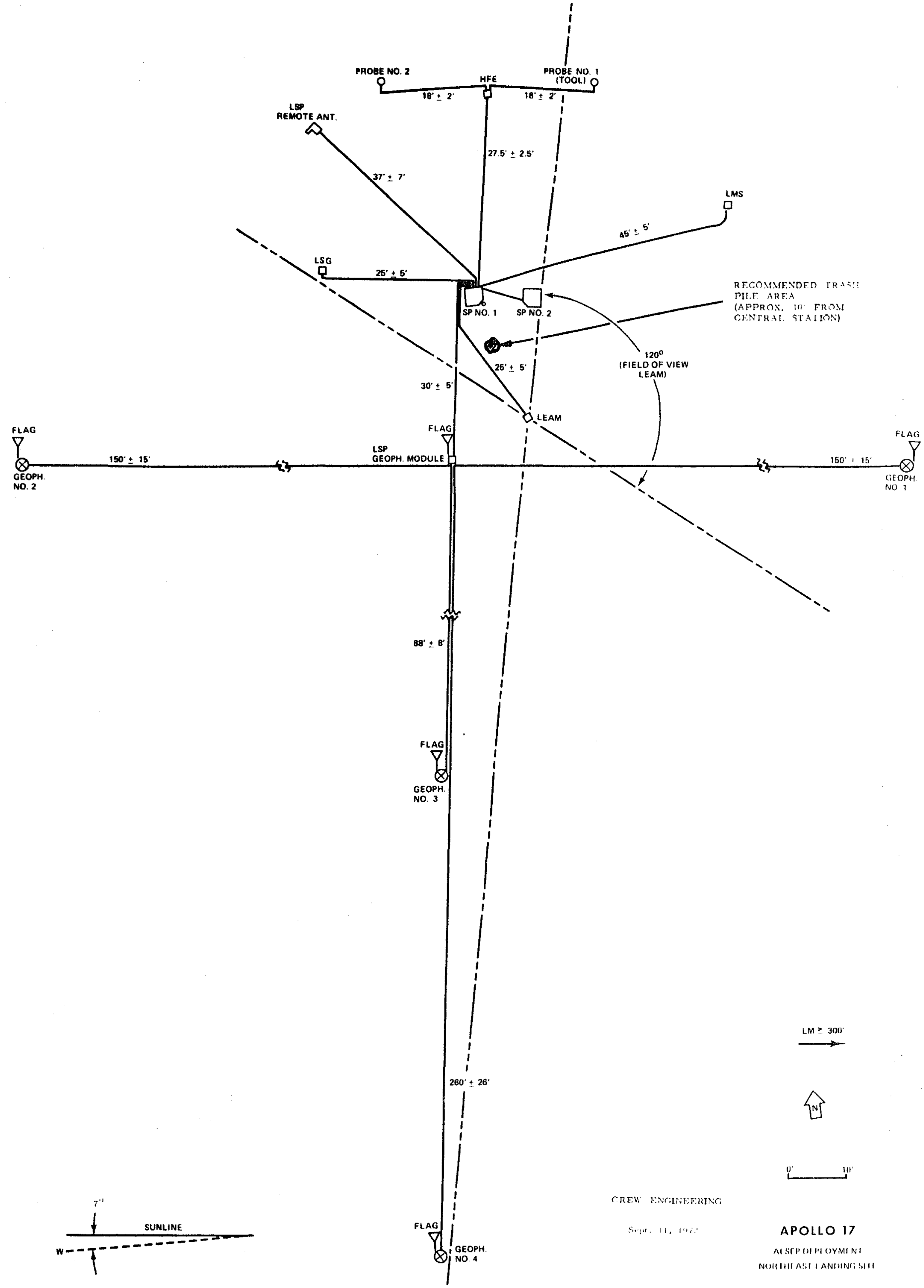

PROBE NO. 2
HFE
PROBE NO. 1 (TOOL)
18' ± 2'
18' ± 2'
LSP REMOTE ANT.
27.5' ± 2.5'
37' ± 7'
LMS
45' ± 5'
LSG
25' ± 5'
SP NO. 1
SP NO. 2
RECOMMENDED TRASH PILE AREA (APPROX. 10' FROM CENTRAL STATION)
120°
(FIELD OF VIEW LEAM)
26' ± 5'
30' ± 5'
LEAM
FLAG
FLAG
FLAG
150' ± 15'
LSP GEOPH. MODULE
150' ± 15'
GEOPH. NO. 2
GEOPH. NO. 1
88' ± 8'
FLAG
GEOPH. NO. 3
260' ± 26'
LM ≥ 300'
N
0'
10'
7°
SUNLINE
W
FLAG
GEOPH. NO. 4
CREW ENGINEERING
Sept. 11, 1972
APOLLO 17
ALSEP DEPLOYMENT
NORTHEAST LANDING SITE

Figure 1-3

1.2.1 (Cont.)

Heat flow into and out of the electronic compartment is minimized by enclosing each within a thermal bag. During the lunar night the heat loss is replaced by the power dissipated in the electronics, plus heaters within each thermal bag. Thermal control is a major function of ALSEP. Details for the Central Station are discussed below in the section entitled "Structural/Thermal Subsystem."

1.2.2 Gathering of Scientific Information

As previously mentioned, the purpose of ALSEP is to increase scientific knowledge. The LSPE and HFE experiments will obtain data on seismic wave propagation and heat flow near the lunar surface. The Lunar Surface Gravimeter (LSG) will measure gravitational fields and the effects of gravity waves at the lunar surface. The Lunar Mass Spectrometer (LMS) and the Lunar Ejecta and Meteorite (LEAM) experiments will increase our knowledge of the lunar atmosphere and the particles moving through it. A description of the instruments used to sense and measure the physical parameters and variables is given below in the Section 5, "Array 'E' Scientific Instruments".

1.2.3 Communication with Earth

The third major ALSEP function is that of communication. The data gathered by the scientific instruments must be transmitted to earth to be of any value.

Although a completely automatic science station may be possible, the functioning of ALSEP is complex, with many modes of operation. Design is simplified and operation becomes more flexible by having the system responsive to command from earth. A description of the information content of the downlink and uplink transmissions is given in the paragraphs which follow, and a description of the hardware required to implement these functions is given in the section entitled "Data Subsystem".

1.2.4 Powering the ALSEP

The electrical energy required to operate ALSEP, to sense the physical environment, to process the information and to heat the electronic equipment during the lunar night is obtained from a self-contained energy source. A description of the equipment which performs this function is given in the section entitled "Power Subsystem".

1.3 COMPONENT LOCATION AND FUNCTIONS

1.3.1 Component Locations

The components located within the Central Station thermal bag are shown in Figure 1-4. All of the Data Subsystem, except the antenna, antenna aiming mechanism and coaxial cable to the antenna, is mounted on a thermal plate within the thermal bag. The LSPE CSE, which is part of one of the experiment subsystems, is located in the Central Station. The Power Conditioning Unit (PCU), a part of the Power Subsystem, is also located within the Central Station. The Structural/Thermal Subsystem and antenna are parts of the Central Station but are not shown in Figure 1-4.

The power source, the RTG, is located on the base plate of subpackage No. 2, which is deployed a short distance from the Central Station, as indicated by Figure 1-3.

All components of the experiment subsystems, except for the LSPE CSE, are deployed as shown by Figure 1-3.

1.3.2 Component Functions

A block diagram of the Array E Power and Data Subsystems is shown in Figure 1-5. A brief description of the functions of major components is tabulated below.

Component	Function
The Radio Isotope Thermo-electric Generator (RTG)	Supplies approximately 74 watts of raw electrical power at 16 VDC
Power Conditioning Unit (PCU)	- Converts raw electrical power to regulated +12V, -12V, +5V and +29V supplies. - Provides constant-voltage load to the RTG at all times - Automatically distributes reserve power to reduce the temperature swing of the thermal plate.
Power Distribution Unit (PDU)	Controls the switching of the regulated supplies to the Central Station components and experiments.
Power Dissipation Module (PDM)	Allows the dissipation of excess power outside the Central Station during the Lunar Day.

ELECTRONICS COMPARTMENT

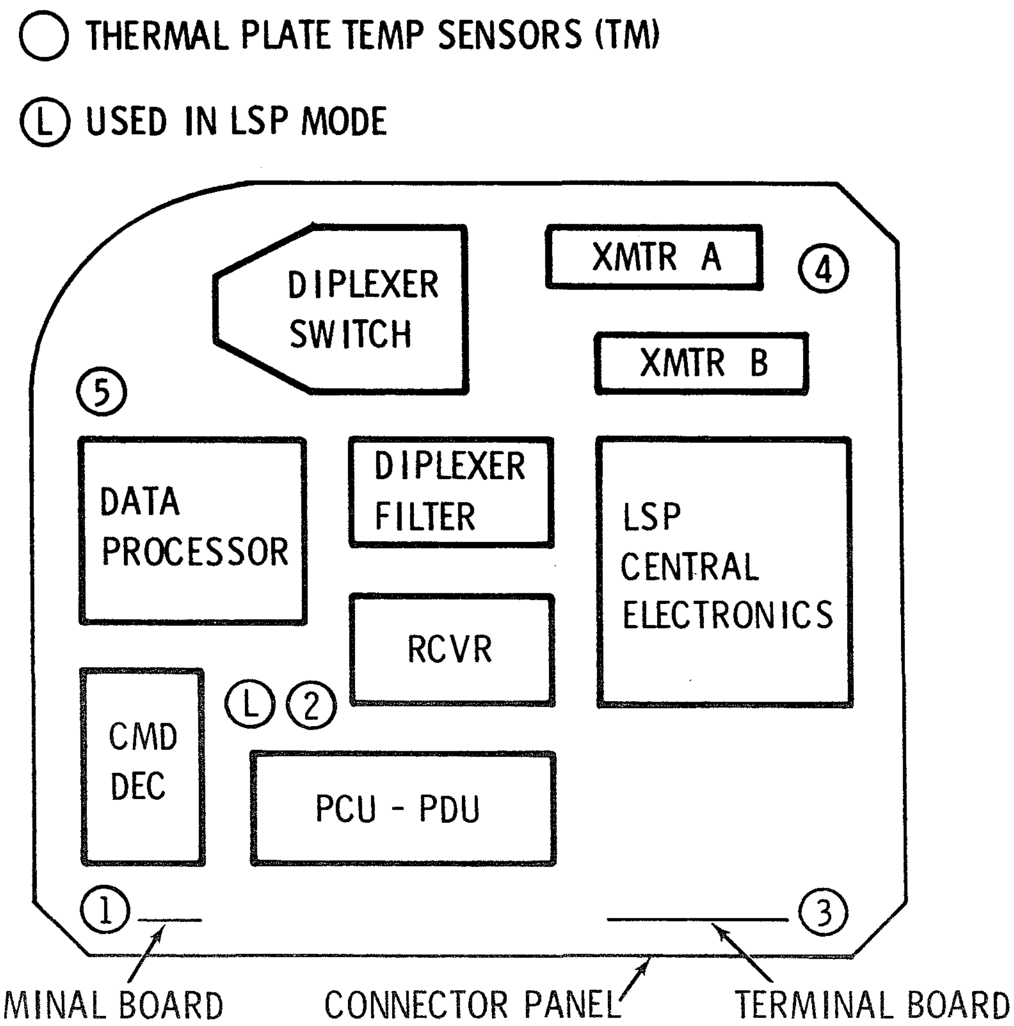


Figure 1-4

MAY 72 3270.2.10

POWER AND DATA FUNCTIONS

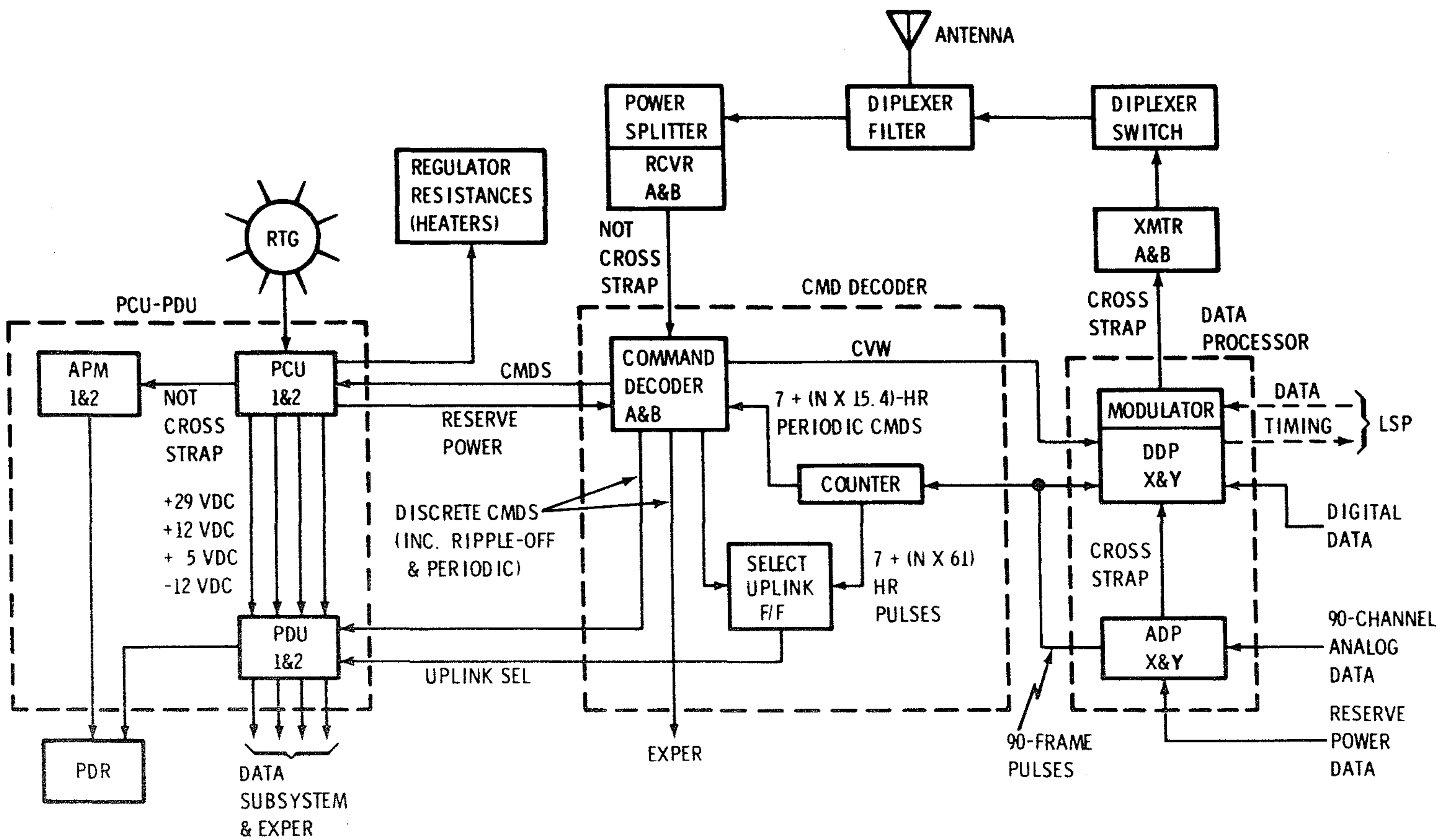


Figure 1-5

MAY 72 3270.2.2

1.3.2 (Cont.)

Antenna	Receives and radiates "S"-Band signals
Diplexer Filter	Connects the receiver input and the transmitter output to the antenna with the required receiver/transmitter isolation.
Command Receiver	Receives and demodulates the Earth-to-Moon Uplink signal
Command Decoder	Decodes demodulated signals and issues commands to the system.
Data Processor	Provides basic timing for the Experiments and the downlink; collects and formats scientific data from the Experiments; collects and digitizes the analog housekeeping data; supplies signal conditioning to analog lines as required.
Transmitter	Generates the Moon-to-Earth downlink carrier
Diplexer Switch	Connects one or the other of the redundant transmitters to the antenna.
Miscellaneous	
a. Central Station Regulator Resistances	- Dissipates regulator power within the Central Station to maintain the thermal plate temperatures during the lunar night.
b. Astronaut Switches	- S1 allows the Astronaut to select the backup Power Conditioner if required. S2 disables the LSPE during the deployment sequence.
c. Temperature Sensors	- Supply the temperature data of selected points in the Central Station and Experiments

1.4 UPLINK CHANNEL

1.4.1 ALSEP Components

The ALSEP components used in receiving and decoding the uplink channel transmissions are the Antenna, Diplexer Filter, the Command Receiver and the Command Decoder. The Command Receiver contains two identical, fully redundant receivers, only one of which is powered at a time. The Command Decoder likewise contains two identical, fully redundant decoders only one of which is powered at a time. The receiver being powered demodulates MSFN ALSEP transmissions and its output is coupled to the decoder being powered. If ALSEP Array E was addressed in the transmission the decoder will output a pulse on the appropriate command line. One receiver-decoder combination is known as Uplink A and the other is known as Uplink B.

The Command Decoder also contains a non-redundant section which automatically generates commands needed for the local control functions, but this section is not a part of the uplink. Figure 1-6 shows the Array E Uplink.

1.4.2 Command Format

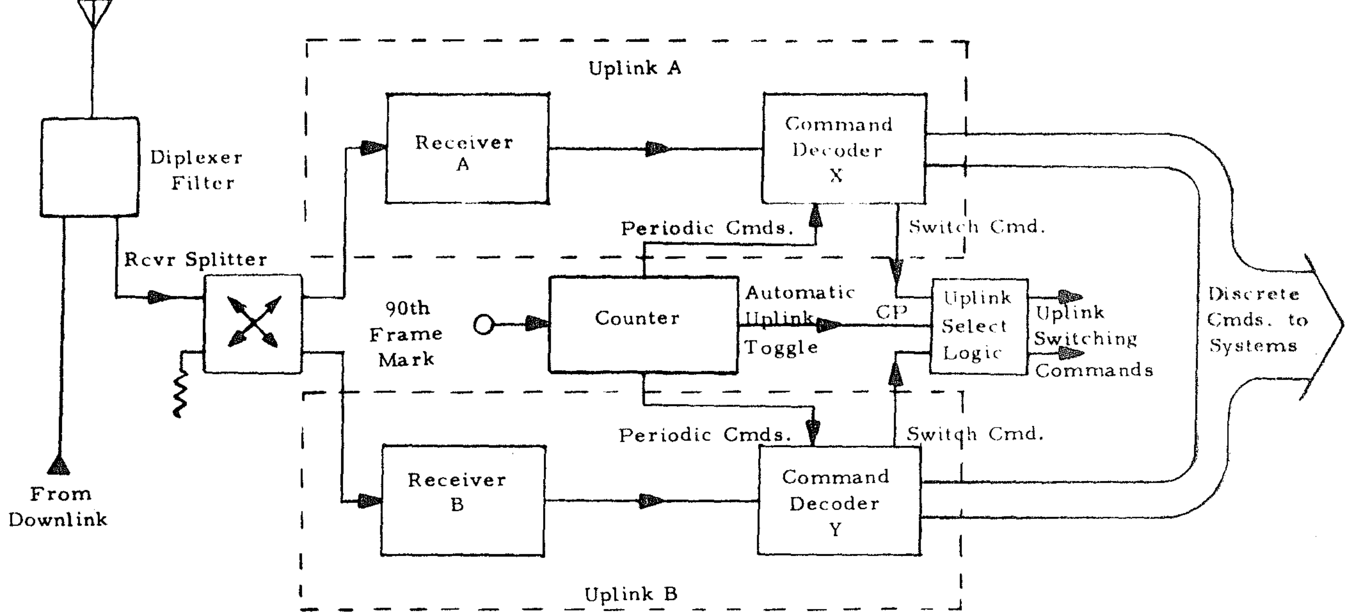
As is the case for earlier ALSEPS, the format for uplink transmissions is a seven bit address, followed by the complement of the seven bit command, followed by the seven bit command, together with leader and trailer bits. The address for Array E is octal 151. Since the two redundant decoders are identical in design and only one is powered, only one address is used.

1.5 DOWNLINK CHANNEL

1.5.1 ALSEP Components

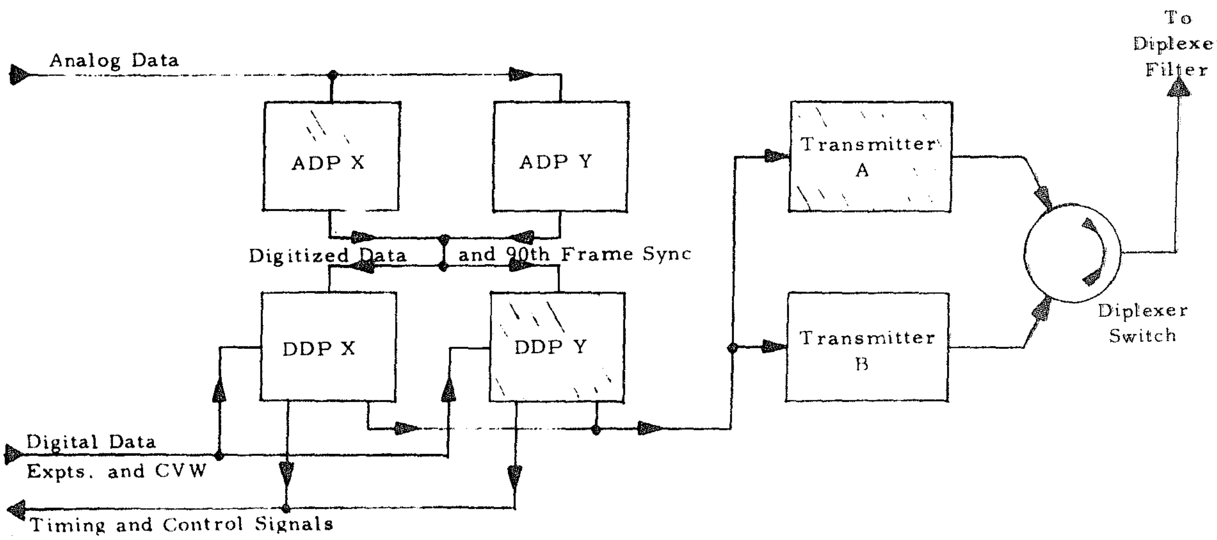
The ALSEP Components used in encoding and transmitting the information about the lunar environment and about ALSEP itself are the Antenna, Diplexer Filter, Diplexer Switch, Transmitter and the Data Processor. The Antenna and Diplexer Filter are shared with Uplink.

The information about ALSEP - status, temperature, voltage levels and reserve power - is known as Housekeeping data. Most of the Housekeeping Data is in the form of analog signals. The Data Processor contains two fully redundant analog sections, known as Analog Data Processor X, (ADP X) and ADP Y to multiplex and convert this information into serial digital data. Only one of the ADP's is powered at any time.



Note: Only Uplink A or Uplink B powered at any one time

Figure 1-6 Array E Uplink



Note: Power to energise any combination of ADP, DDP and Transmitter may be selected by ground command.

Figure 1-7 Array E Downlink

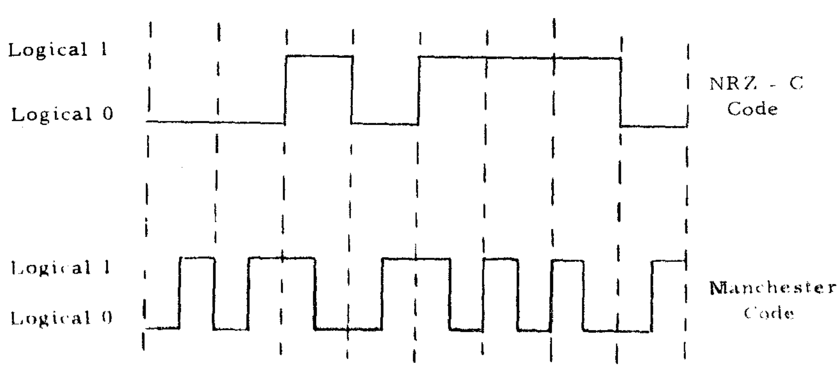


Figure 1-8 Manchester Encoding

1.5.1 (Cont.)

The information from the experiment subsystems is available on demand by the Data Processor as serial digital data. The LSG, LEAM, LMS and HFE experiments can operate simultaneously, time sharing the downlink. The Data Processor contains two fully redundant digital sections, known as Digital Data Processor X (DDP X) and DDP Y to format and encode the housekeeping data and data from these four experiments. Only one DDP is powered at any one time. Figure 1-7 shows the Array E downlink.

When the LSPE subsystem is being operated, the outputs of its sensors must be sampled at a comparatively higher rate to avoid loss of information. Since ALSEP does not have a data storage capability, the downlink data in the LSPE mode consists of LSPE data only, plus selected housekeeping information. In this mode, multiplexing, digitizing and formatting is performed within the LSPE CSE, the Data Processor being used to generate the clocks required, to accept and encode the serial output of the LSPE, and to interface with the Transmitter.

The Data Processor also contains non-redundant circuitry for input signal conditioning and for rise time control of the data demand lines and other timing signals.

Either ADP may be used with either DDP and either or both Transmitters may be powered on or off. If both transmitters are turned on the output of Transmitter A is routed into a dummy load.

1.5.2 Downlink Data Formats

The downlink data is transmitted in one of two formats each having two possible bit rates.

In both data formats the data is transmitted in the form of a Manchester coded or a split phase modulated digital waveform.

Manchester encoding of digital data is shown in Figure 1-8.

The two data formats are as follows:

1.5.2.1 DP Data Format. The Data Processor within the Central Station Data Subsystem formats the Science and Engineering Data from the Central Station and all Experiment Subsystems except the LSPE.

The Data Processor formats the data collected from the ALSEP into a telemetry frame of 64, ten-bit words as shown in Figure 1-9. The Data Processor is constructed so that with the exception of Words 1, 2 and 3 (the Control Word), the allocation of the remainder of the data words in the telemetry frame is flexible. The words are assignable to the Experiments or to the CVW and engineering data by means of a hard wired printed circuit matrix; subject only to the following limits on the total number of words per experiment.

Experiment	Max. No. of Words Assignable
#1	60
#2	10
#3	10
#4	10
#5	10
Housekeeping Data	1
Reserve Current Data	1
Command Verification Word (CVW)	1

Control Word. The bit assignments for the control word are shown in Figure 1-10. A 22-bit synchronization word is used, consisting of an 11 bit Barker Code and its complement. The next 7 bits (23-29) provide frame identification for one through ninety frames for correlation of the analog multiplexer data (Housekeeping Channel). Each frame is identified by a unique binary number beginning with binary 0000001 for frame number one and increasing one binary count per frame up to the 89th frame which is identified by binary 1011001. The 90th frame is identified by binary 0000000. These 7 bits are known as the Incrementing Sync Pattern (ISP).

The 30th bit provides "normal bit rate" or "slow bit rate" information during the first two frames of the 90 frame sequence. The presence of a digital one in the first frame and a digital zero in the second frame indicates the "normal bit rate" of operation. The presence of a digital zero in the first frame and a digital one in the second frame indicates the "slow bit rate" of operation. The 30th bit of frames three, four, and give is used to identify the ALSEP. The most significant bit is in the third frame with the next two bits being in the fourth and fifth sequentially. The ALSEP Array E ID number is in the binary form 100. The 30th bit of frame six through 90 contains a digital zero.

DOWNLINK DATA FORMAT

- DOWNLINK FREQUENCY 2275.5 MHz
- NORMAL OPERATION: DATA PROCESSOR (DP) FORMAT AT 1060 BITS PER SECOND IS 64-WORD FRAME OF 10-BIT WORDS (640 BITS PER FRAME)
- THE SAME DP FORMAT AT 530 BITS PER SECOND CAN BE SELECTED BY COMMAND
- LSP FORMAT, SELECTED BY COMMAND, IS COMPLETELY DIFFERENT (1800 BITS PER FRAME) AT EITHER 3533.3 BITS PER SECOND (NORMAL) OR 1060 BITS PER SECOND (LOW)
- ALL DATA TRANSMITTED WITH MOST SIGNIFICANT BIT (MSB) FIRST
- DATA PROCESSOR FORMAT:

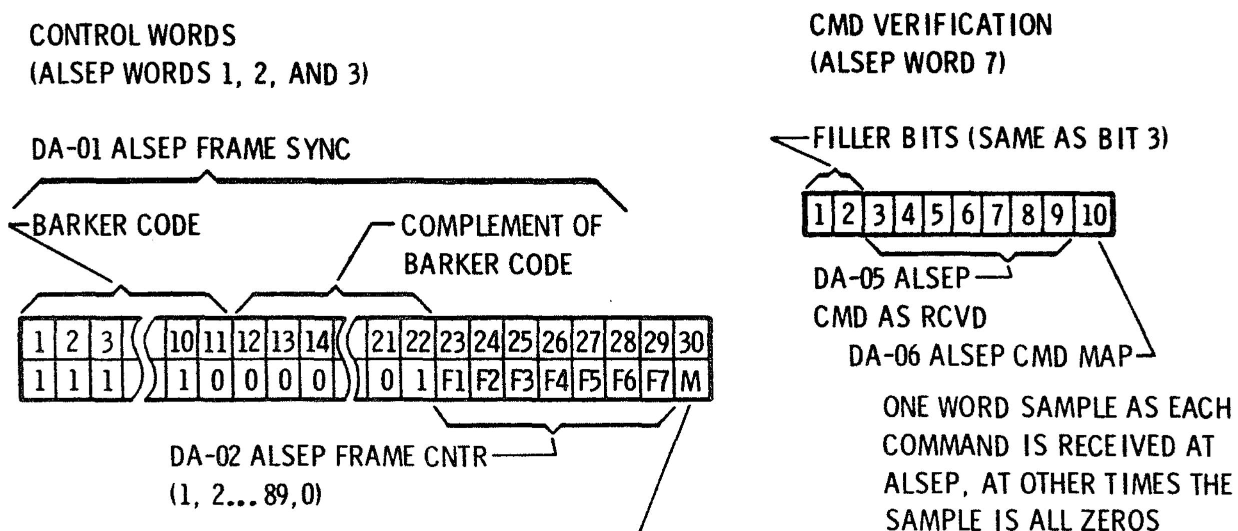
1 X	2 X	3 X	4 G	5 A	6 G	7 CV	8 G
9 B	10 G	11 B	12 G	13 B	14 G	15 B	16 G
17 A	18 G	19 A	20 G	21 A	22 G	23 HF	24 G
25 G	26 G	27 G	28 G	29 G	30 G	31 J	32 G
33 HK	34 G	35 G	36 G	37 G	38 G	39 J	40 G
41 B	42 G	43 B	44 G	45 B	46 G	47 B	48 G
49 B	50 G	51 B	52 G	53 B	54 G	55 B	56 G
57 B	58 G	59 B	60 G	61 B	62 G	63 RP	64 G

LEGEND:

- X CONTROL WORD
- A LUNAR MASS SPECTROMETER EXPERIMENT
- CV COMMAND VERIFICATION WORD
- G LUNAR SURFACE GRAVIMETER EXPERIMENT
- HF HEAT FLOW EXPERIMENT
- J LUNAR EJECTA AND METEORITE EXPERIMENT
- HK HOUSEKEEPING (ENGINEERING) DATA
- RP RESERVE POWER
- B BLANK

Figure 1-9

CONTROL WORDS AND COMMAND VERIFICATION



MODE BIT, DEFINED AS FOLLOWS:

FRAME	MODE BIT	MEANING	
1	1	NORMAL BIT RATE	DA-03 ALSEP BIT RT ID
2	1	LOW BIT RATE	
3	X MSB	DATA PROC ID NO.	DA-04 ALSEP ID: 1 0 0 — DECIMAL 4 FOR APOLLO 17 ALSEP
4	X		
5	X		
6	NONE	NONE	
.	"	"	
.	"	"	
.	"	"	
89	"	"	
0	NONE	NONE	

Figure 1-10

1.5.2.1 (Cont.)

Housekeeping Word. Ninety channels of engineering data are submultiplexed into Word 33 of the telemetry frame. This word is known as the "Housekeeping Word" and the 90 channels are known as the "Housekeeping Channels".

The Housekeeping data is sampled consecutively so that each channel is read out once in every 90 telemetry frames.

The engineering data input to each channel is represented as an analog voltage between the limits of 0 V and +5 Vdc.

Reserve Current Word. The voltage analog of the total current flowing in the PCU Regulator and APM circuits is sampled and digitized once per frame, and inserted in Word 63.

Since the PCU input voltage is essentially constant, this current may be used as an indication of reserve power. (As a backup the same quantity is transmitted in Channel 30 of Housekeeping Word 33.)

Command Verification Word (CVW). Following the receipt of a Command Message, the CVW is transmitted back to the MSFN in word 7 of the telemetry frame. The format of the CVW is as follows: Bits 1 and 2 are the same as the MSB of the Command. Bits 3 through 9 are a repeat of the Command Word, MSB first. Bit 10 is the parity bit, or Message Acceptance Pulse (MAP); a digital '1' indicates parity, i.e. that the command has been accepted by the ALSEP system.

1.5.2.2 LSPE Data Format. The LSP Experiment formats its own data, together with six selected Central Station Analog Data Channels, into a NRZ-C bit stream. The LSP Data is Manchester Encoded in the Central Station Data Subsystem. All other Data Lines are inhibited while the ALSEP is operating in the "LSPE Mode."

LSPE Data. The LSPE formats 16 channels of data, and some status and mode information, into a main frame that consists of three subframes. Each subframe contains 20 30-bit words, as shown in Figure 1-11.

All three subframes are similar in format, but contain different housekeeping and status channels.

<table>
<tr><th rowspan="2">LSP Subframe</th><th rowspan="2">LSP Word</th><th colspan="30">LSP BIT POSITION</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th></tr>
<tr><td>1</td><td>1</td><td colspan="10">DP-17</td><td colspan="5">DP-01</td><td colspan="5">DP-06</td><td colspan="5">DP-11</td><td colspan="5">DP-16</td></tr>
<tr><td>"</td><td>2</td><td colspan="7">DP-01</td><td colspan="7">DP-06</td><td colspan="7">DP-11</td><td colspan="7">DP-16</td><td>DP-18</td><td>DP-19</td></tr>
<tr><td>"</td><td>3</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-20</td></tr>
<tr><td>"</td><td>4</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-02</td></tr>
<tr><td>"</td><td>5</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>6</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>7</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>8</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-03</td></tr>
<tr><td>"</td><td>9</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>10</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>11</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>12</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">AE-24</td></tr>
<tr><td>"</td><td>13</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>14</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>15</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>16</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-05</td></tr>
<tr><td>"</td><td>17</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>18</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>19</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>20</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-21</td></tr>
<tr><td>2</td><td>1</td><td colspan="10">DP-17</td><td colspan="5">DP-01</td><td colspan="5">DP-06</td><td colspan="5">DP-11</td><td colspan="5">DP-16</td></tr>
<tr><td>"</td><td>2</td><td colspan="7">DP-01</td><td colspan="7">DP-06</td><td colspan="7">DP-11</td><td colspan="7">DP-16</td><td>DP-18</td><td>DP-19</td></tr>
<tr><td>"</td><td>3</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">Spare</td></tr>
<tr><td>"</td><td>4</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">AE-03</td></tr>
<tr><td>"</td><td>5</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>6</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>7</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>8</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">AT-16</td></tr>
<tr><td>"</td><td>9</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>10</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>11</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>12</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-10</td></tr>
<tr><td>"</td><td>13</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>14</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>15</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>16</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">AE-04</td></tr>
<tr><td>"</td><td>17</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>18</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>19</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>20</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-21</td></tr>
<tr><td>3</td><td>1</td><td colspan="10">DP-17</td><td colspan="5">DP-01</td><td colspan="5">DP-06</td><td colspan="5">DP-11</td><td colspan="5">DP-16</td></tr>
<tr><td>"</td><td>2</td><td colspan="7">DP-01</td><td colspan="7">DP-06</td><td colspan="7">DP-11</td><td colspan="7">DP-16</td><td>DP-18</td><td>DP-19</td></tr>
<tr><td>"</td><td>3</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">Spare</td></tr>
<tr><td>"</td><td>4</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">AB-04</td></tr>
<tr><td>"</td><td>5</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>6</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>7</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>8</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-14</td></tr>
<tr><td>"</td><td>9</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>10</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>11</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>12</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">Spare</td></tr>
<tr><td>"</td><td>13</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>14</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>15</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>16</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">AB-05</td></tr>
<tr><td>"</td><td>17</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>18</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>19</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">"</td></tr>
<tr><td>"</td><td>20</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="7">"</td><td colspan="2">DP-21</td></tr>
</table>

Notes

30 LSP Bits = 1 LSP Word
20 LSP Words = 1 LSP Subframe
3 Subframes = 1 LSP Frame

When the LSP transmitter is commanded to "RF Fire Pulse ON", item DP-20 (RF Fire Pulses Status) will be 11 in LSP Subframe 1 in only one subframe out of 174 subframes (29.55 seconds) which is coincident with the actual RF transmitter pulse train.

Figure 1-11 LSPE Data Format

1.5.2.2 (Cont.)

Word 1 contains a 10 bit synchronization Pattern and four 5 bit geophone samples, each geophone being sampled once per word.

The remaining nineteen words in each subframe each contain four 7 bit geophone channels (each geophone channel being sampled once per word) and 2 bits of engineering data.

In Word 2 the engineering data contains information on the calibration pulse and geophone amplifier gain status.

In Word 3 of Subframe 1 only, the engineering data contains information on the LSPE Transmitter Pulse Status. In Subframe 2 and 3 no engineering information is present in these two bits.

In Words 4 thru 19, the engineering data consists of 12 engineering data channels of eight bits each; the data being submultiplexed into the frame format at the rate of two bits per subframe word.

In Word 20, the engineering data consists of the subframe I.D. number.

The LSPE Format thus contains 4 geophone channels and 12 engineering channels of data. The LSP itself has only five engineering channels, the remaining seven being fed to the LSP from the Central Station. (One of the seven Central Station channels is an unused spare.)

The Central Station engineering data in the LSP telemetry frame provides critical status information on the Central Station during the period of LSPE operation.

The following Central Station Analog Engineering data are present in the downlink LSPE telemetry frame:

1. Reserve Current
2. PC #1 Input Voltage
3. Input Current
4. Experiment 1 and 2 Power Status
5. Experiments 3 and 4 Power Status
6. Thermal Plate Temperature (from point adjacent to the Thermal Plate #2 Temperature Sensor).

1.5.3 Housekeeping Channels Allocation Summary

The Housekeeping Engineering Data Channels in the Array are assigned as follows:

Structure	14
PCU	16
Uplink	10
PDU	2
PDM	2
Transmitter	8
Data Processor	6
RTG	6
Experiments	26
TOTAL	90

The type and location of each sensor generating housekeeping data for the above 90 channels are outlined below.

Structure

Thermal Plate Temperatures. Five sensors monitoring the thermal plate temperature are located approximately at the center and at the corners of the thermal plate. The range of measurement is from -50°F to +210°F.

Primary Structure and Sunshield Temperatures. Seven sensors monitor the Central Station external structure temperatures and have the range of measurement -300°F to +300°F.

Thermal Bag Temperatures. Two sensors, one inside, one outside monitor the temperatures of the thermal bag. The measurement range is -300°F to +300°F in each case.

1.5.3 (Cont.)

PCU

PCU Converter Input Current. This channel monitors the input current to the PCU.

PCU Converter Input Voltage. Two channels each monitoring the RTG +16 Volt line one sensor being located at the output of each redundant PC input filter.

PCU Automatic Changeover Sensor Status. This channel monitors the status of the relay that switches the output of the PC Automatic changeover circuit between PC #1 or PC #2, so as to change PCs in the event of a PC failure.

PC Output Voltages. Four channels monitoring the +29V, +12V, +5V, and -12V Power Supply Lines. The supply voltage from both halves of the redundant PCU are diode OR'd together in the PDU. The signal conditioning circuitry is provided in the Data Processor.

PCU APM Current. Two channels each monitoring the current in one APM 30 watt dump resistor. The signal is the voltage developed across the resistor, and it is approximately proportional to the total power in the APM circuit.

PCU APM Temperature. Two channels each monitoring the temperature of one APM Regulator transistor within a range of -25°F to +210°F.

PCU APM Status. Monitors the Enabled/Disabled status of each APM.

PCU Regulator Temperatues. Two channels each monitoring the temperature of one regulator transistor in the redundant PCU. The range of measurement is -25°F to +210°F.

Uplink

Receiver Command Subcarrier Status. Two channels each monitoring the presence or absence of the 1kHz signal in one of the redundant halves of the receiver.

Receiver Case Temperature. Monitors the receiver case temperature; only active in uplink A.

1.5.3 (Cont)

Receiver Input Signal (AGC) Level. Two channels each monitoring the carrier level in one of the redundant sides of the receiver.

Command Decoder Data Demodulator Temperature. Two channels each monitoring the temperature of one of the voltage controlled oscillator cards in the command decoder within a range of -50°F to +210°F.

Command Decoder Periodic Command Status. Monitors the status of the Enable/Inhibit circuit for the periodic calibration command pulses.

Uplink A/B and Power Routing Status. Monitors the Uplink status and the position of the redundant Power Routing Relay of the uplink. The two uplinks, uplink A and uplink B can each be powered through relay position X or relay position W. The circuitry is fully described in Section 4.1.3.

Uplink Switch Delay Status. Monitors the status of the Command Decoder filp-flop which enables or inhibits the automatic "switch uplink" pulse.

PDU

PDU Temperature. Two channels each monitoring the temperature of the PDU baseplate in the region of one of the transmitter power switching relays, within a range of -25°F to +210°F.

PDM

7W/14W External Load Status. Monitors the operational status of each external load. A four-level readout is provided indicating all the discrete on/off combinations.

PDM Temperature. Monitors the temperature of the PDM with a range of -300°F to +300°F.

Transmitter

Transmitter Power Amplifier Temperatures. Two channels each monitoring the temperature of the Power Output Stage in one transmitter within a range of -50°F to +200°F.

1.5.3 (Cont.)

Transmitter Case Temperatures. Two channels each monitoring the case temperature of a transmitter within a range of -50°F to +200°F.

Transmitter 23 Volt Regulator Voltage. Two channels each monitoring the +23 volt regulator voltage in one transmitter.

Transmitter 17 Volt Regulator Current. Two channels each monitoring the +17 volt regulator current in one transmitter.

Data Processor

ADC HI and LO Calibration. Two channels supplying calibration points to the ADC at +0.25V and +4.75V.

DDP Status. Monitors the operation status of the redundant DDP's. The information is presented as a two-level signal.

DP Temperatures. Two channels monitoring the base and internal temperatures of the data processor within a range of -50°F to +210°F. The internal temperature sensor is located on the signal conditioner card.

ADP X/Y and Power Routing Status. Monitors the ADP status and the position of the redundant power routing relay. The information is presented in a similar manner to that of the Uplink A/B and Power Routing Status telemetry channel data.

RTG

RTG Hot Frame Temperatures. Three channels monitoring the RTG hot frame temperatures. The range of measurement is +1000°F to +1200°F.

RTG Cold Frame Temperatures. Three channels monitoring the RTG Frame temperatures. The range of measurement is +350°F to +550°F.

Experiments

Experiment Power Distribution Status. Two channels each monitoring the operational status of a pair of experiments. They provide for a readout in nine levels of all three states of each of the power switching circuits (ON - STANDBY - OFF). A third channel monitors the status of Experiment #5 only, in three levels.

1.5.3 (Cont.)

LSG Telemetry. Ten channels providing engineering and Seismic, Tide and Free Mode Oscillation science data.

LMS Telemetry. Three channels providing temperature, sweep voltage and sub-multiplexed housekeeping data. The LMS electronics temperature sensor is conditioned directly by the Central Station Data Processor and monitors the temperature within the range -40°F to +130°F independent of the LMS power status.

LSPE Electronics Internal Temperature. Monitors the LSPE temperature. The signal conditioning circuitry is located within the Central Station Data Processor. This telemetry signal is continuous and is independent of the LSPE operational status.

LEAM Telemetry. Three channels providing engineering data. The LEAM survival temperature sensor is conditioned directly by the Central Station Data Processor and monitors temperatures within a range of -50°F to +210°F, independently of the LEAM power status. Ten LEAM Engineering data channels are sub-multiplexed into the two other channels.

HFE Telemetry. Six channels, four monitoring internal supply voltages, and two monitoring heater power status in the High and Low Conductivity modes of operation.

1.6 SYSTEM OPERATION

1.6.1 Locally Controlled Functions

Certain functions are best controlled automatically. Voltage regulation, thermal control, overload protection, and power conservation, are examples.

Provision is made to automatically generate recalibration commands for experiments which require frequent recalibration.

Standby redundancy is used in the Data Subsystem and parts of the Power Subsystem to achieve the reliability required, and selection of a redundant element is performed automatically if a failure occurs which dictates local action. An overload in any redundant unit of the Data Subsystem causes power to be removed from the failed unit and, with the exception of the Transmitter, causes the standby unit to be powered on. Loss of function of the Uplink or Power Conditioner causes automatic selection of the standby unit.

1.6.2 Remotely Controlled Functions

The tasks being performed by ASLEP at any time are dependent upon ground commands. In general, experiment subsystems are commanded on or off or to standby. Various modes of operation are selectable. There are options on downlink data format and bit rates and the downlink transmission can be commanded on or off. Redundant units of the Data Subsystem in standby can be commanded into operation and some of the automatic control functions can be inhibited, enabled or overridden by ground command.

1.6.3 Ground Commands

Decoding logic is provided for 104 of the 128 possible commands. Of these, 15 are used to control the power subsystem, 2 are required for the uplink, 12 affect the downlink, and 49 commands are used by the five experiments. Twenty-six commands, originally provided as spares, or for test or for alternative arrays, are not used.

1.6.3.1 Uplink Commands.

122 Switch Uplink. Switches the uplink from one redundant side to the other.

174 Delay Uplink Switchover. Array E is designed to switch over to the redundant uplink automatically in the event of an uplink failure. However, this switchover does not occur at the time of failure. The Command Decoder automatically generates a "switch uplink" pulse at periodic intervals. In normal operation MSFN sends command 174 to ALSEP to inhibit the next auto-toggle pulse. After the next pulse has been inhibited, the inhibition is automatically removed by the Command Decoder. This mechanism is necessary to eliminate a possible single-point failure, with the result that command 174 must be sent repeatedly if it is desired to prevent uplink switchover.

1.6.3.2 Downlink Commands.

003 LSP Formatting On. The Data Processor is put into the LSPE Formatting Mode in which only LSPE data and six critical Central Station quantities are encoded and fed to the downlink.

005 DP Formatting On. The Data Processor is put into the DP Formatting Mode (at the normal bit rate) in which data is collected from all the experiments (except the LSPE) and from the Central Station. The data is formatted, Manchester encoded and fed to the transmitter.

1.6.3.2 (Cont.)

006 Normal Bit Rate. In the LSP Formatting Mode the data rate is 3533.3 bps. In the DP Formatting Mode the bit rate is 1060 bps.

007 Slow Bit Rate. In the LSP Formatting Mode the data rate is 1060 bps. In the DP Formatting Mode the bit rate is 530 bps.

024 Select ADP-X. Power is applied to ADP-X and removed from ADP-Y.

025 Select ADP-Y. Power is applied to ADP-Y and removed from ADP-X.

034 DDP-X Select. Power is applied to DDP-X and removed from DDP-Y.

035 DDP-Y Select. Power is applied to DDP-Y and removed from DDP-X.

The implementation of the above four commands (024, 025, 034 and 035) takes place in the PDU. The power changeover circuitry is such that either the X or the Y unit is powered.

012 Transmitter A On. Power is applied to Transmitter A. No power is applied to the diplexer switch so that the RF output from Transmitter A is routed to the antenna.

013 Transmitter A Off. Power is removed from Transmitter A so that it ceases to operate. Since no power was applied to the diplexer switch the antenna remains routed to the output connector of Transmitter A.

014 Transmitter B On. Power is applied to both Transmitter F
to the diplexer switch. The RF output from Transmitter B i
routed to the antenna.

smitter B
015 Transmitter B Off. Power is removed from bo the output
and the diplexer switch so that the antenna i
connector of Transmitter A.

has no effect on
The implementation of a Transmit thus possible to set up
the state of the redundant tran are switched on or off simultaneously.
conditions in which both tr being switched on simultaneously the
In the event of both trar er A is routed to a dummy load. Since there
rf power output of T ansmitters in Array E both transmitters can
are no heaters in t contingency mode for power management.
be switched off

1.6.3.3 Power Subsystem Commands

017 PDU #1 On. Power is applied to Power Dump Resistor #1 (PDR #1). This dissipates 7.0 watts of reserve power in the Power Dump Module (PDM).

021 PDU #1 Off. Power is removed from PDR #1.

022 PDR #2 On. Power is applied to PDR #2. This dissipates 14.0 watts of reserve power in the PDM.

023 PDU #2 Off. Power is removed from PDR #2.

The PDR's are:

(i) Backup thermal control components to dump power outside the Central Station during Lunar Day, in the event of an APM failure.

(ii) Range switches on the APM to extend the range of APM by changing its operating point.

027 APM #1 On. Switches on the Automatic Power Management for Power Conditioner #1 (PC #1).

031 APM #1 Off. Switches off the APM for PC #1.

115 APM #2 On. Switches on the APM for PC #2.

113 APM #2 Off. Switches off the APM for PC #2.

APM #1 and APM #2 are associated with PC #1 and PC #2 respectively and are not cross strapped. Each APM is able to dissipate up to 30 watts, but not simultaneously.

060 Select PC #1. Switches the RTG power lines so that Power Conditioner #1 provides power for the ALSEP System.

062 Select PC #2. Switches the RTG power line so that PC #2 provides power for the ALSEP System.

Array E has two-way automatic switching between the redundant PC sections. In the event of a failure in the PC in use the redundant unit will be automatically selected. To avoid "belling" the changeover sensing circuitry must be commanded to the appropriate position, as follows:

1.6.3.3. (Cont.)

120 Select PC Auto Switch #1. Switches the changeover sensor so that an out of tolerance condition of PC #2 will cause an automatic PC changeover to PC #1.

121 Select PC Auto Switch #2. Switches the changeover sensor so that an out of tolerance condition on PC #1 will cause an automatic PC change to PC #2.

In order to preserve maximum system reliability the states of the PCU Auto Switch Sensor and the operational PC must be as follows:

PC #1 Operational: Auto Switch Sensor to Select PC #2 and
PC #2 Operational: Auto Switch Sensor to select PC #1.

107 Select ADP Power Routing X. The power to the ADP is supplied through a redundant power routing network from the Power Distribution Unit (PDU) to the Data Processor in order to avoid the contingency of having both sides of the ADP powered at the same time. This command is a contingency function for selecting an alternative power supply route. This feature is described in detail in Section 4.1.3.

110 Select Uplink/ADP Power Routing W. The power to the uplink and the ADP is supplied through redundant power routing networks, to prevent both sides of the ADP or both sides of the uplink being powered by the +5V supply at the same time.

This command selects one power route so that an automatic uplink toggle pulse (initiated by the loss of uplink) will select the alternative uplink power route. The alternative ADP power route may only be selected by ground command. The operation of the power circuits is described in detail in Section 4.1.3.

032 Ripple Off Reset. The Command Decoder contains logic to generate the commands which cause power to be removed from the power dumps and causes experiments to be switched to standby if the reserve power drops below about one watt. The ripple-off commands then remove loads in sequence as long as the reserve power remains below 3-4 watts. If the ripple-off circuit runs through the entire sequence then it will automatically lock itself out. Command 032 resets the counter in the Ripple Off Circuitry to the ripple-off enabled condition.

1.6.3.4 Experiment Commands

104 Periodic Commands Enable. The Command Decoder contains logic to generate two LEAM Calibrate HIGH/LOW commands approximately four minutes apart at intervals of approximately fifteen hours. Two other periodic calibration commands are generated to provide for alternate Arrays, but are not used in Array E. Command 104 enables these signals to appear on the command lines.

105 Periodic Commands Inhibit. Inhibits the output of the automatic calibration commands.

The following commands are allocated to Experiment Power Switching.

036	LMS	EXPERIMENT #1 POWER ON
037		EXPERIMENT #1 POWER STANDBY
041		EXPERIMENT #1 POWER OFF
042	LEAM	EXPERIMENT #2 POWER ON
043		EXPERIMENT #2 POWER STANDBY
044		EXPERIMENT #2 POWER OFF
045	HFE	EXPERIMENT #3 POWER ON
046		EXPERIMENT #3 POWER STANDBY
050		EXPERIMENT #3 POWER OFF
052	LSG	EXPERIMENT #4 POWER ON
053		EXPERIMENT #4 POWER STANDBY
054		EXPERIMENT #4 POWER OFF
055	LSP	EXPERIMENT #5 POWER ON
056		EXPERIMENT #5 POWER STANDBY
057		EXPERIMENT #5 POWER OFF

The remainder of the experiment commands implement setting up, measurement and calibration functions. The number of experiment control functions available is expanded by using sequential logic as is mentioned in the section entitled "Experiment Subsystems".

The power switching sequence in Array E is limited as follows:

a) An experiment may be switched from ON to either STANDBY or OFF.

b) An Experiment may be switched from STANDBY to either ON or OFF.

c) An experiment may be switched from OFF to ON. It can not be switched from OFF to STANDBY. This eliminates the possibility of an experiment being switched from OFF to STANDBY by a ripple-off command.

1.7 POWER DISTRIBUTION AND DEFINITION

1.7.1 Introduction

This section describes the distribution and locations of the power within the Array.

1.7.2 Power Distribution Equation

The power distribution equation for Array E may be stated as follows:

The Input Power from the RTG is equal to the sum of the Central Station Power, the Experiment Power, the System Power Losses and the Reserve Power.

1.7.3 Power Distribution Definitions

Each of the above powers may be defined as follows:

1.7.3.1 The Input Power - [Pin] is the power supplied by the RTG. This power is measured as the product of the input current and the input voltage (measured at the astronaut Switch S1).

1.7.3.2 The Central Station Power - [Pcs] is the sum of the fixed power consumed within the Data Subsystem (e.g., uplink and downlink) plus the sum of the other fixed losses within the Central Station (e.g., PCU, PDU, harness).

1.7.3.3 The Experiment Power -[Pex] is the total power consumed by the experiments plus the sum of the cable losses between the Central Station Connector and the individual experiments.

1.7.3.4 The System Power Losses -[Ps] is the sum of the remaining variable (with respect to load) power losses (e.g., PCU converter, PDU load, harness).

1.7.3.5 The Reserve Power -[Pr] is then defined by the following equation:

$$Pr = Pin - [Pcs + Pex + Ps]$$

1.7.3.6 APM Power -[Papm] is the power dissipated within the APM circuitry. This power is dissipated both within the PCU and within the PDM.

1.8 SYSTEM GROUNDING

1.8.1 Description

The most significant change in grounding philosophy in Array E, compared with that of previous ALSEP arrays, is the use of the entire Central Station thermal plate as the system "single point" ground. All points on the thermal plate are considered to be electrically equivalent and all ground connections are made to it by the shortest practical paths.

Ground path inductance and resistance in the Central Station Components are minimized by employing ground planes on component PC boards and by using the component mounting structure and baseplate as the return path to the thermal plate. The component mounting structure base and the thermal plate surface are designed to provide good electrical continuity and a low impedance path at high fequencies. The thermal plate and new components employ gold mounting interfaces to optimize electrical continuity between mechanical interfaces. (Thermal grease is employed if it is not detrimental to electrical characteristics.) The entire thermal plate is gold plated to provide a low resistance path between components, and the dimensions of the thermal plate ensure that it has a low inductance.

The thermal plate provides three means for completing ground connections.

a. Component mechanical mounting interface;

b. Terminal board ground strips; and

c. Three ground studs.

Except for the receiver, components in Array E employ method (a), but carry a "safety" ground wire in the component connector for test purposes. The receiver has been designed to operate on an anodized thermal plate. Its ground is therefore connected through the Central Station harness to a thermal plate ground stud. Except for the LSPE, experiment ground lines are interconnected on multi-terminal ground strips on the terminal boards, which are returned via the terminal board fixings to the thermal plate. The LSPE electronics unit is mounted upon the thermal plate and like the other Central Station components, it makes its primary ground connection through its baseplate. The RTG is returned to the thermal plate ground studs.

1.8.1 (Cont.)

The system grounding arrangements are depicted in Figure 1-12. The following comments apply:

a. Parallel alternate signal return conductors are used in all the experiment flat cables in lieu of the previously employed alternate shield conductors. This modification reduces crosstalk on the timing and control lines.

b. The Receiver mounting surface is not compatible with the gold finish and is thus isolated from the thermal plate by an anodized aluminum shim less than 1/32 inch thick.

2.0 STRUCTURE/THERMAL SUBSYSTEM

The structure/thermal subsystem provides the structural integrity and the passive thermal protection required by the ALSEP experiment and support subsystems to withstand the different environments encountered in storage, testing, loading on the LM space flight, and lunar deployment. During the operation on the lunar surface, the structure/thermal subsystem continues to provide structural support to, and thermal/protection for the Data and Power subsystems inside the Central Station.

2.1 PHYSICAL DESCRIPTION

The structure/thermal subsystem includes the basic structural assembly of the ALSEP system subpackages, the fuel cask support, fuel transfer tool (FTT), universal handling tool (UHT), and the dome removal tool (DRT).

The structure/thermal portion of subpackage 1 consists of a machined forged primary structure, thermal plate, sunshield, side curtains, reflector, and thermal bag as shown in Figure 2-1. The primary structure is recessed to contain the Central Station components. The sunshield provides mounting for the experiment subsystems prior to their deployment.

The structure/thermal portion of subpackage 2 consists of a pallet and a subpallet as shown in Figure 2-2.

The fuel cask support structure consists of the thermal shield and the structure that supports the fuel cask on the outside of the LM.

The fuel transfer tool (FTT) consists of fingers for engaging the fuel capsule, an outer tool shaft and an engaging/disengaging mechanism operated by a rotating knob at the handle end.

The dome removal tool (DRT) consists of spring loaded engagement pins, a shaft and a handle.

The universal handling tool (UHT) comprises an outer tool shaft and a locking and release mechanism that runs through the center of the shaft operated by a trigger on the handle end. These tools are also shown in Figure 2-2.

SUBPACKAGE NO. 1 STRUCTURE

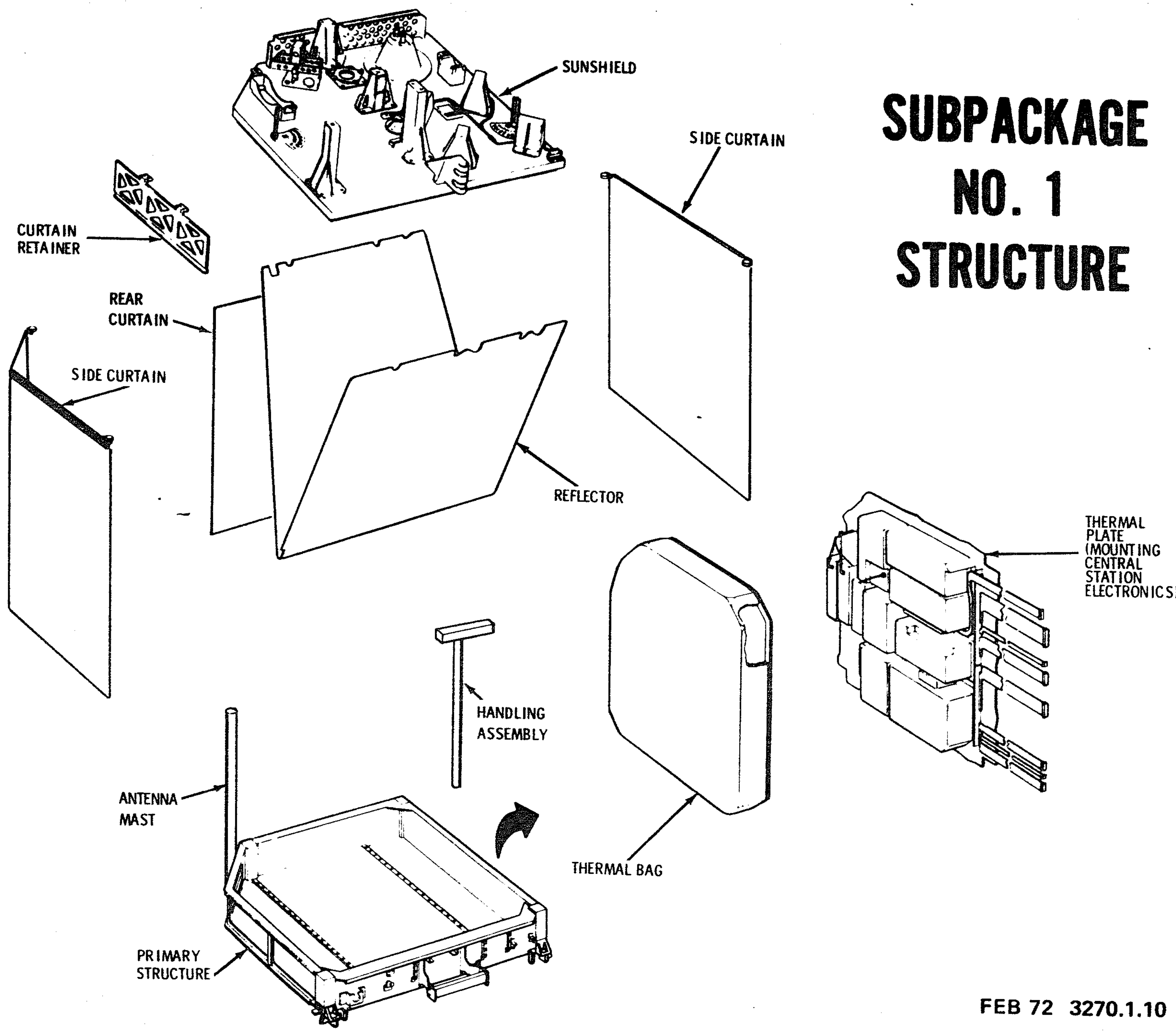


Figure 2-1

SUBPACKAGE NO. 2 STRUCTURE AND TOOLS

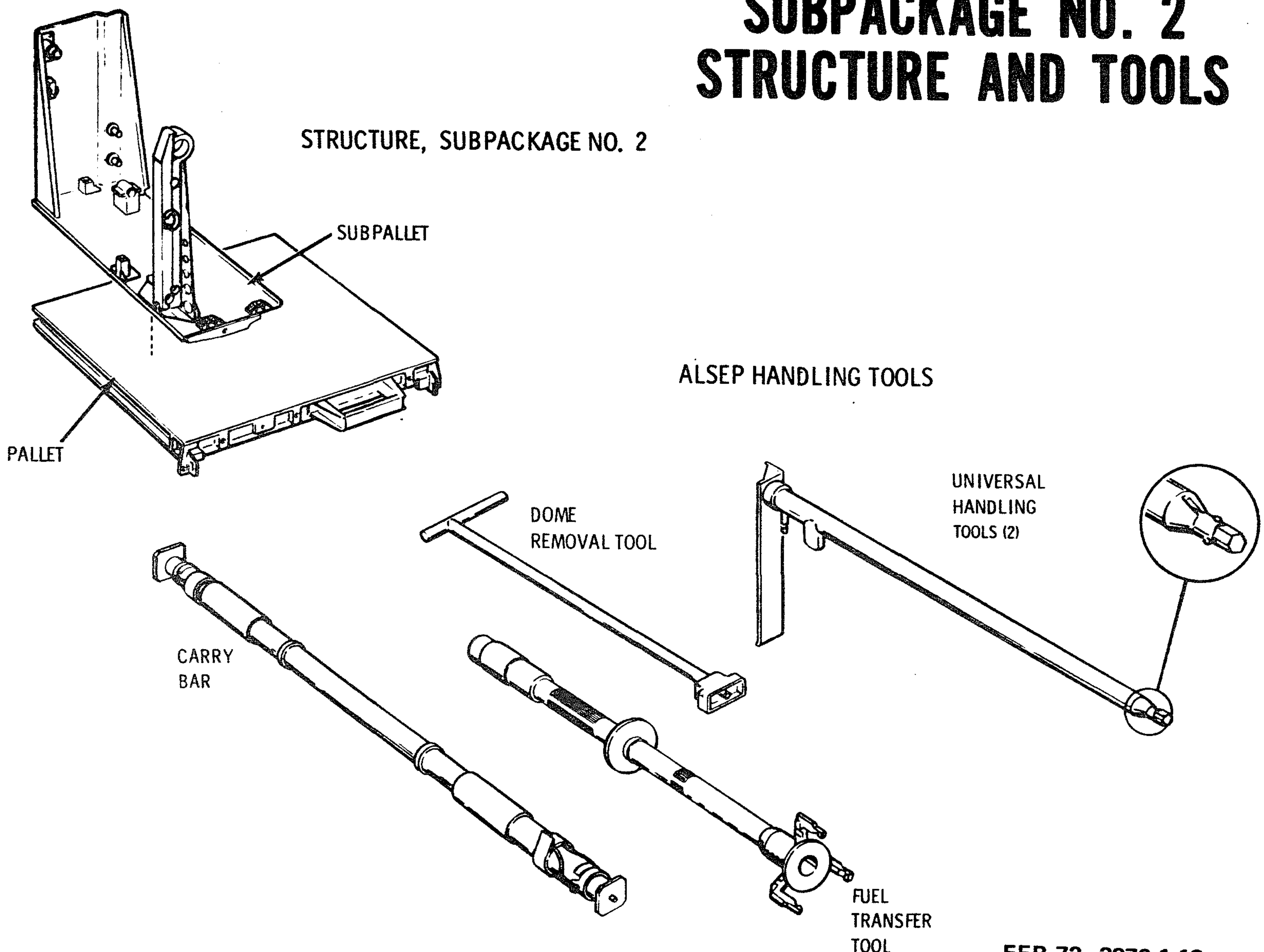


Figure 2-2

FEB 72 3270.1.12

2.2 FUNCTIONAL DESCRIPTION

The subpack 1 structure provides tie points for mounting three experiment subsystems, and for securing the subpackage in the SEQ bay of the LM. The sunshield, side curtains, and reflector are raised during deployment to provide thermal protection for the central station electronics.

Two thermistor temperature detectors are mounted on the sunshield to monitor temperature during operation on the lunar surface. This temperature data is supplied to two analog data (housekeeping) channels of the data subsystem.

The subpackage 2 structure provides tie points for mounting two experiments and support subsystems, and for securing the subpackage in the SEQ bay of the LM. The pallet assembly protects the astronaut from the power subsystem (RTG) components during deployment, and serves as a base for the RTG during operation on the lunar surface.

The fuel cask support structure provides for the attachment of the fuel cask to the exterior of the LM during the Earth-to-Moon flight. The support structure provides a thermal shield to reflect the fuel capsule thermal radiation away from the LM. The structure includes a mechanism to allow the fuel cask to be tilted from the vertical, facilitating the transfer of the fuel capsule to the RTG during deployment.

The UHT is used by the astronaut during deployment to transport and emplace the experiment subsystems. The insertion end of the UHT is a positive locking device that provides a rigid interface between the tool and the experiment subsystem as well as the fasteners securing the experiments. A trigger located on the handle end must be pulled to insert or release the tool from the subsystem receptacle. The fuel transfer tool (FTT) is used by the astronaut to grasp the fuel capsule, transfer it from the fuel cask, insert it into the generator assembly, and lock it in place. The handle end of the FTT is shaped so as to provide a good gripping surface.

3.0 POWER SUBSYSTEM

The Electrical Power Subsystem (EPS) provides the electrical power for the lunar surface operation of the ALSEP. The primary electrical power is developed by thermoelectric action, the thermal energy being supplied by a radio isotope source. The primary power is converted, regulated and filtered to provide four operating voltages for the ALSEP.

3.1 PHYSICAL DESCRIPTION

The major components for the electrical power subsystem are the radioisotope thermoelectric generator assembly (RTG), a fuel capsule assembly, a fuel cask, the PCU and the PDM.

3.1.1 Radio Isotope Thermoelectric Generator (RTG)

The RTG is a cylindrical case with eight heat ejection fins on the exterior, and a central cavity for the fuel capsule. The thermoelectric couple assembly (thermopile) is located between the hot frame, which surrounds the cavity, and the cold frame which interfaces with the outer case and the heat ejection fins.

3.1.2 Fuel Capsule Assembly (FCA)

The fuel capsule assembly is a thin walled, cylindrical - shaped structure having an end plate for mating with and locking to the fuel cask and the RTG. It contains the radioisotope fuel, plutonium (PU-238), encapsulated to meet the nuclear safety criteria.

3.1.3 Fuel Cask

The fuel cask is a cylindrical shaped structure made of graphite with a screw-on end at each end. The cask provides fuel capsule support elements, a free radiation surface for the rejection of fuel capsule heat during the launch and flight, and re-entry protection in the event of a mission abort.

3.1.4. Power Conditioning Unit (PCU)

The functional elements of the PCU are redundant dc voltage converters, shunt regulators, automatic power management circuits, filters and command amplifiers. The active circuits are mounted in printed circuit modules within the PCU case.

3.1.5. Power Dissipation Module (PDM)

The PDM is a flat plate on the outside of the structure containing the power dissipation resistors as described in Section 3.4.

3.2 FUNCTIONAL DESCRIPTION

The RTG supplies primary power to the PCU. Voltage conversion circuits in the PCU convert the primary power to the four ALSEP operating voltages. The PCU is started when the astronaut rotates the shorting switch during the Array E deployment sequence.

One astronaut switch is a contingency switch allowing the manual selection of PC #2. The operation of the PCU is controlled by uplinked commands from the MSFN through the data subsystem.

Telemetry sensors in the RTG and PCU provide temperature, voltage, current and power dissipation information to the data subsystem.

3.3 THE RTG

The operation of the RTG is illustrated in the block diagram of Figure 3-1. A radio isotope fuel source developes thermal energy that is applied to the hot frame. The temperature differential between the hot and the cold frames causes the thermopile to develop electrical energy by thermoelectric action.

The electrical output power of the RTG is of the order of 74 watts at a potential of 16 volts at the power supply connector of the Central Station.

Excess heat from the thermopile is conducted through a cold frame to a thermal radiator (fins) for dissipation into the lunar environment.

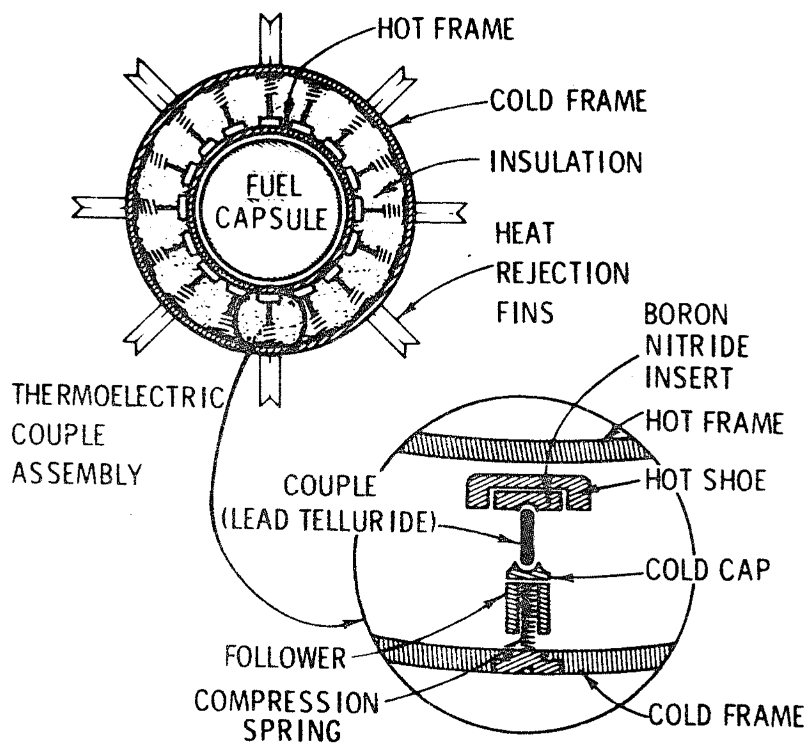
Temperatures are monitored at three cold and three hot frame locations, providing six temperature telemetry channels to the data subsystem.

3.4 THE POWER DISSIPATION MODULE (PDM)

3.4.1 Configuration

The PDM contains resistance networks for dissipating excess power outside the Central Station. The PDM contains two Power Dump Resistors (PDR's) and the PCU Automatic Power Management (APM) load resistors.

POWER GENERATING FUNCTION



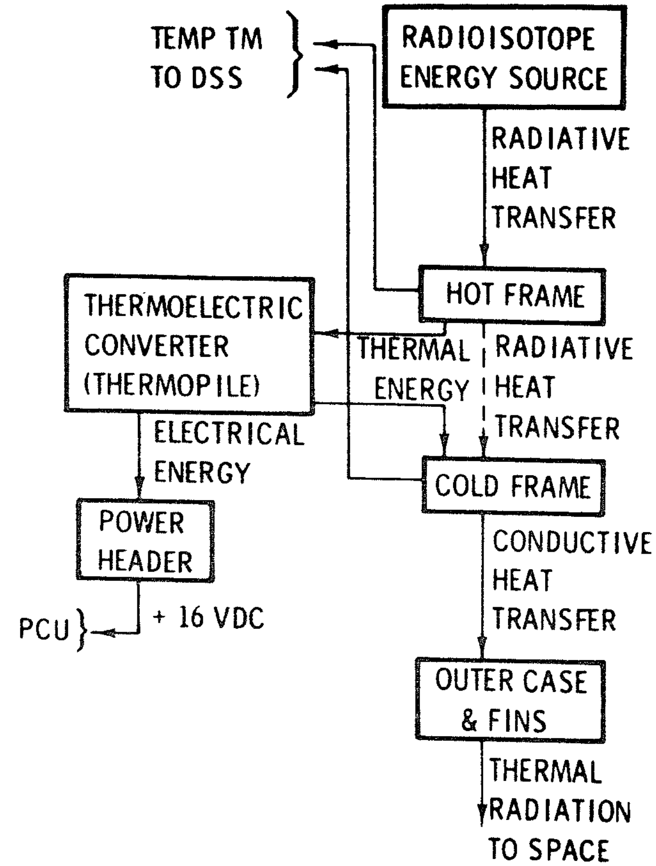


Figure 3-1

FEB 72 3270.1.18

3.4.2 Function

The PDM is used as a part of the thermal control system and as a dump for excess system power. The portion of the excess system power controlled by the PCU Regulator constitutes the Reserve Power. At low temperatures it is dissipated in heaters within the Central Station; whereas at high temperatures it may be dissipated externally through the action of the APM circuits. Each APM load may dissipate up to 30 watts of reserve power.

By MSFN command, 7 watts of excess power may be dumped into PDR #1, and/or 14 watts of excess power may be dumped into PDR #2.

3.5 THE POWER CONDITIONING UNIT (PCU)

3.5.1 Configuration

The PCU is a multioutput, DC/DC Converter designed to operate from an RTG source so as to supply all power to the ALSEP Data Subsystem. The PCU also provides the +29V supply to the experiments via the power control circuits of the PDU.

The PCU contains two redundant Power Converters (PC's) each of which can supply the ALSEP power needs. Each PC consists of a shunt regulator, power invertor, multi-output transformer-rectifier units and an Automatic Power Management (APM) circuit.

Each PC contains telemetry sensors monitoring its operation.

The non-redundant section of the PCU consist of the "out-of-regulation" condition sensors, the PC Switching Circuitry, and some telemetry combining networks.

An outline diagram of the PCU is shown in Figure 3-2.

3.5.2 The Shunt Regulator

Since the RTG source must be loaded at all times after being fueled, and as it has a significant internal impedance, a shunt regulator is used in the PCU.

The shunt regulator regulates the +12V line by altering the load on the +16V input line to maintain the +12V line at a fixed value, and also to present a constant-voltage load to the RTG. The +12V line has been chosen as the reference line to provide one accurately known supply to the central station components.

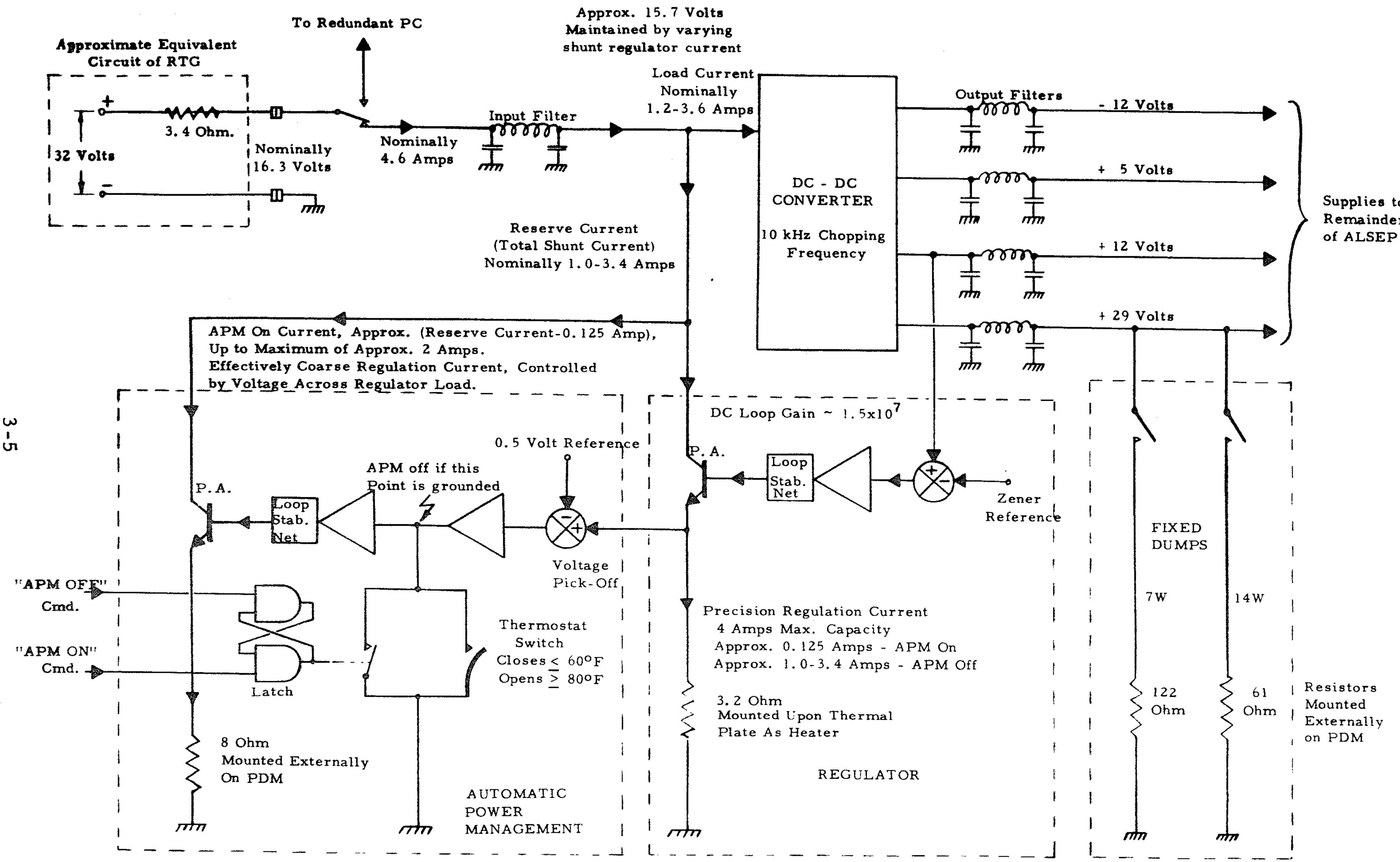


Figure 3-2 Power Conditioning Unit

3.5.3 The DC/DC Converter

The self starting DC/DC converter provides four voltage-regulated outputs, developed by the transformer operating in association with bi-phase half wave rectifier circuits. Center tapped transformer secondary circuits are used to reduce the number of diodes used in the unit.

The +29V line, which receives the greatest loading under normal operation, is generated by an auto transformer configuration to minimize its source impedance and associated losses. The +16V line from the RTG is applied directly to the center-tap of the transformer primary and is DC coupled via the auto transformer winding to the +29V line output. The oscillation of the invertor provides a boost to the output as governed by the auto transformer turns ratio such that a nominal +29V is developed on the +29V line.

3.5.4 The Automatic Power Management (APM) Circuit

The APM is a shunt regulator connected in parallel with the shunt regulator controlling the +12V line in order to dissipate excess power outside the Central Station structure.

The operation of the APM is such that it will turn on only if three conditions are satisfied. The APM must be commanded ON, there must be sufficient power through the voltage regulator to maintain regulation, and the thermal plate temperature must be greater than 80°F. There is hysteresis in the temperature control so that once ON it will not shut off the APM until the temperature falls below 60°F.

The APM may be commanded off by the MSFN. The ON command is really an ENABLE command, because the APM will not switch on unless the power and thermal conditions have been met.

3.5.5 Power Filters

All power lines input and output are provided with π type filters so as to reduce any electromagnetic interference to the data subsystem from the switching transients generated within the PCU.

3.5.6 PC Auto Switch Sensor Circuitry

In Array E the status of PC #2 has been changed from a contingency mode of operation to a redundant PC mode of operation. This required the inclusion of switching between the redundant units so as to maintain the automatic changeover facility in the event of a failure.

3.5.6 (Cont.)

The PC auto switch sensor circuitry is sketched in Figure 3-3. The output circuit of the auto switch sensor is commanded by the MSFN to route the "Select PC" fault signal to either PC. The input of the circuit senses the ± 12V and +5V lines within the two PC's. A fault condition generates the "Select PC" signal after a dealy of 300 ± 50 mS if the line voltage decreases or after a delay of 5 mS if the +12V line increases as follows:

1. When the voltage on the +12V line decreases to 11.5 ± 0.25V or increases to 13.6 ± 0.25V;

2. When the voltage on the +5V line decreases to approximately 1.6V; or

3. When the voltage on the -12V line increases to approximately -4.5V.

Due to the potential drops through the distribution and protection circuits in the PDU, the voltages on the supply lines to the components are numerically about 0.7V less than those listed in 1, 2, and 3 above.

The "Select PC" pulse is gated into the PC changeover relay itself in parallel with the normal relay driver outputs. To ensure that a changeover will occur even if the supply lines drop to very low levels, the pulse is derived from energy stored in capacitors.

3.5.7 Ripple-Off Sensor

The ripple-off sensor provides a ripple-off signal to the Command Decoder when the value of reserve power falls below about 2 watts. The operation of the ripple-off circuit is described in Section 4.2.6.

3.5.8 The PCU Telemetry Networks

The PCU provides the following housekeeping signals to the data subsystem.

(1) PCU Input Current
(2) PC #1 Input Voltage
(3) PC #2 Input Voltage
(4) APM Status
(5) PC #1 APM Current
(6) PC #2 APM Current
(7) PC #1 APM Temperature
(8) PC #2 APM Temperature
(9) PC #1 Regulator Temperature
(10) PC #2 Regulator Temperature

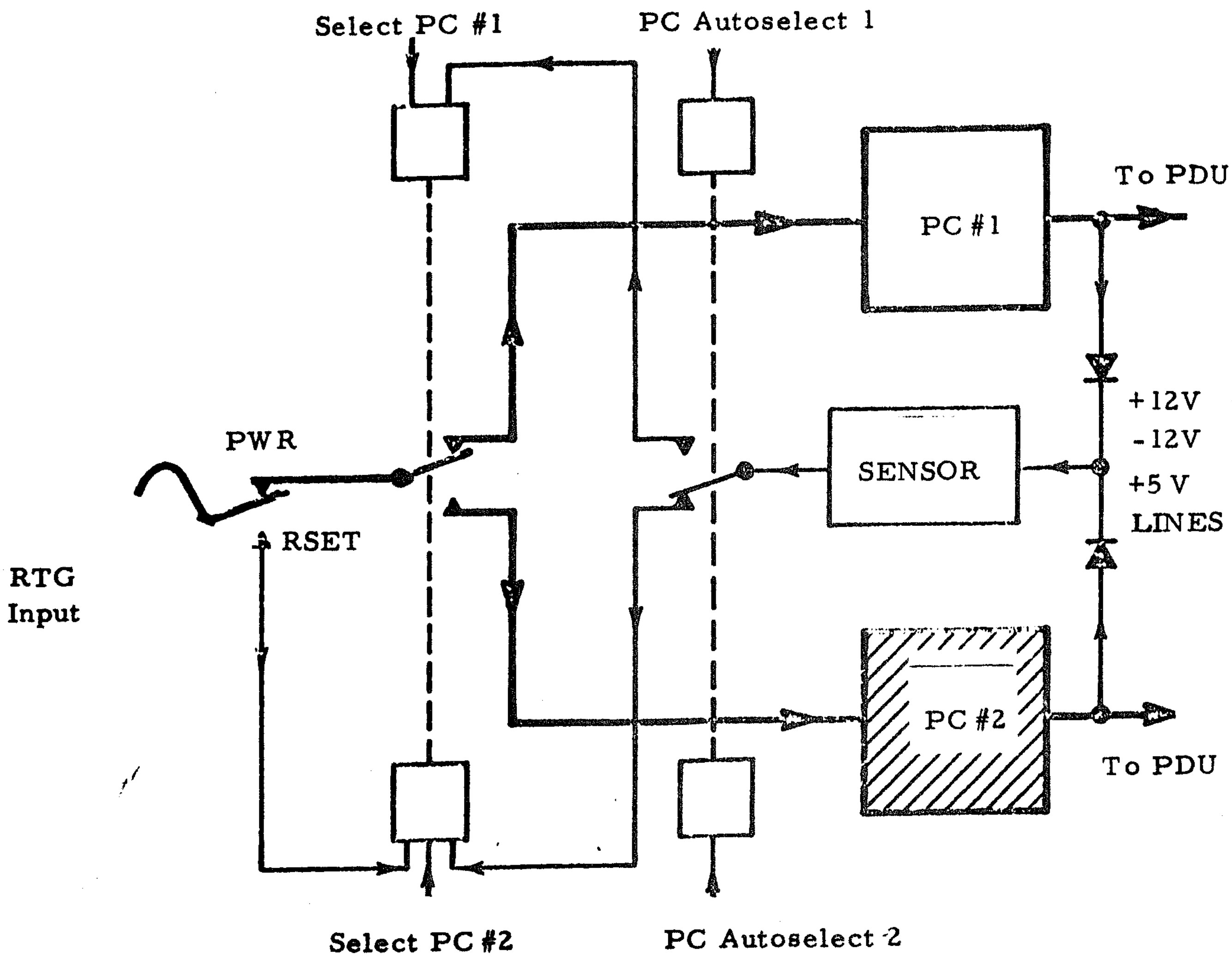


Figure 3-3 PCU Auto Switch Circuitry

4.0 DATA SUBSYSTEM

4.1 POWER DISTRIBUTION UNIT

4.1.1 General Description

The PDU accepts power from whichever of the two P.C.'s is in operation and routes it to the various components and experiments within the ALSEP. It contains the relay switching circuits which provide the On-Off and changeover control of the loads; and the power protection circuits and diodes which combine the P.C. output supplies while maintaining isolation between the individual P.C.'s. It also provides telemetry signals indicating the power status of the load lines and its own internal temperature.

There is only one PDU in the system; redundancy is provided at the electronics part level, primarily by routing the supplies from the two P.C.'s via separate switching relays. All relay driver circuits are powered at all times, so that both relays controlling a load respond to a command. The combining takes place on the output side of the relay contacts, so that in the event of a failure occuring in the PDU it may be necessary to switch PC's to reinstate full control of the power routing.

Supply lines to Data Subsystem redundant units or to loads which can be commanded on or off are protected by circuit breakers. Supply lines to non-redundant Data Subsystem units are energized continuously and are protected by fuses.

The experiment ON supply lines are all switched by command and are protected by circuit breakers. The experiment STANDBY lines are protected by fuses.

As the redundant control relays respond to all commands, a PC change-over does not result in a change in the operational configuration of the ALSEP. In the event of an overload causing the circuit breaker to operate, only the power control relay in use at that time changes state, so that any later change in PC's, will find the system routing power to the side having the overload, which if still present, will cause an automatic change to the "good" side of the controlled load. The only exception to this control action in the event of an overload is the behavior of the Uplink/ADP Power Routing Circuit which is described in Para. 6.1.3.1.

4.1.1 (Cont.)

The +5V supply to the relay drivers is controlled by a special electronic switching circuit which prevents spurious relay switching occurring at initial ALSEP turn-on, or during a PC changeover. This circuit is an input voltage sensing switch which does not close the supply to the PDU drivers until the PC output voltage has reached a level at which all logic turn-on transients have terminated and the logic has settled into normal steady-state operation.

Five different types of Power Routing Circuits are employed, namely:

1. Transmitter/DDP Power Routing
2. Uplink/ADP Power Routing
3. Experiment Power Routing
4. Power Dumps Power Routing
5. Unswitched Power Supplies

4.1.2 Transmitter/DDP Power Routing

The circuit shown in Figure 4-1, consists of two driver circuits, a magnetic latching relay, a circuit breaker and a diode in each output line. The diodes isolate the redundant power supply circuits from each other.

The only switched supply required by the DDP is a +5V supply, while the transmitters require both a switched +29V and a +12V supply. The DDP control module causes an automatic DDP change in the event of an overload, or a command, while in the event of an overload the Transmitter control module only switches off the particular transmitter in use, requiring a command from the MSFN to switch on the second transmitter. It is also possible to switch both transmitters on simultaneously, a condition that causes no system damage but does add about eight watts to the Central Station thermal plate power dissipation.

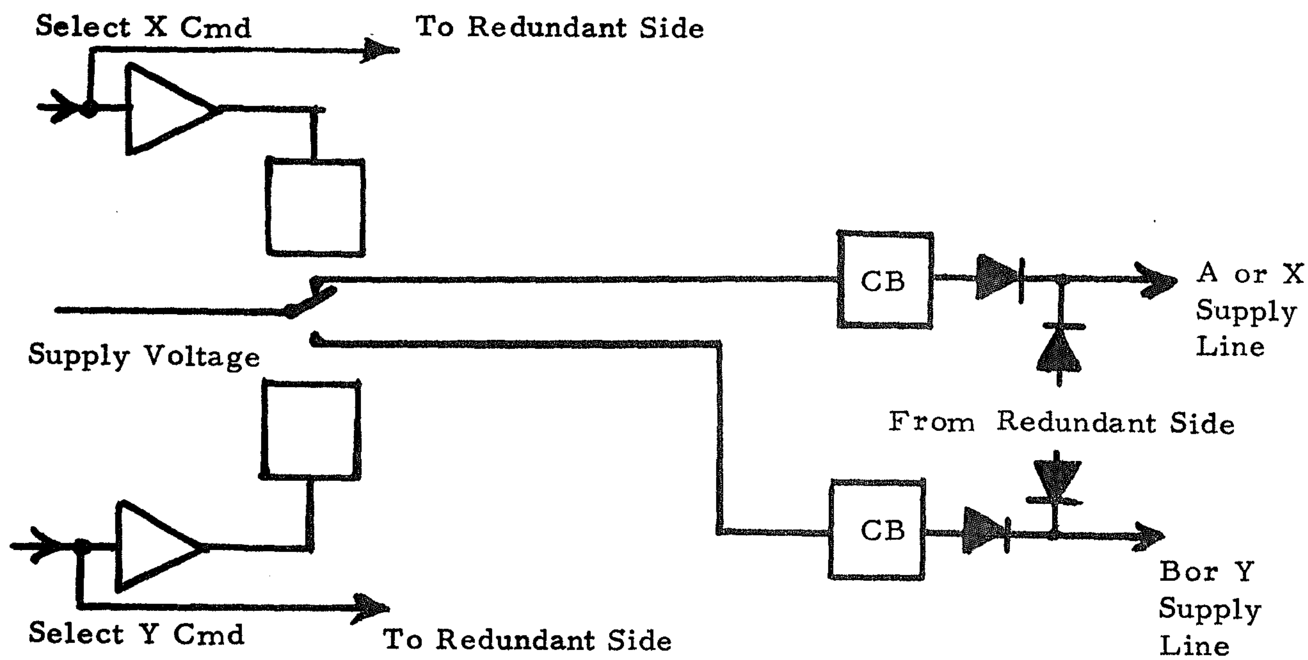


Figure 4-1. Transmitter/DDP Power Control

4.1.3 Uplink/ADP Power Routing

4.1.3.1 Circuit Configuration

Within the PDU, the Uplink and ADP Power Routing Circuits are identical. The circuitry is shown in outline form in Figure 4.2. The difference between the operation of the Uplink and the ADP Power Routing Circuits is in the command circuitry within the Command Decoder.

The circuit is described below with reference to the Uplink. Power is routed to the Uplink by means of four double pole double throw relays. Three select the A or B Uplinks; the fourth provides the Redundant Power Routing for the +5V line. The Uplink uses three switched supply lines (+12V, -12V and +5V).

Each supply line is routed through redundant sets of contacts in DIFFERENT relays so that it is possible to route a supply voltage to both Uplinks simultaneously in the event of a failure. To overcome this failure mode in the +5V line, an extra relay (K3) has been introduced so as to provide "Redundant Power Routing."

Four command lines are used to control the power routing. Two of these select the redundant load, i.e. Uplink A or Uplink B;(or ADP X or ADP Y); and the other two select the Redundant Power Routing Relay state, i.e. X or W.

In the event that an overload is sensed by any one of the +5, +12 or -12V supplies the circuit breaker initiates a changeover to the redundant Uplink, (or ADP). A subsequent PC changeover may be performed without any interaction with these circuits occurring, as the circuit breakers are downstream of the control relays.

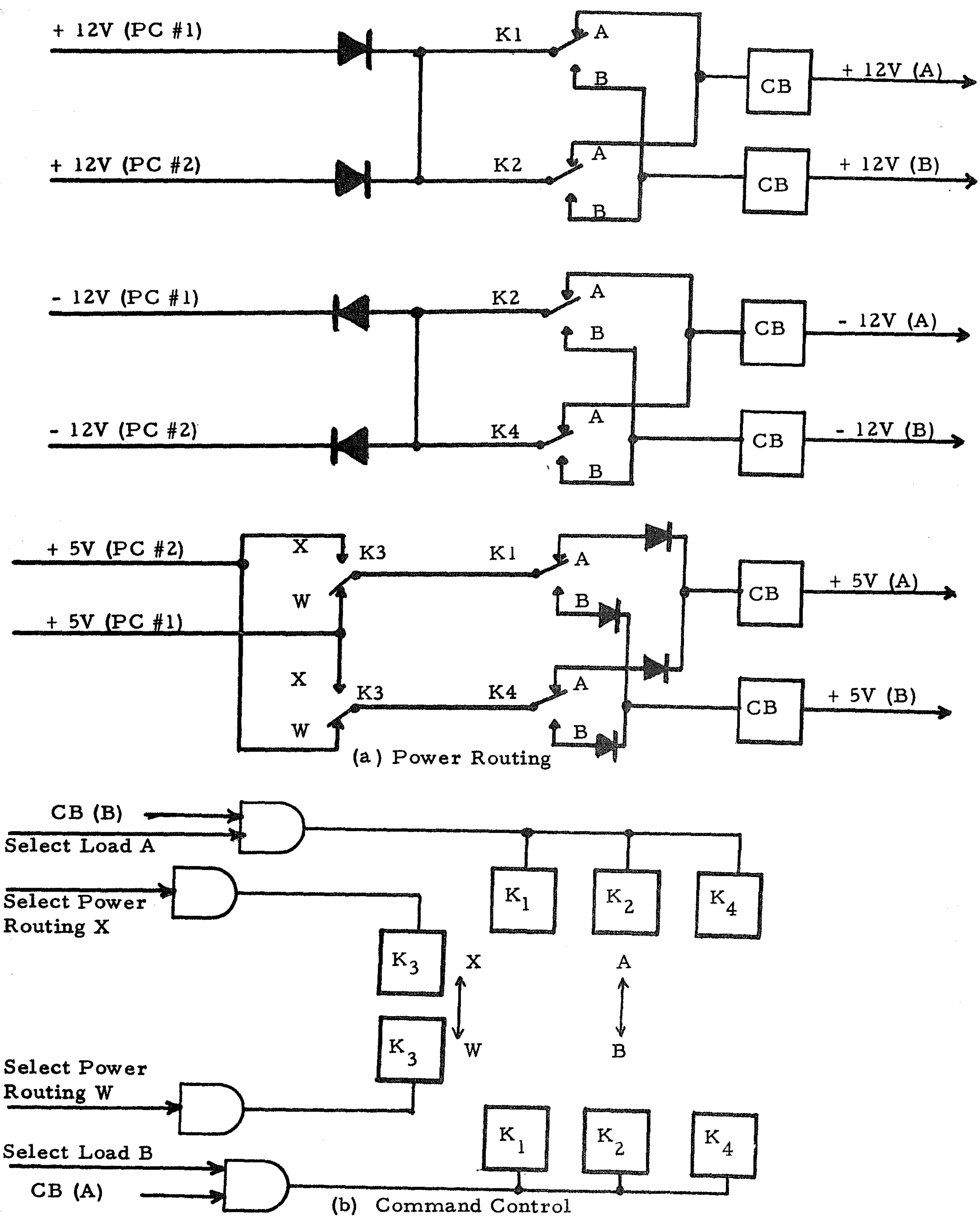
4.1.3.2 Command Control of the Uplink Power Routing

The MSFN cannot directly select Uplink A or Uplink B. The Select Load command pulses are supplied by control logic contained within the Command Decoder, which is illustrated in Figure 4-3 (a). This circuit responds to two input signals:

1. The OCTAL 122 Switch Uplink Command, and

2. The Automatic Uplink Toggle Pulse.

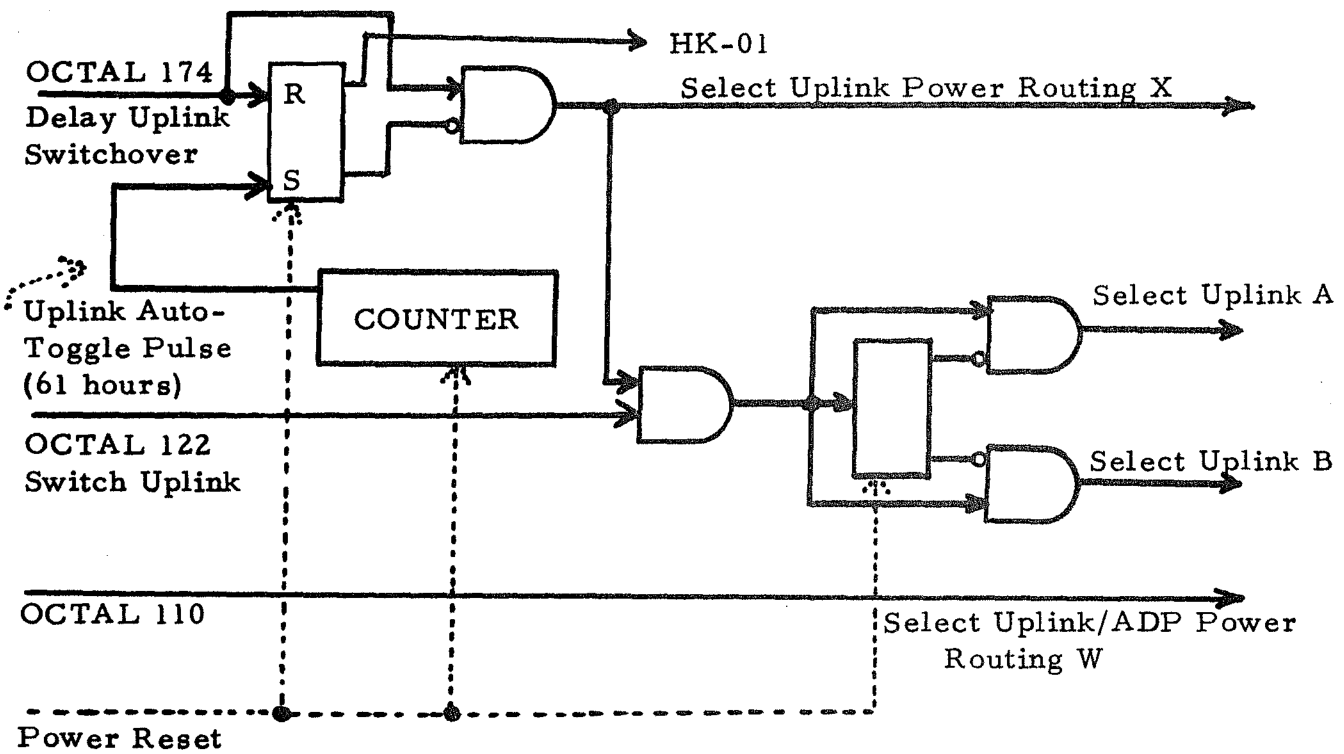
The control logic incorporates a Command Routing Flip Flop which will route either of the input signals to the PDU Select Load Command lines to implement Uplink changeover.



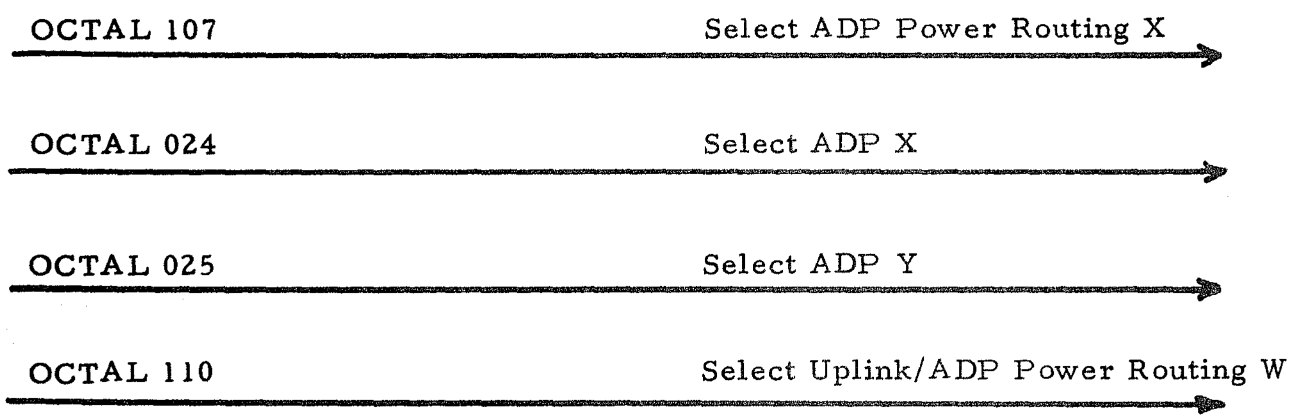
(a) Power Routing

(b) Command Control

Figure 4-2 Uplink/ADP Power Routing



(a) Uplink Command Routing Functional Circuitry



(b) ADP Command Routing Functional Circuitry

Figure 4-3 Uplink/ADP Command Routing

4.1.3.2 (Cont.)

The Automatic Uplink Toggle Pulse is generated by the Command Decoder Repeated Command Sequencer as described in Para. 4.2.5 below. The first Toggle Pulse occurs 7.6 hours after initial ALSEP turn-on, and every 61.8 hours thereafter. Its action may be inhibited by the MSFN by an OCTAL 174 Delay Uplink Switchover Command.

If OCTAL 174 is received it inhibits the Automatic Uplink Toggle Pulse from switching any relays in the PDU Power Routing Section. The Automatic Uplink Toggle Pulse however will "Un-inhibit" or enable the Automatic Uplink Changeover Inhibit/Enable Flip Flop, and thus the action of the next Automatic Uplink Toggle Pulse. Thus to keep from switching Uplinks, OCTAL 174 must be transmitted at least once every 61 hours.

The status of the Automatic Uplink changeover Inhibit/Enable Flip Flop is monitored and presented in the Housekeeping Telemetry Data as HK-01.

Note that the OCTAL 174 command has no effect on the response of the ALSEP to the OCTAL 122 Switch Uplink command.

The application of a power reset will set the Command Routing Flip Flop to the "A" side (next command selects Uplink B) and the Automatic Uplink Changeover Inhibit/Enable Flip Flop to the Enable position. A power reset is not applied to the PDU Power Routing section so that if in test, Array E is powered down while operating in Uplink B, at Turn-On it will still be in Uplink B but the Command Routing Flip Flop will be in the "A" position. The first OCTAL 122 Switch Uplink Command would be routed so as to Select Uplink B. As the Array is operating in Uplink B no apparent change will be seen in any status and a CVW will be returned; however, the Command Routing Flip Flop is changed to the "B" position and a subsequent OCTAL 122 command will cause the Uplink to changeover.

The OCTAL 110 Select Uplink/ADP Power Routing W Command is applied directly to the Uplink Power Routing Circuit to select Route W. Route X cannot be selected by command, it is selected whenever an Uplink changeover is initiated by an Automatic Uplink Toggle Pulse. This causes both the Uplink and its Power Routing to be switched simultaneously, thus overcoming any single failure within the Uplink Power Routing Circuitry.

4.1.3.3 Command Control of the ADP Power Routing

As shown in Figure 4-3 (b), the MSFN controls all the ADP Power Routing relay positions by direct commands as follows:

OCTAL 024	Select ADP X
OCTAL 025	Select ADP Y
OCTAL 107	Select ADP Power Routing X
OCTAL 110	Select Uplink/ADP Power Routing W.

The ADP is normally operated in the Power Routing W position since OCTAL 110 command puts both the Uplink and the ADP Redundant Power Routing Relays into the W position.

4.1.4. Experiment Power Routing

Each experiment can be operating in one of three possible modes at any time, namely ON, STANDBY (STBY) or OFF. The Power Routing for the experiments is governed by the following constraints:

a) The ( )→ STBY transition may be activated by either a command or by an automatic mechanism (i.e., ripple off, or circuit breaker each activiating an ON→ STBY transition).

b) An experimental which is in the OFF state is never to be set into the STBY position by the ripple-off circuitry.

c) Since the ( ) → STBY transition takes place without the Power Switching Circuit knowing that it is a ripple-off, circuit breaker or commanded transition it is necessary to rule that an OFF → STBY transition is never to occur under any condition.

d) A ( ) → STBY action must never be equivalent to a ( ) → OFF transition, i.e., no fault-free relay switching combination must be possible which allows the STANDBY line to be without power when selected.

The allowable switching sequence is thus as shown in Figure 4-4.

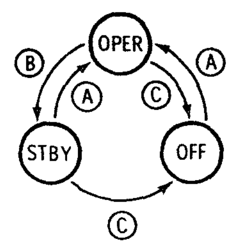
Note that to set an experiment to STBY from an OFF state, a command sequence, which must pass thru the ON state, is required.

EXPERIMENT POWER CONTROL (CONT'D)

- SELECTION COMMANDS (OCTAL):

EXPER	(A) OPER	(B) STBY	(C) OFF
#1, LMS	036	037	041
#2, LEAM	042	043	044
#3, HFE	045	046	050
#4, LSG	052	053	054
#5, LSP	055	056	057

- POWER SWITCHING FROM OFF TO STBY IS INHIBITED:



- NORMAL OPERATING SEQUENCES:

SEQUENCE	RELAY CONTACT POSITION		
	1	2	3
OFF TO OPER	UP	UP	DOWN
OPER TO STBY	DOWN	UP	DOWN
STBY TO OFF	DOWN	DOWN	DOWN
OPER TO OFF	DOWN	DOWN	DOWN

- OVERLOAD (CIRCUIT BREAKER) SEQUENCE:

SEQUENCE	RELAY CONTACT POSITION			
	1	2	3	
OPER (INITIAL)	UP	UP	DOWN	
OPER TO OVERLOAD 1	UP	UP	UP	
OVERLOAD 1 TO OVERLOAD 2	DOWN	UP	UP	
OVERLOAD 2 TO STBY	DOWN	UP	DOWN	← RESET OF C/B

MAY 72 3270.2.47

Figure 4-4

4.1.4. (Cont.)

The simplified Experiment Power Control Circuit is shown in Figure 4-5. Three transistorized relay drivers, two magnetic latching relays and one overload sensor (circuit breaker) are utilized to perform the power routing and circuit breaking function for each experiment operating power line in each side of the PDU. Three command inputs are provided, namely Experiment ON, STBY and OFF. The truth table in Figure 4-5 shows the relay positions resulting from any particular input command.

It can be seen that although the operating supply line is protected by circuit breakers the standby supply only has fuse protection.

4.1.5. Power Dissipation Module Power Routing

The PDM Power Routing consists of a redundant circuit supplying power for each PDR, so that no single failure will cause a PDR to be permanently locked on. The routing circuitry is sketched in Figure 4-6.

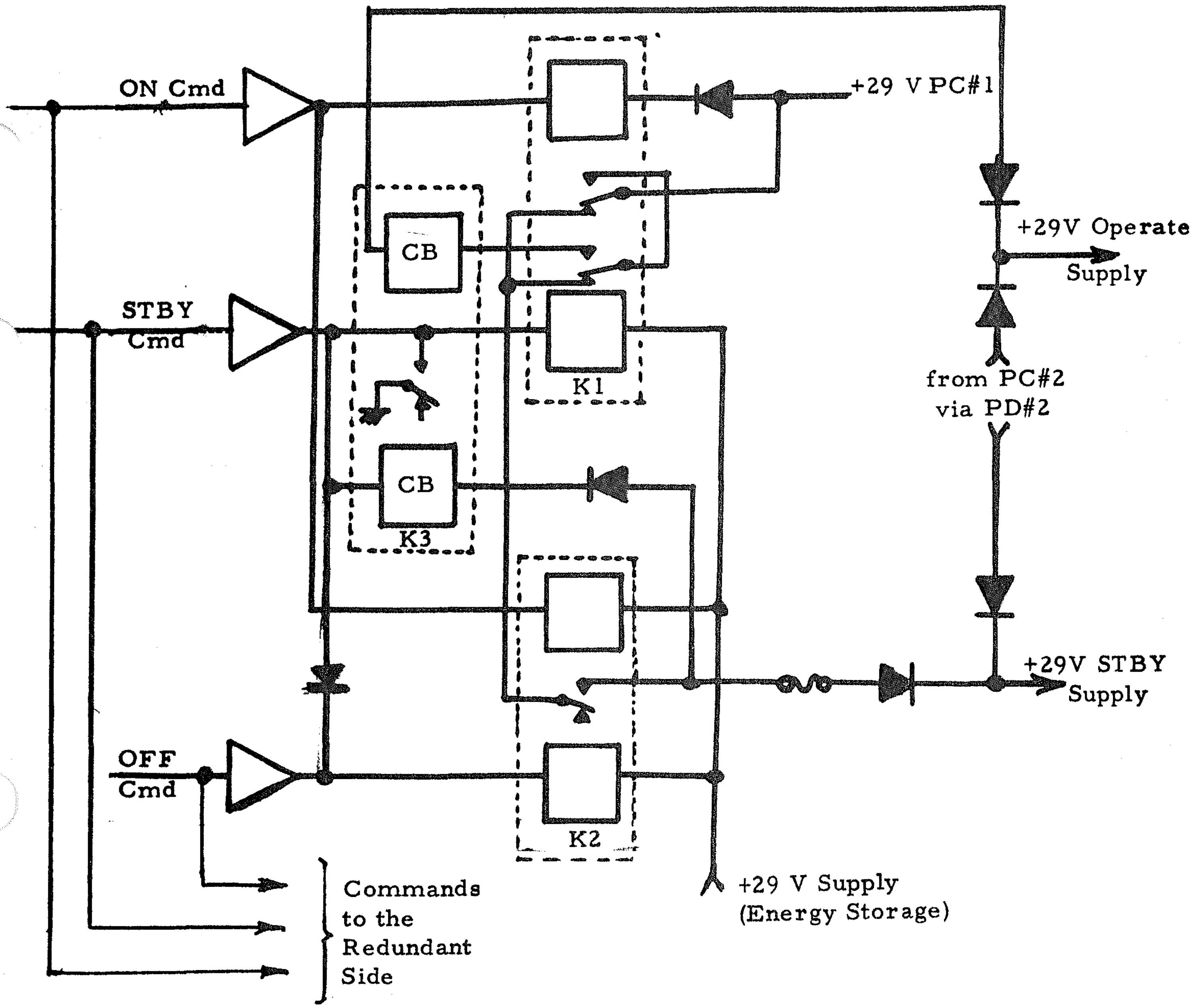
4.1.6. Telemetry

4.1.6.1 Status Telemetry. Status telemetry is provided within the PDU to indicate which of its output lines are energized. The circuits are diode protected potential dividers or resistance summing networks, with diode isolation to block any current flow to an unpowered supply line. Status telemetry is also available indicating the position of the Redundant Power Routing relays in the Uplink/ADP circuitry. All telemetry lines are protected so that potentially damaging voltages are not supplied to the Data Processor (ADP).

Supply lines specifically monitored are:

1. OPERATE and STANDBY lines to all experiments;
2. Uplink Load and Power Routing Relay position;
3. ADP Load and Power Routing Relay position;
4. DDP Load; and
5. PDM Loads.

All the power status telemetry networks are located within a separate telemetry module, except for the Uplink/ADP circuits, which are located within their respective modules.



Steady Power State	Relay Position K1	K2	K3
OFF	DOWN	DOWN	DOWN
ON	UP	UP	DOWN
STBY	DOWN	UP	DOWN
Steady ON	UP	UP	DOWN
ON + OVERLOAD	UP	UP	UP
intermediate state	DOWN	UP	UP
End state = STBY	DOWN	UP	DOWN

Figure 4-5 Simplified Experiment Power Control Circuit

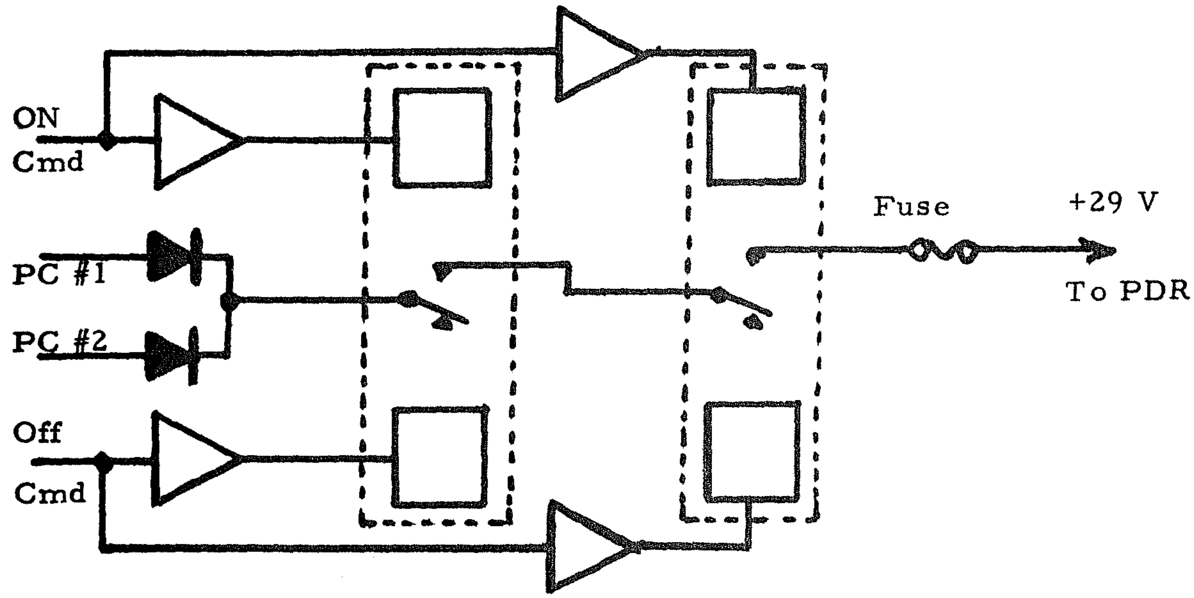


Figure 4-6 PDR Power Control

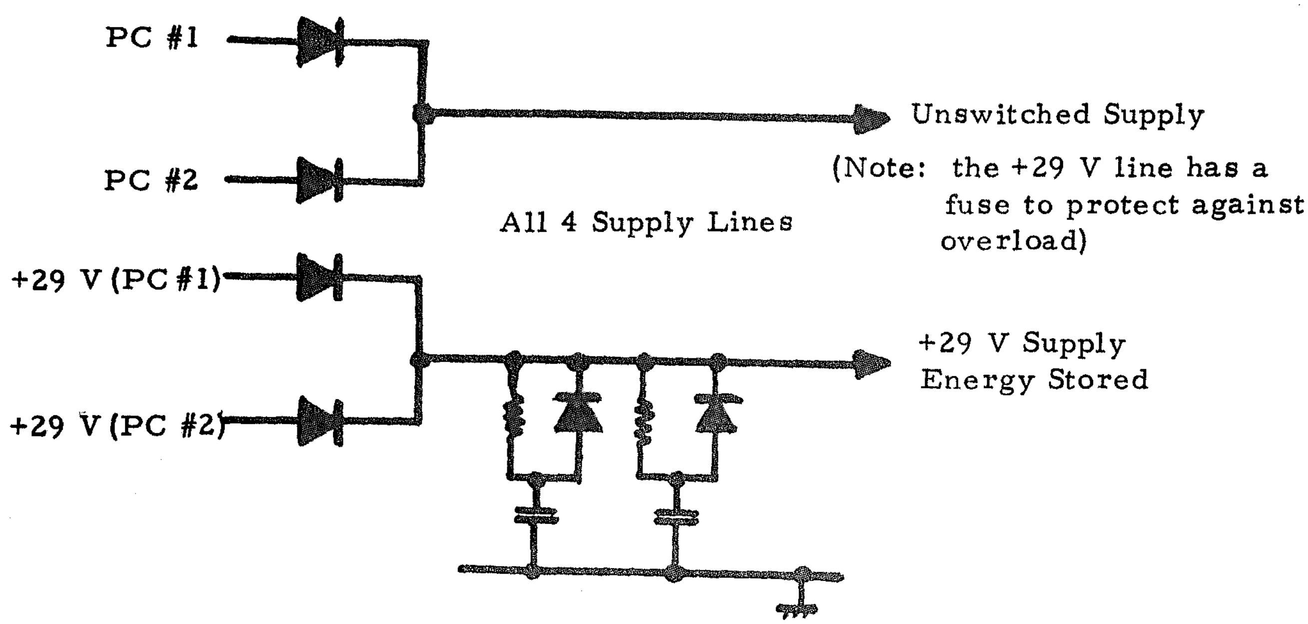


Figure 4-7 Data Subsystem Unswitched Supply Lines

4.1.6.2 Temperature Telemetry. The PDU contains two temperature sensors each monitoring the temperature of the PDU Baseplate in the region of one of the transmitter power switching relays within a range of -25° to $+210^{\circ}F$. Both sensors operate continuously.

4.1.7 Unswitched Supplies

Certain components within the Central Station require unswitched supply lines, regardless of which side of the redundant component is being powered or which PC is supplying that power.

These unswitched supplies are made available by diode "OR" ing the outputs from each PC.

There is also a requirement within the PDU for a power supply to the relays so that the relays may still operate should the +29V Supply line be grounded.

This storage type of supply line is obtained by the use of energy storage capacitors.

The unswitched supplies are shown diagramatically in Figure 4-7.

4.2 COMMAND DECODER

4.2.1 General Description

The ALSEP Central Station and experiment assemblies are commanded from the earth-based Manned Space Flight Network (MSFN) to perform a variety of prescribed functions throughout their useful life on the moon's surface. The command decoder accepts biphase modulated command messages from the uplink receiver and:

1. Extracts the sync information;
2. Converts the data to digital form;
3. Decodes the command information; and
4. Supplies discrete command pulses to the command-controlled circuits.

4.2.1 (Cont.)

A block diagram of the Command Decoder is shown in Figure 4-8. The Command Decoder may be though of as having five sections, three of which are duplicated in redundant A and B units. These units are operated in the redundant uplink chains such that only one unit is powered at any given time.

The five sections of the Command Decoder are as follows:

1. Data Demodulator

2. Control Logic

3. Decode Gates

4. Repeated Command Sequencer

5. Ripple-Off Circuitry.

A Command Message from the MSFN passes from the Receiver to the Data Demodulator. The message is converted into a digital format in the Data Demodulator then passed to a shift register within the Control Logic and on to the Decode Gate Circuitry.

The Command Sequencer provides the functions generating the periodic commands, and the uplink auto-toggle pulses.

The Ripple-Off Circuit switches off the PDR's and commands operating experiments into the standby mode of operation when and if a power shortage occurs in the ALSEP.

Consider the operation of each section of the Command Decoder.

4.2.2 Data Demodulator

A block diagram of the Data Demodulator showing the three basic sections of the unit is shown in Figure 4-9.

These three sections are:

1. Phase Lock Loop and Clock Generator

2. Data Detector

3. Threshold Circuits

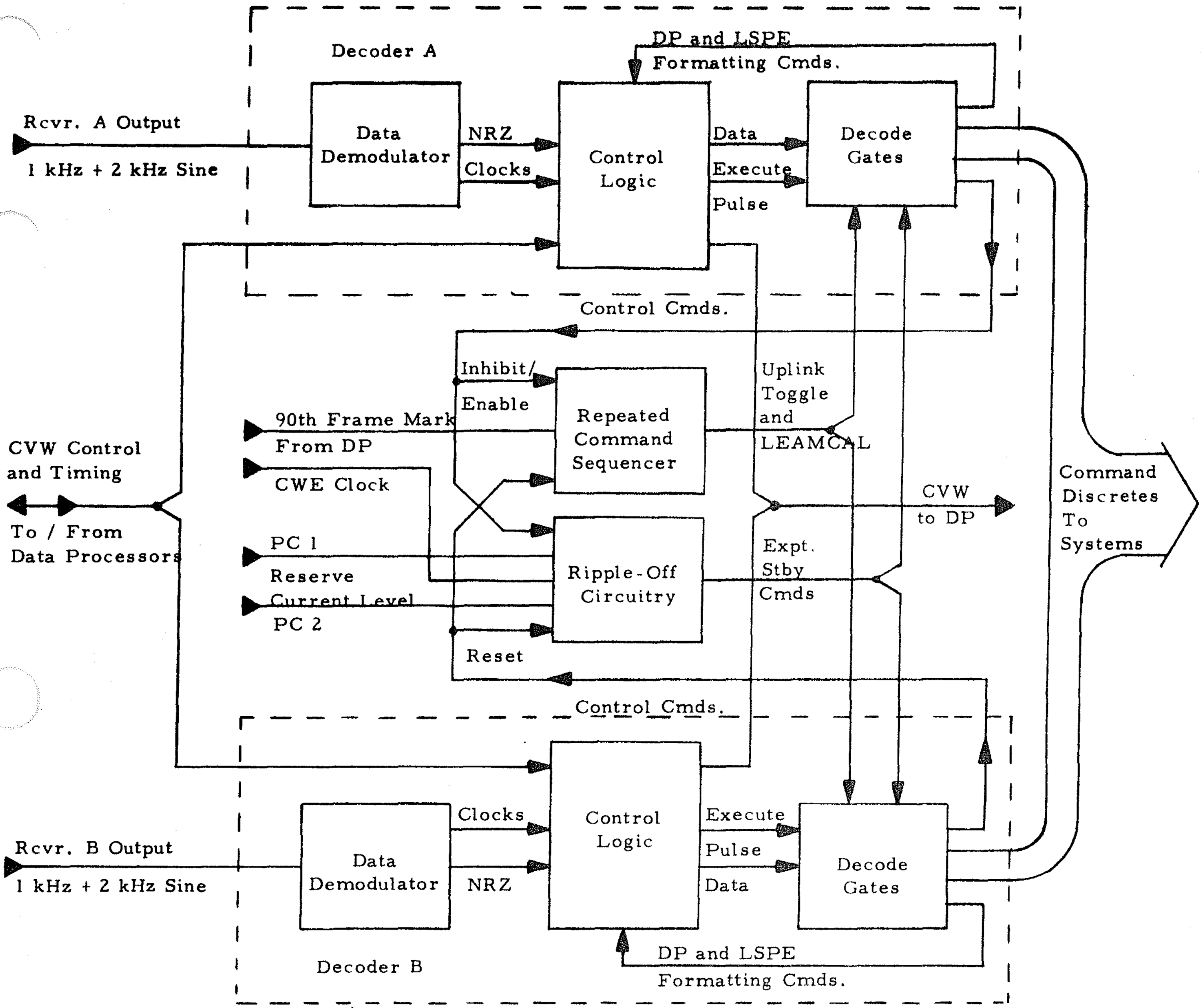


Figure 4-8 Command Decoder

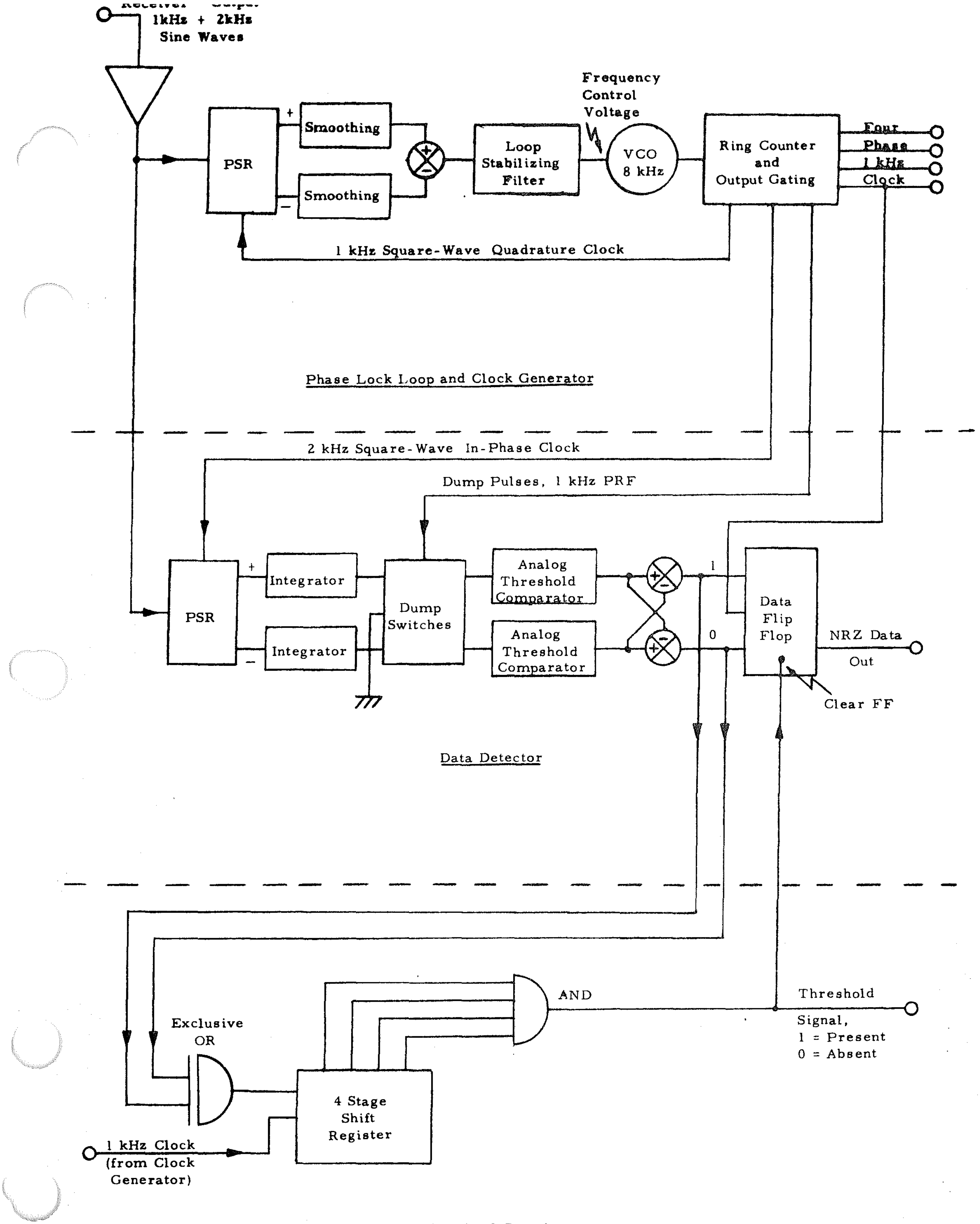


Figure 4-9 Data Demodulator

4.2.2 (Cont.)

The Data Demodulator circuit converts biphase baseband data from the Command Receiver into "Non Return to Zero" (NRZ) digital data and provides the uplink clock and the threshold signals for the Control Logic unit of the Command Decoder.

The Data Demodulator accepts a composite waveform which is the sum of a 1 kHz clock and a 2 kHz data subcarrier. The 2 kHz subcarrier is biphase modulated by 1000 bps serial data.

4.2.2.1 Phase Lock Loop and Clock Generator

The Phase Lock Loop (PLL) provides signals to detect the incoming data and clock it out to the Command Register in the Control Logic Unit by locking on to the 1kHz uplink clock generated by the MSFN.

The phase lock loop contains a voltage controlled oscillator at a free running frequency of 8 kHz. The VCO output is divided by a four stage ring counter so as to generate 4 phases of a 1 kHz square wave. The phase at 90° to the incoming 1 kHz signal drives the phase sensitive rectifier (PSR) switches, so as to produce an error signal proportional to the phase error between the incoming 1 kHz and the locally generated 1 kHz. This error signal is filtered and amplified, and is then used as the control voltage for the VCO. The phases of the 1 kHz clock are also gated together so as to produce the control logic clocks and to provide 2 kHz signals for the data detector.

4.2.2.2 Data Detector

The data detector contains two detection chains, one to detect the "1" bits and the second to detect the "0" bits. Each chain consists of a PSR and an "integrate and dump" circuit. In each chain the incoming audio signal is sampled by the PSR at either the first and third or the second and fourth quarters of a bit period, by the 2 kHz signals generated in the phase lock loop. The output of the PSR has a net positive or negative voltage depending on whether the incoming bit is a "1" or a "0". This voltage is applied to an integrating capacitor for the period of one bit. The capacitor charge is then dumped through a switch to ground. The output of the integrate and dump circuit is compared to a fixed threshold. If a 2 kHz signal of sufficient amplitude, either inphase or out of phase with the 2 kHz reference, is present, only one of the comparators generates a digital "1" output and a valid signal is presented to the J-K flip flop. The comparator outputs are clocked into the data flip flop by a short pulse generated near the end of each bit. Thus, the NRZ data is outputted by the data flip flop, with a one bit delay with reference to the baseband data.

4.2.2.3 Threshold Circuits

The threshold circuits are in two sections.

The analog threshold circuit has already been described in section 4.2.2.2. It ensures that the integrate and dump circuit output is of sufficient amplitude to allow the comparators to produce valid data.

The digital threshold circuit requires that at least four valid data bits are produced before the NRZ data is allowed to pass into the Command Register of the Control Logic. This is accomplished by applying the outputs of the data comparators to an "exclusive or" gate. A digital "1" signal is produced only if the inputs are different i.e., valid data. The "exclusive or" gate output signal is shifted through a 4 stage register by the data flip flop clock, the outputs of each stage of the register are gated so that a digital "1" signal is produced only if all of the shift register outputs are digital "1" 's i.e., four valid bits of data have been detected successively, which is possible only if the system has achieved phase lock. The output of this gate is the digital threshold signal, and is used to inhibit the data flip flop as well as resetting the control logic in the event of a data dropout. Removal of the uplink modulation (or carrier) may be used to force a control logic reset via the threshold signal.

4.2.3 Control Logic

The Control Logic consists of an eight bit shift register, two counters, and reset circuitry, as shown in Figure 4-10. The demodulated data from the MSFN passes through the shift register (Command Register) at the uplink data rate of 1 kHz. The first seven bits of the shift registers are constantly sampled for the Array E address (1101001) vy the address recognition gate.

When the address is recognized, a timing sequence is initiated. The first counter counts seven clock pulses. Its output clocks a binary counter which acts as the master timing control. After address recognition, the following seven pulses shift the command complement into the Command Register.

The binary counter (now in the state 001), ensures that the next seven bits of data (the command) clocked into the Command Register are checked for parity. An "exclusive or" gate compares the first and the last bits of the shift register so as to perform a parity check on the corresponding bits of the command and the command complement. A failure to achieve parity will set the parity memory to "false".

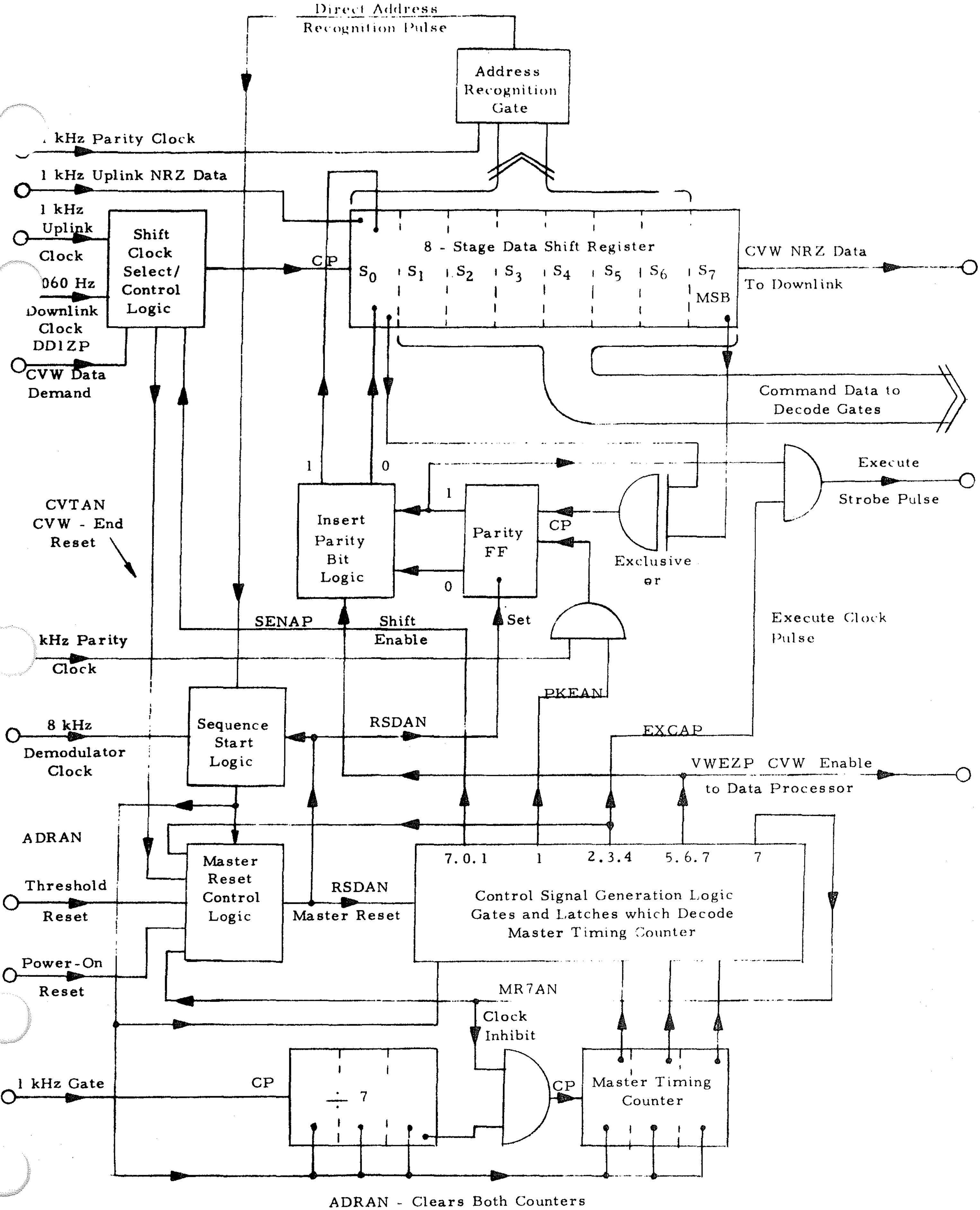


Figure 4-10 Control Logic

4.2.3-(Cont.)

The following three states of the binary counter occupy a time of 21 mS and define the command execute sequence by setting a latch, while inhibiting the clock pulses to the command register by means of a second latch. At this time, the command register will contain the received command in its last seven bits.

The command sequence pulse is gated with the parity memory to produce a command execute pulse, causing the command line corresponding to the command contained in the command register to be activated, executing the command. This only occurs if the parity check is valid.

After the command has been executed, a digital signal (VWEZP) is sent to the Data Processor by a timing latch, causing a data demand signal DD1ZP to be sent back to the command decoder during the Command Verification Word interval in the downlink telemetry frame. A dual flip flop gates out the first two data shift pulses received from the Data Processor, effectively inserting two filler bits into the Command Message and then allows the next eight data shift pulses to transfer the contents of the command register to the Data Processor as the signal (ED1ZP). In the 10 bits of the CVW received by the MSFN, the first two bits are filler bits, and are identical to the most significant bit of the command word, which occupies bits 3 to 9. The tenth bit is the parity check bit, in which a digital "1" indicates valid parity and the execution of a command.

A master reset occurs at the end of the data demand pulse. It resets all latches to the address search mode. The two counters that control the timing are not reset by this master reset, the counting continues until an automatic self lock at a count of 111 occurs. The master reset pulse which is raised at the end of the data demand pulse is terminated by the next address recognition. The two counters are reset to 000 whenever an address is recognized.

When the Central Station Data Subsystem is commanded into the "LSP Formatting" mode of operation, no data demands are generated by the Data Processor and an alternative means of achieving master reset is used. A latch generates the high data rate command EXFZN sent to the Data Processor, and utilizes the last 1 mS of the 21 mS command execute period to the master reset. This has a side effect of causing all command pulses to be 20 mS long while the Central Station Data Subsystem is operating in the "LSP Formatting" mode of operation.

4.2.3 (Cont.)

There is a set of six status signals within the control logic which defines the command decoders operating mode. Five of the signals are derived via decode gates and latches from the master control counter, the sixth from the CVW data demand pulse.

The six status signals are:

MR7AN	Master Control Counter 7 Count
SENAP	Shift Enable to Uplink Shift Register
EXCAP	Execute Command Clock Pulse
VWEZP	Command Verification Word Enable to the Data Processor
CVSAP	CVW Shift Enable from the Data Processor

Table 4.2-1 shows the relationships between the Master Control Counter Setting, and the Operating Mode and Status Signals.

TABLE 4.2-1

CONTROL LOGIC MODES AND CORRESPONDING STATUS SIGNALS

Master Control Counter Setting	Operating Mode	MR7AN	SENAP	PKEAN	EXCAP	VWEZP	CVSAP
7	Address Search	1	1	0	0	0	0
0	Read Complement	0	1	0	0	0	0
1	Read Command	0	1	1	0	0	0
2 3 4	Execute Command	0	0	0	1	0	0
5	CV Wait 1	0	0	0	0	1	0
6	CV Wait 2	1	0	0	0	1	0
7	Downlink CV	1	0	0	0	1	1

4.2.4 Decode Gates

The decode gate matrix decodes the seven bit command into individual command lines. A command execute pulse is utilized to achieve the correct command pulse period of 20 $\pm$ 2 mS.

The decoding takes place at two levels. The first level creates outputs from the combinations of the first four bits (16), and from the combinations of the remaining three bits (8) of the command in the command register. This is accomplished by the use of four-input gates, with the fourth input of the group of eight gates being used for the command execute strobe pulse.

The output decoding is carried out by the use of two-input gates, all inputs being associated with each of the two groups of the first level gates as shown in Figure 4-11. This ensures that each output is dependent on the states of all seven input bits as well as on the command execute pulse.

One hundred and four discrete commands may be decoded and utilized within the ALSEP. Rise time control networks are provided on 53 command output lines.

4.2.5 Repeated Command Sequencer

The repeated Command Sequencer consists of a binary counter with decoding logic wired to the Experiment Calibrate command lines as shown in Figure 4-12. The sequencer also functions as an uplink changeover command generator so as to ensure a switch from one uplink chain to the other in the event of an uplink failure.

The clock pulse applied to the binary counter is the 90th frame mark, a pulse 118 μS long appearing every 54 seconds, generated by the Data Processor. The repeated Commands are generated by sensing the binary count of the first 10 bits of the binary counter. Since only the 10 least significant bits of the counter are sensed, the count repeats after approximately 15.4 hours. Each number in the count lasts for one clock pulse period (i.e., 54 seconds), so an 18.8 mS strobe is generated to produce the correct time period for a command. This strobe pulse is started by the 90th frame mark and is ended at the start of the control word three pulse, THRZN, also obtained from the Data Processor.

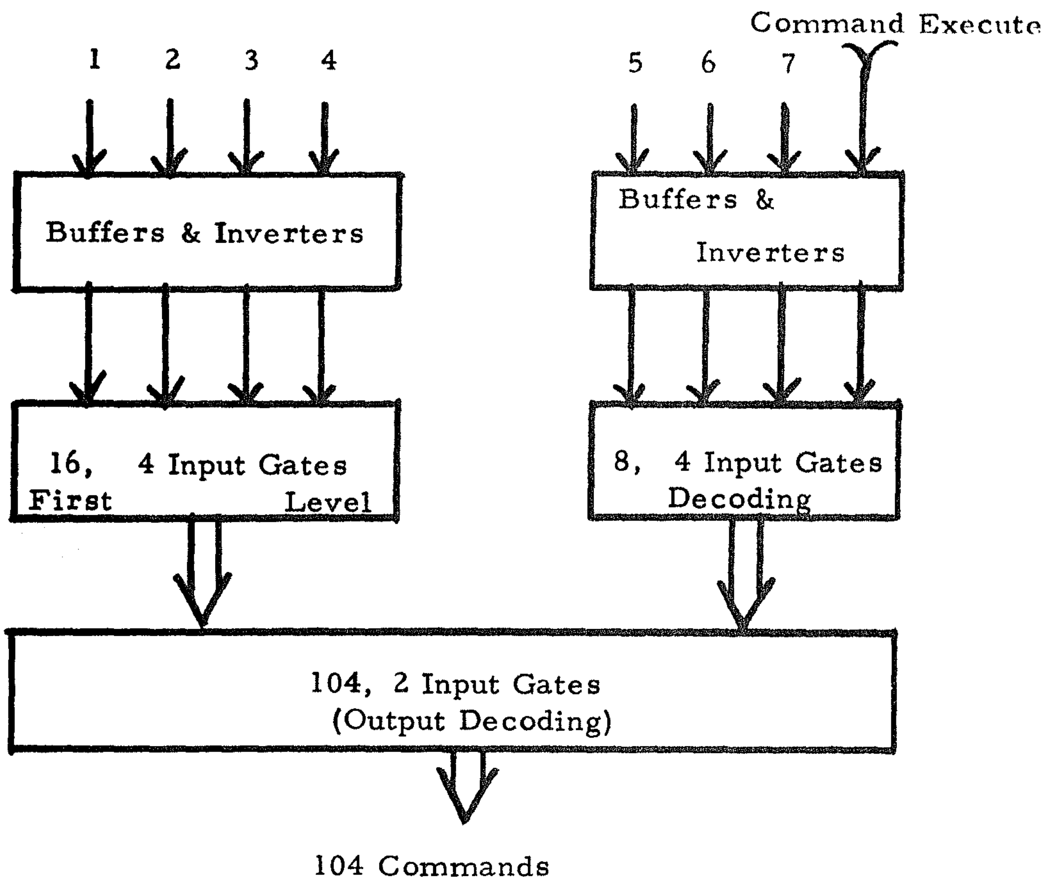
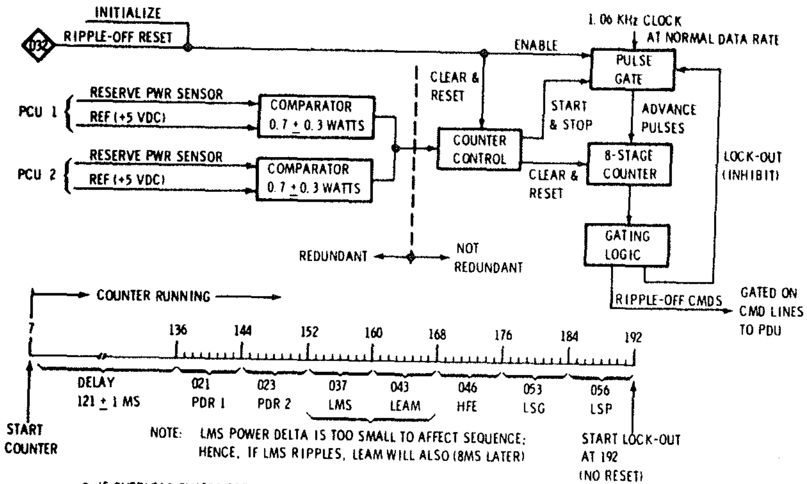


Figure 4-11 Decode Gates

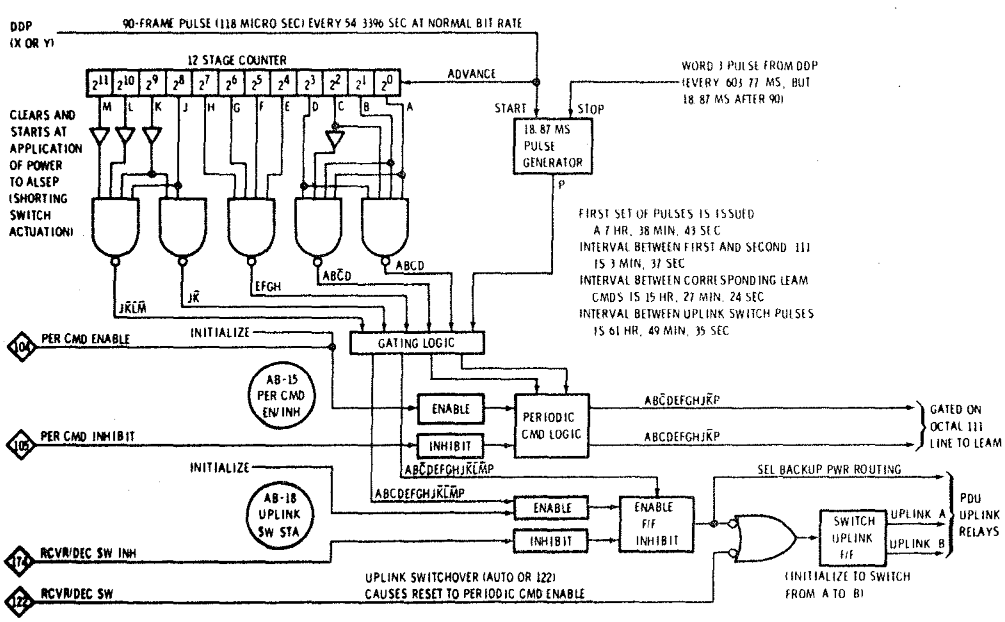
RIPPLE-OFF SEQUENCER FUNCTION



- IF OVERLOAD EXISTS FOR 121 ± 1 MS, THEN PDR OFF AND EXPER STBY CMDS ARE ISSUED SEQUENTIALLY FOR 8 COUNTS EACH UNTIL OVERLOAD NO LONGER EXISTS
- WHEN OVERLOAD IS CLEARED, THE COUNTER IS RESET TO 7 AUTOMATICALLY AND NO FURTHER RIPPLE-OFF CMDS ARE ISSUED
- NOTE THAT EXPERIMENTS CAN NOT SWITCH FROM OFF TO STBY; IF THEY ARE OFF, THEY REMAIN OFF
- IF COUNTER RUNS TO 192, IT MAY BE A RIPPLE-OFF MALFUNCTION; THEREFORE, A LOCK-OUT FEATURE IS PROVIDED TO INHIBIT FURTHER COUNTER ACTION. EXPER/PDR SHOULD BE RESET BY CMD AND THEN ISSUE CMD 032 TO CHECK PERFORMANCE.
- PCU SWITCHOVER MAY CAUSE INITIALIZATION AND CLEAR LOCK-OUT IF IT EXISTS

MAY 72 3270.2.57

UPLINK AND PERIODIC CMD FUNCTIONS
(NOT REDUNDANT)



MAY 72 3270.2.54

Figure 4-12

4.2.5 (Cont.)

Once the commands are generated, they are "OR'd" with the experiment calibrate command lines in the redundant section of the command sequencer. There is also a commandable "enable/inhibit repeated commands" flip flop within this redundant section which allows the MSFN to inhibit the periodic calibrate commands feature. The inhibit feature also permits the disabling of the periodic command sequencer in the event of a failure in any part of the non-redundant circuitry.

The Periodic Command pulses in each 15.4 hour three-pulse group are generated at intervals of 3.6 minutes; however, since the LEAM experiment requires two calibrate pulses, the Octal 065 calibrate pulse is "OR'd" into the LEAM calibrate command line so as to produce two LEAM calibrate pulses about three and a half minutes apart. The order of the experiment calibrate commands generated every 15.4 hours is thus Octal 065 and Octal 111 (LEAM), Octal 111, Octal 131.

The 12-bit binary counter also acts as the automatic uplink changeover counter by producing a 19 mS strobed switchover command every 61.8 hours. If during the previous 61.8 hour period on MSFN "Delay Uplink Switchover" command has been received it will inhibit the switchover. This command should be transmitted during each operating period, so that the Uplink will remain permanently in one state. However, should this Uplink fail, the command will not be received, and the automatic uplink switchover command will be executed. The initial turn-on state of the counter is such that the first automatic uplink switchover command will occur at 7.6 hours, between the first and second EVA's.

4.2.6 Ripple-Off Circuit

The Ripple-Off circuit consists of an 8-bit binary counter and the relevant decoding gates as shown in Figure 4-12. The counter is clocked by the CWE clock, a 1060 Hz clock generated by the Data Processor. The loss of a "reserve power" signal from the PCU causes the seven power loads to be switched sequentially to a lower power mode of operation after a predetermined length of time.

4.2.6 (Cont.)

During a switching sequence, the PDM external loads are commanded to "Off" and an experiment which is "On" is switched to "Standby". Experiments which are already at "Off" or "Standby" are unaffected and remain in their current state. The order in which the loads are switched is:

7W External Load
14W External Load
LMS
LEAM
HFE
LSG
LSP

The counter is set to a count of 7 by the Power-On reset pulse. If the reserve power signal becomes a digital "0", the clock pulses to the counter are enabled, and the count starts. If the reserve power line is still at a digital "0" when a count of 136 has been reached, an output pulse lasting for a period of 8 input clock pulses will be generated on the first command line. If the lack of reserve power continues each of the remaining six command lines will successively receive pulses lasting for the periof of 8 input clock pulses.

There is thus a delay of about 120 mS before the first Ripple-Off pulse is sent to the PDU. Pulses are transmitted at intervals of the order of 8 mS until the Reserve Power has increased so as to inhibit the operation of this circuit, as discussed below.

If the reserve power line changes back to a digital "1" state during the sequence, a command pulse being executed will remain valid for its period, equal to 8 input clock pulses. This is ensured by delaying the resetting of the counter and the inhibiting of the clock pulses until a binary count of 111 exists in the first three stages of the counter.

If the circuit ripples-off all seven power loads, the clock pulses are inhibited by a second line driven by a gate sensing "1's" in the last two stages of the counter. This second mode of inhibiting the clock pulses is a stable state and can only be reset by a MSFN command. This feature and the redundancy in the decode gates ensure that no single point failure exists on any of the output lines.

4.3 DATA PROCESSOR

4.3.1 General Description

The data processor consists of two identical digital data processors (DDP) and two identical analog data processors (ADP). Each ADP contains a ninety channel analog multiplexer and an analog-to-digital converter (ADC). DC Power switching and cross-strapping circuits are used so that either ADP can be used with either DDP. Only one DDP and ADP are powered at any given time.

The data processor also contains signal conditioning circuitry for the RTG and some other temperature sensors, and voltage scaling resistor networks. A functional block diagram of the Data Processor is shown in Figure 4-13.

The data processor supplies status information so as to identify which of the redundant ADP or DDP units are operational at any given time.

The data processor is capable of two modes of operation each at two bit rates, as described in the following paragraphs.

4.3.1.1 DP Formatting Mode. In this mode of operation, the data processor collects both digital and analog data from each of the experiments, except LSPE, and analog housekeeping data from the Central Station in accordance with the pre-programmed format. Each analog signal is sampled once every 90 telemetry frames and converted to an 8-bit digital word.

The data processor formats the collected data into an NRZ (C) serial bit stream, and then Manchester encodes it. The encoded bit stream is output to modulate the downlink transmitters.

4.3.1.2 LSPE Formatting Mode. In this mode of operation, the data processor provides data shift pulses and 28 kHz sub-bit timing pulses to the LSP experiment. At the same time it accepts formatted serial NRZ (C) data from the experiment, Manchester encodes it, and outputs it to the downlink transmitters. The data collection and formatting that occurs during the "DP Formatting" mode of operation is inhibited.

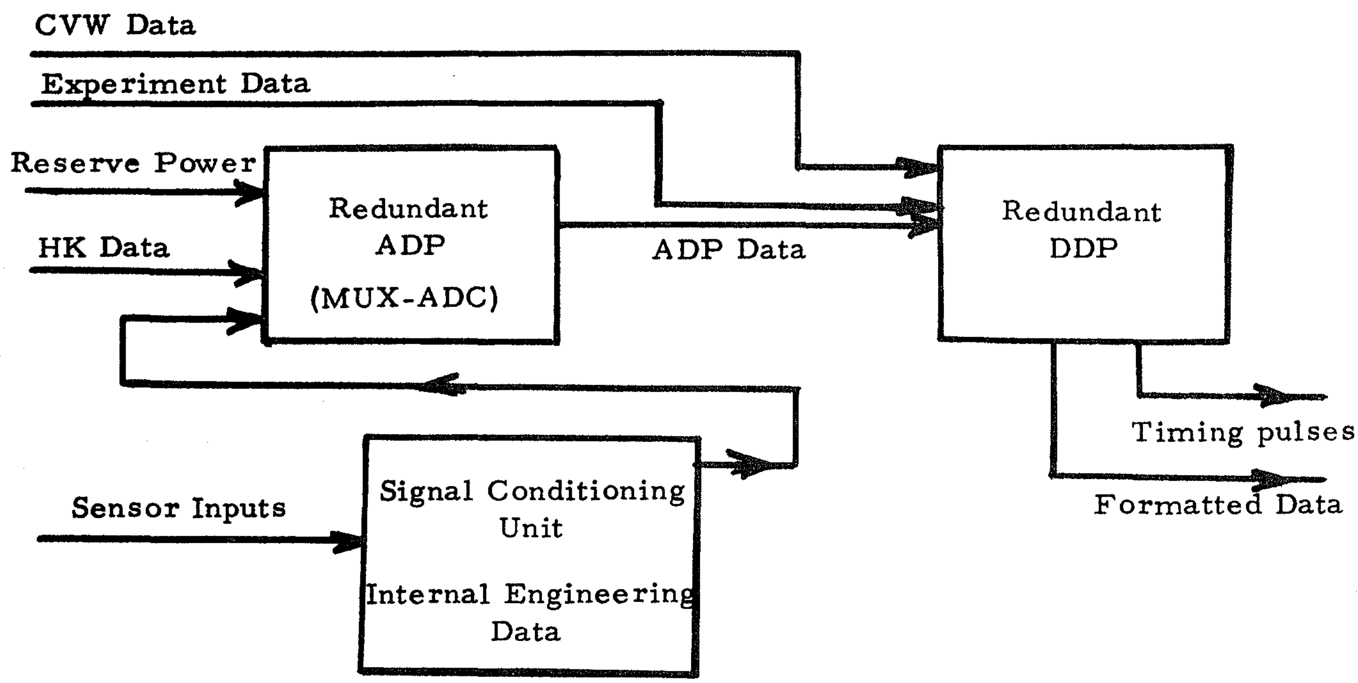


Figure 4-13 Data Processor

4.3.1.3 Bit Rates. The data processor can operate in one of two bit rates at any time. These two bit rates are called the "Normal" and the "Slow" bit rates.

4.3.1.4 The Normal Bit Rate. In the "DP Formatting Mode" of operation the bit rate is 1060 bps. In the "LSPE Formatting Mode" of operation the bit rate is 3533.3 bps.

4.3.1.5 The Slow Bit Rate. In the "DP Formatting Mode" of operation the bit rate is 530 bps. In the "LSPE Formatting Mode" of operation the bit rate is 1060 bps.

4.3.1.6 Changeovers. A commanded changeover from any mode of operation to any other mode of operation or from one bit rate to another, occurs only at a time corresponding to the end of the sixty-fourth word of a DP format data frame and the start of the first work of the following data frame, irrespective of the time the command was received during the frame.

If a power supply glitch occurs the data processor may revert to the "DP Formatting Mode" of operation when the power supply recovers, or it may change bit rate while remaining in the same formatting mode. The determining factors are the depth and duration of the power glitch, and their effects upon the system power reset circuits.

4.3.2 Analog Data Processor

4.3.2.1 Configuration

The Analog Data Processor (ADP) contains two redundant chains, each consisting of an Analog Multiplexer and an Analog to Digital Converter (ADC) circuit. Redundancy is achieved by paralleling the inputs and outputs of each multiplexer - ADC combination and by applying power to only one of the two circuits at a time, as shown in Figure 4-14. The ADP also contains non-redundant signal conditioning circuits for some temperature and voltage monitoring channels. These signal conditioning circuits receive power continuously.

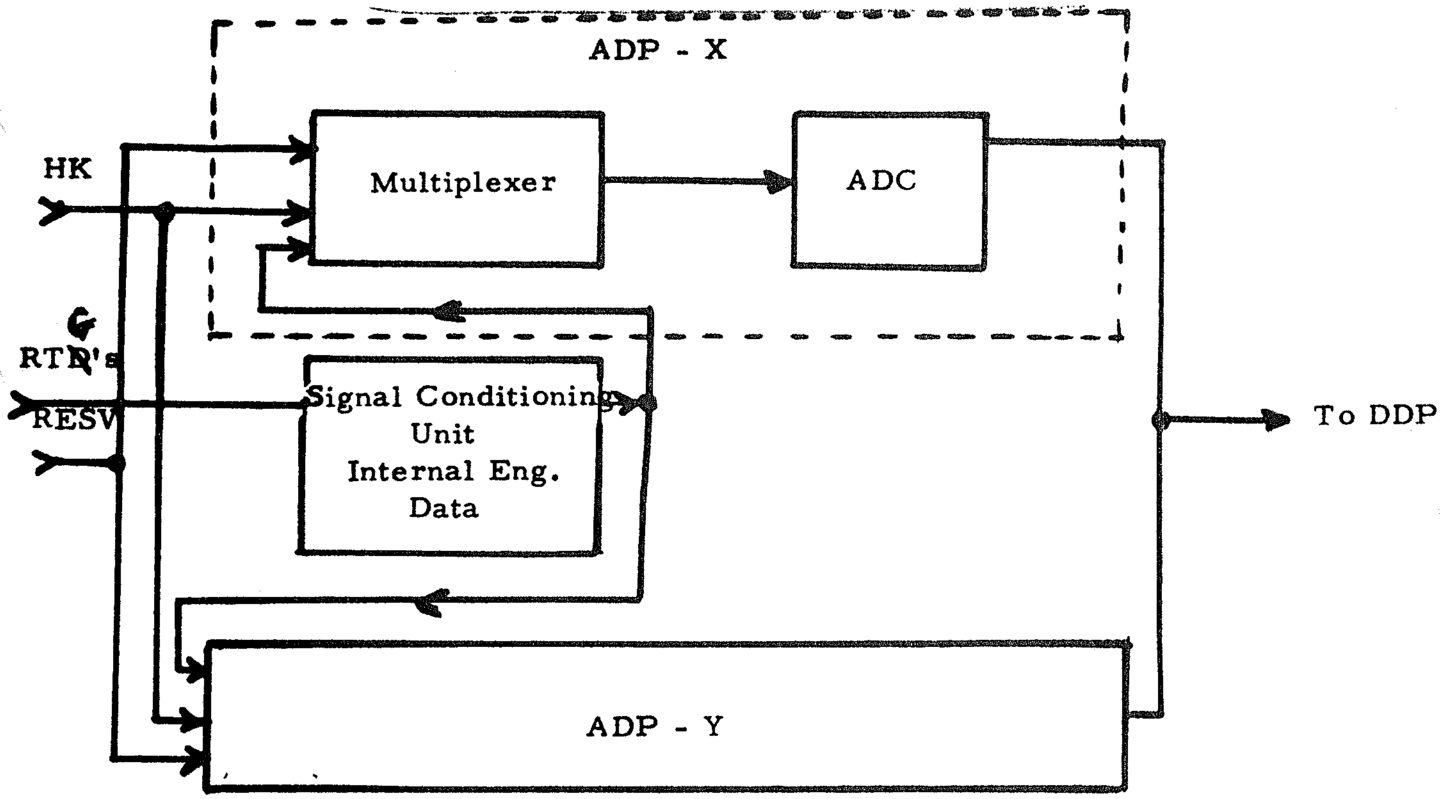


Figure 4-14 Analog Data Processor (ADP)

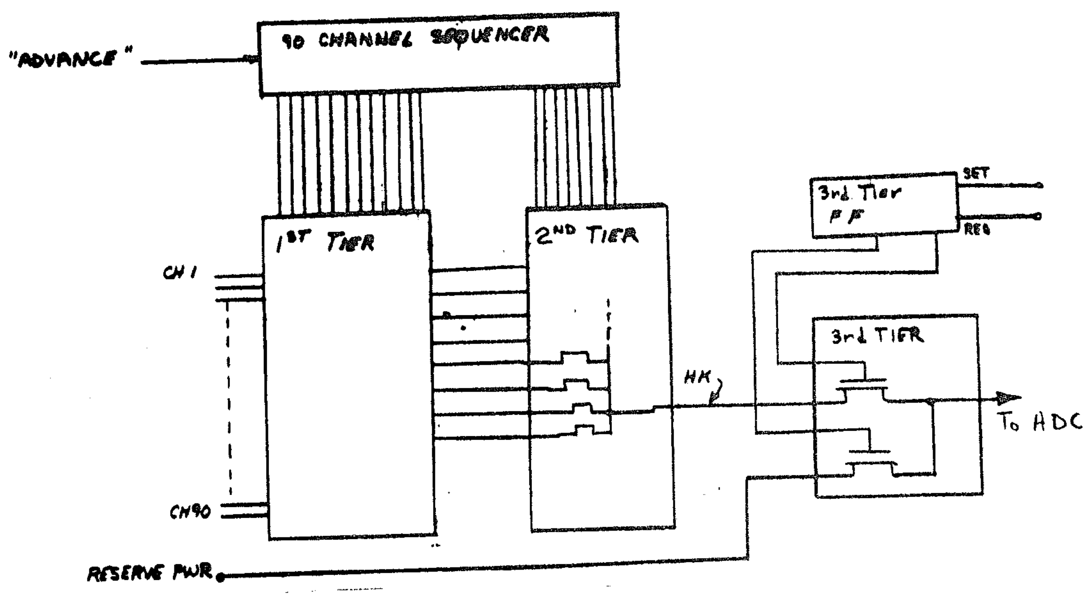


Figure 4-15 Analog Multiplexer

This page intentionally left blank - Page 4-30 was missing from this document.

4.3.2.2 (Cont.)

During the entire period that the multiplexer is sampling Channel 90, a signal allowing the generation of the 90th frame pulse, while simultaneously resetting the frame counter in the digital Data Processor to zero, is generated.

After Channel 90 has been sampled, the multiplexer is reset, so as to sample Channel 1, by the Analog Multiplexer Advance Pulse from the digital Data Processor, and the sequence then repeats.

The input impedance of each channel of the analog multiplexer is of the order of 50 Megohms in the non-sampling state. In the sampling state the analog multiplexer represents a series impedance of the order of 350 ohms in the analog line, but the load impedance seen by the analog source still exceeds 10 Megohms.

4.3.2.3 Analog to Digital Converter (ADC)

The ADC accepts analog data from the multiplexer converts it to digital data in the form of a ten bit word and transfers it in serial format to the DDP. The first two bits of the ten bit word are filler bits and are always binary zeros. The remaining eight bits are the digital data output with the most significatnt bit (MSB) in the bit 3 position and the least significatn bit (LSB) in the bit 10 position.

The ADC is shown in outline form in Figure 4-16. It uses the Ramp generator-comparator ADC method, in which the input voltage is compared to a linear ramp voltage, while a counter advances one bit per unit voltage increment. The counter is stopped when the ramp voltage exceeds the input voltage. The number in the counter is read out to a buffer storage register as the binary equivalent of the magnitude of the analog voltage.

The conversion takes place following the receipt of a "start conversion" pulse from the control logic section. The conversion is over in less than 140 μS after the trailing edge of the "start conversion" pulse.

The Ramp generator is then reset, the counter cleared and the converter waits for a "start conversion" pulse to initiate the next ADC sequence.

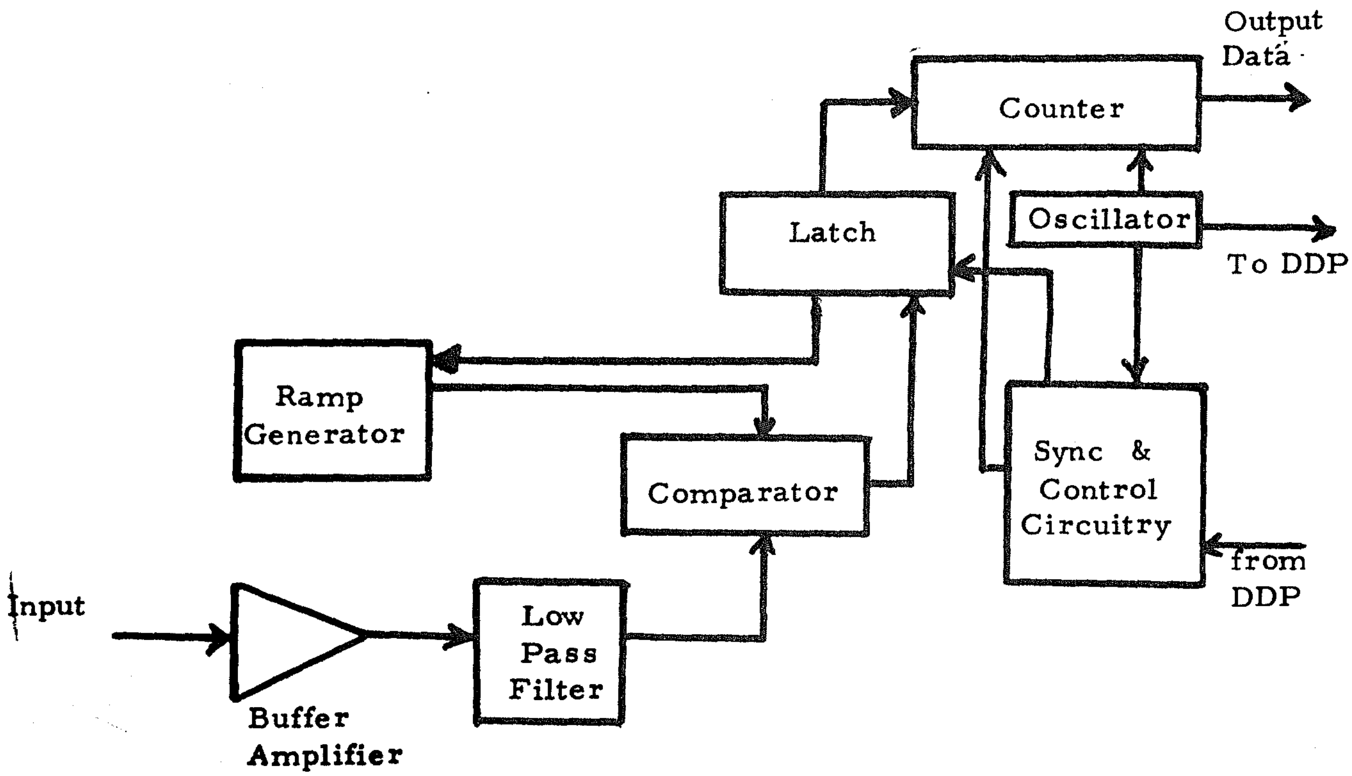


Figure 4-16 ADC Block Diagram

4.3.2.3 (Cont.)

The timing pulses are generated by the buffered output one of a pair of Crystal Controlled Oscillators, at a frequency of 2.0352 MHz. These oscillators are physically located on the ADP cards, but electrically parts of the redundant DDP's. One oscillator is associated with each DDP, and either ADP may be run with either oscillator, depending upon which DDP is selected. The 2.0352 MHz is divided by twelve to provide the basic Data Processor clock frequency of 169.6 kHz.

The Low Pass filter between the Buffer Amplifier and the Comparator is a 1 mS time constant R-C network.

The following specifications apply to each redundant ADC.

Input impedance during sampling	10^7 ohms
Conversion time	140 μSec
Analog Accuracy	±0.3%
Quantizing level	20 mV
Quantizing error	±0.5 bit
Output format	Serial
Resolution	8 bits
Safe input voltage range	-12V to +12V
Input voltage range for conversion	0 to +5V

4.3.2.4 Signal Conditioning Unit

The Signal Conditioning Unit contains the following telemetry circuits.

(1) ADC Calibration Circuitry
(2) Power Supply Voltage Monitor Circuitry
(3) Temperature Sensor Supply Circuitry
(4) Data Processor Status and Temperature Telemetry Circuits
(5) RTG Temperature Sensor Circuitry

These circuits are described below.

4.3.2.4.1 ADC Calibration Circuitry. Zener diode stabilized signals are derived from the +12V supply via voltage divider networks within the unit to provide the following output voltages:

CAL HI +4.750V
CAL LO +0.25V

4.3.2.4.2 Power Supply Voltage Monitor Circuitry. These are simple resistance divider networks, so as to scale down the DC voltages in the Central Station to within the input range of the ADC. The networks are protected, so that a failure in the network does not cause a voltage input to the ADP that is greater than ± 12 VDC.

The characteristics of the four networks are as shown below:

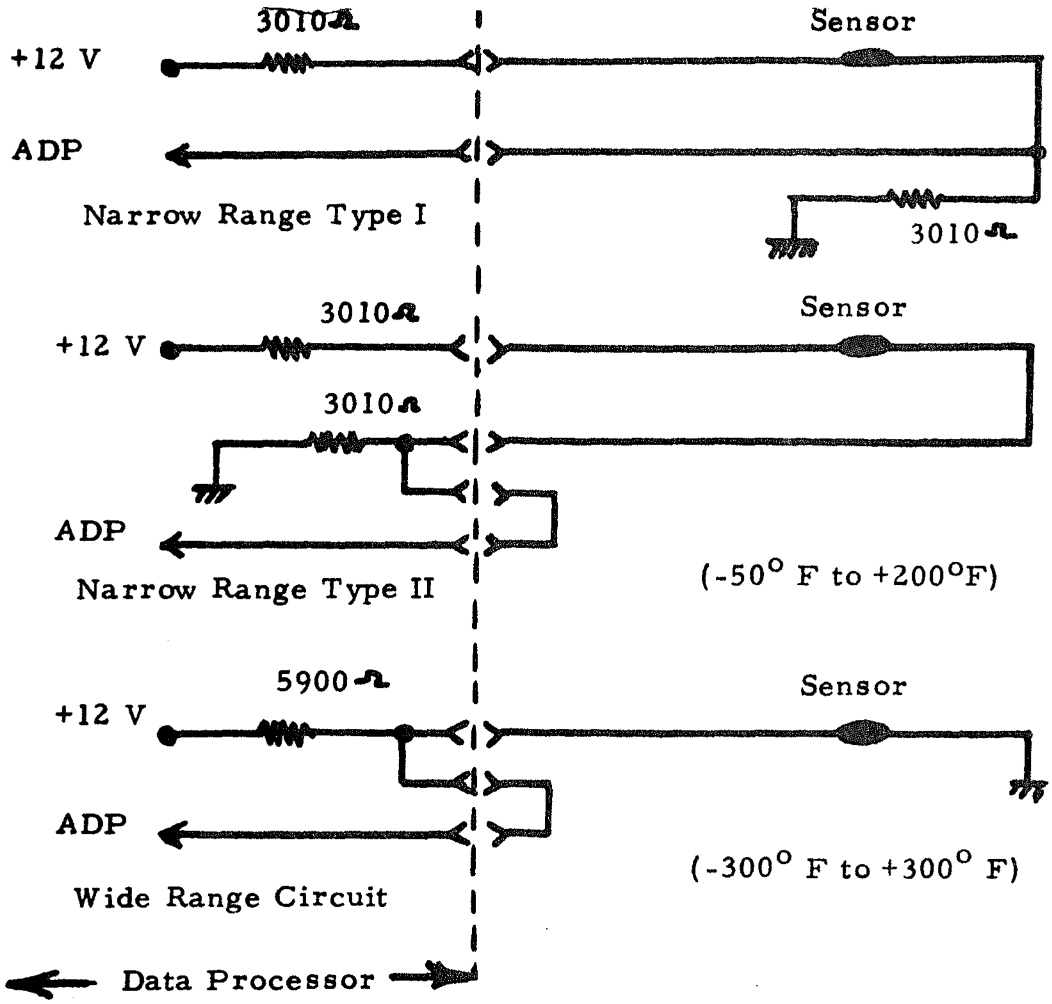
Measured Voltage	Nominal Output	Sensor Range
+29V Supply	4.125 V	0 to 35V
+12V Supply	4.0 V	0 to 15V
-12V Supply	4.0 V	-9 to -18 V
+5V Supply	4.167V	0 to 6V

4.3.2.4.3 Temperature Sensor Supply Circuitry. There are two types of temperature sensors used in Array E, namely, wide range (nickel-wire) and narrow range thermistor temperature sensors; the circuitry in use is shown in Figure 4-17.

4.3.2.4.4 Data Processor Temperature and Status Telemetry Circuits. Two temperature sensors are present inside the Data Processor monitoring the internal temperatures. These circuits are identical to those used for the rest of the ALSEP Narrow Range Temperature Sensors.

The Status telemetry sensors are potential divider networks across the power supplies indicating which redundant ADP or DDP is powered at any given time.

4.3.2.4.5 RTG Temperature Sensor Circuitry. Six platinum wire sensors are located within the RTG so as to provide signals monitoring the hot and cold frame temperatures. The resistance of the hot sensor varies from 2950 ohms at +1000°F to 3310 ohms at +1200°F. The resistance of the cold sensor varies from 1675 ohms at +350°F to 2085 ohms at +550°F. Three of the sensors monitor the hot frame and three the cold frame. Each sensor is wired in a circuit as shown in outline format in Figure 4-18.



NOTE: The LSP Electronics Internal Temperature Sensor (HK-25) is the only Type II sensor circuit in the ALSEP

Figure 4-17 Temperature Monitoring Circuit

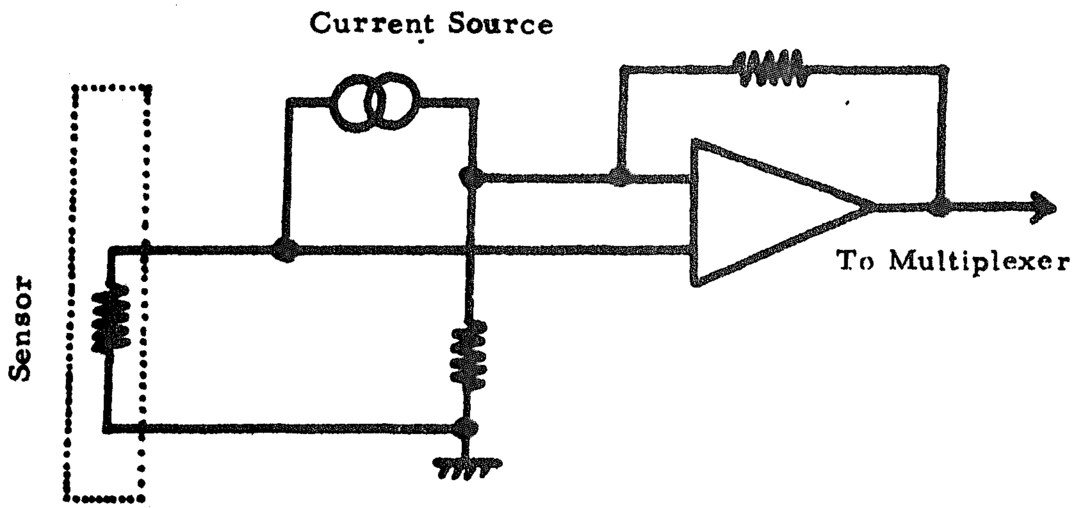


Figure 4-18 RTG Temperature Sensing Circuitry

This page intentionally left blank - Page 4-38 was missing from this document.

DDP FUNCTIONS

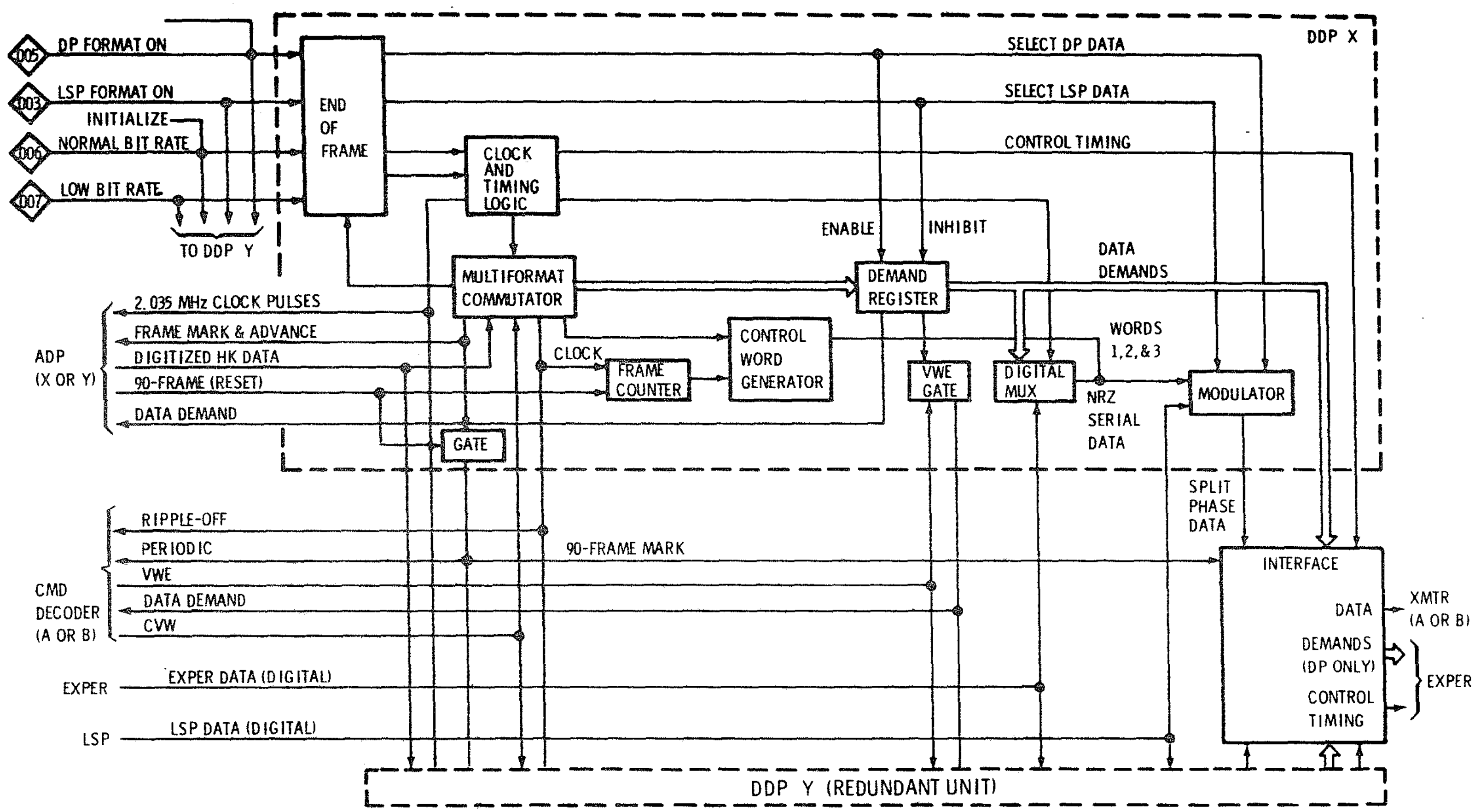


Figure 4-19

MAY 72 3270.2.34

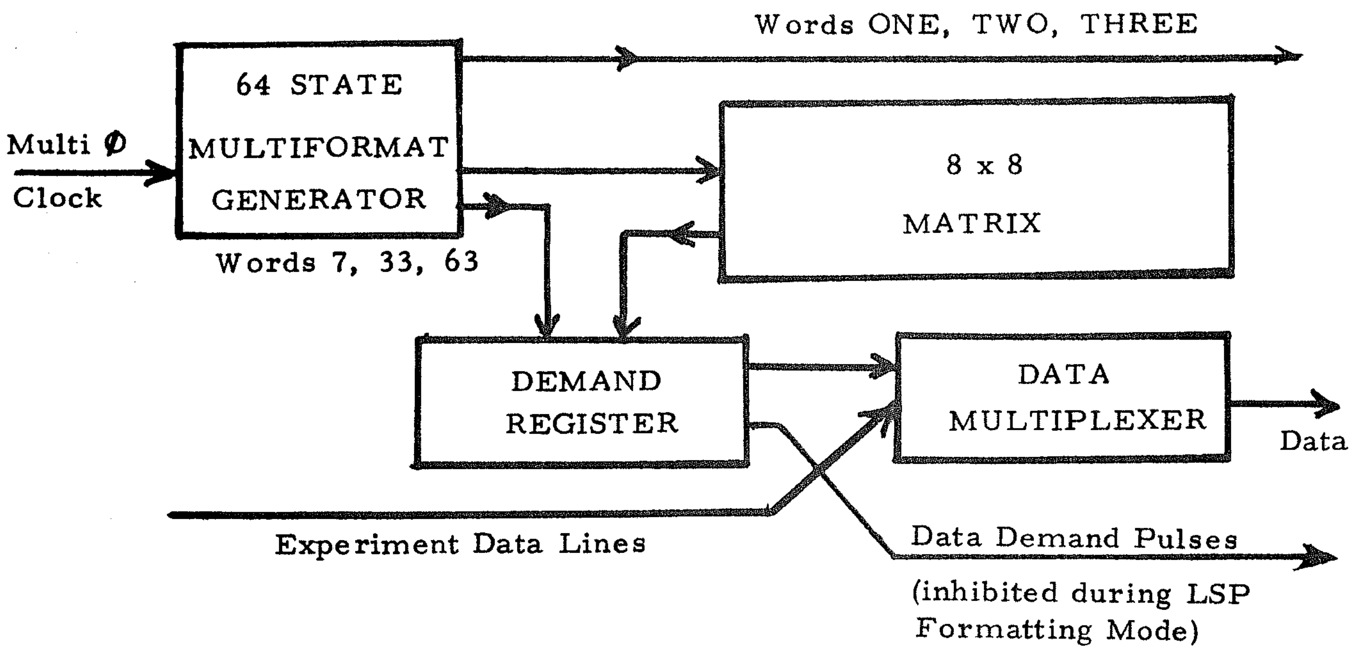


Figure 4-20 Demand Matrix

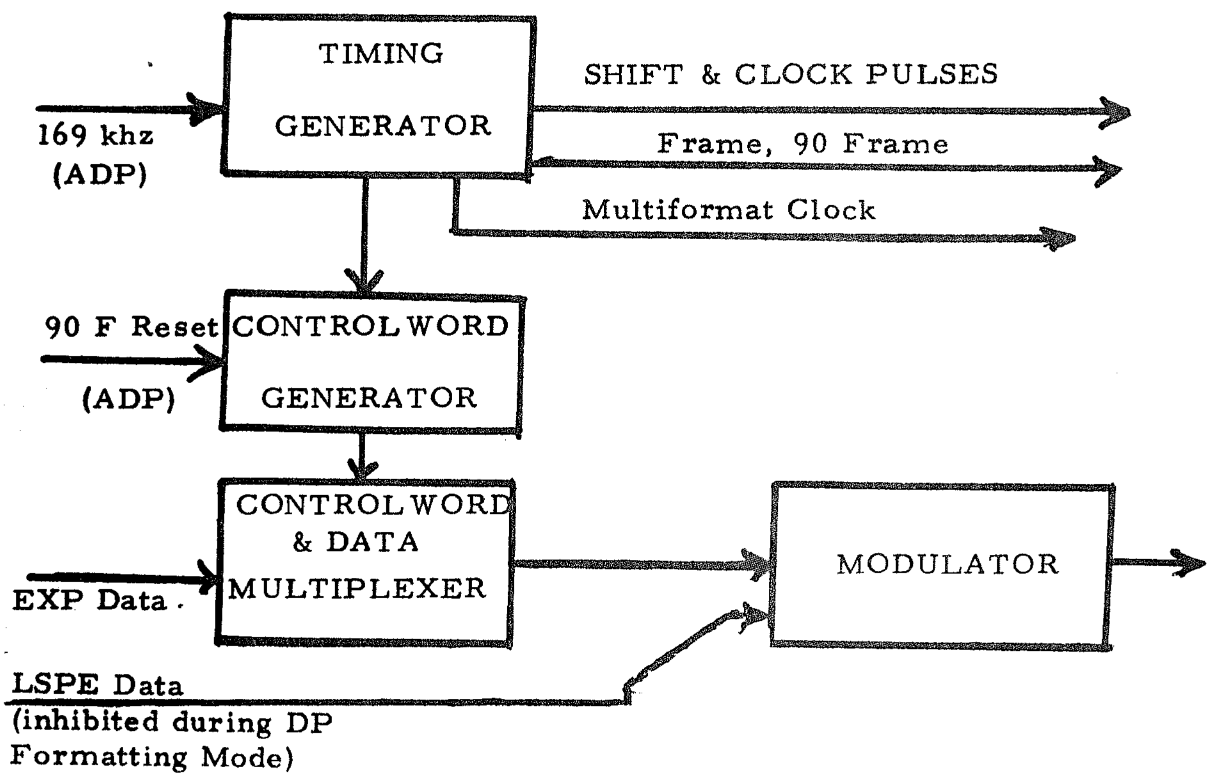


Figure 4-21 Timing and Control Word Generator

4.3.3.3 Timing and Control Word Generator

The function of the Timing and Control Generator is as follows:

1. The generation of all primary timing signals
2. The generation of Control Words One, Two , and Three
3. Manchester Encoding of Downlink Data

The operation of the Timing and Control Word Generator is controlled by the Uplink. The modes of operation are as described in Section 1.5.2.

A block diagram of the Timing and Control Word Generator is shown in Figure 4-21.

The timing generator is essentially a series of counters, gates and shift registors, from which signals of succeeding time periods are obtained. The DDP is driven by the 169.6 kHz clock pulse, which is divided by two to generate the 84. 8 kHz clock.

The 84.8 kHz clock is divided down to generate the 28.266 kHz, the 10.6 kHz, the 3.5333kHz, the 1060 Hz timing pulses used within theArray.

The control word generator generates the synchronization code and provides the information to the output register during the proper bit times of the control word. Mode, frame, and DP serial number are stored in flip-flops. This information is also provided to the output register at the appropriate bit times.

The frame counter is a ripple through counter which is advanced by one step at each"word One" count. It is reset by means of the 90th frame pulse generated by the ADP.

The modulator accepts serial data and Manchester codes it as described in Section 1.5.

All control and timing lines between the DP and the Experiments contain RC networks to degrade pulse rise and fall times. Furthermore, each experiment data line contains a capacitor to ground. These component parts are located within the DDP. All capacitors are 0.001 ufd and the resistors are 330 ohms. Since the DDP has been designed to include control, timing, and data lines for all five experiments, the appropriate resistors and capacitors are installed within the DDP.

4.3.3.4 Timing Signals

The DDP generates the following external timing signals.

(a) Data Shift Pulses

(b) Data Demand Pulse

(c) Data Gate Pulse

(d) 90 Frame Mark Pulse

(e) Frame Mark Pulse

(f) Even Frame Mark Pulse

(g) CWE Clock, Control Word Three (Command Decoder only)

The timing relationship between the above pulses is shown in Figure 4-22.

(h) LSPE Sub-bit Timing Pulse

(i) LSPE Data Shift Pulse

The timing relationship between the above two pulses is shown in Figure 4-23.

Details of the circuitry and internal timing characteristics of the DDP are given in the Data Processor Modules Specifications AL 310930-1 through -6.

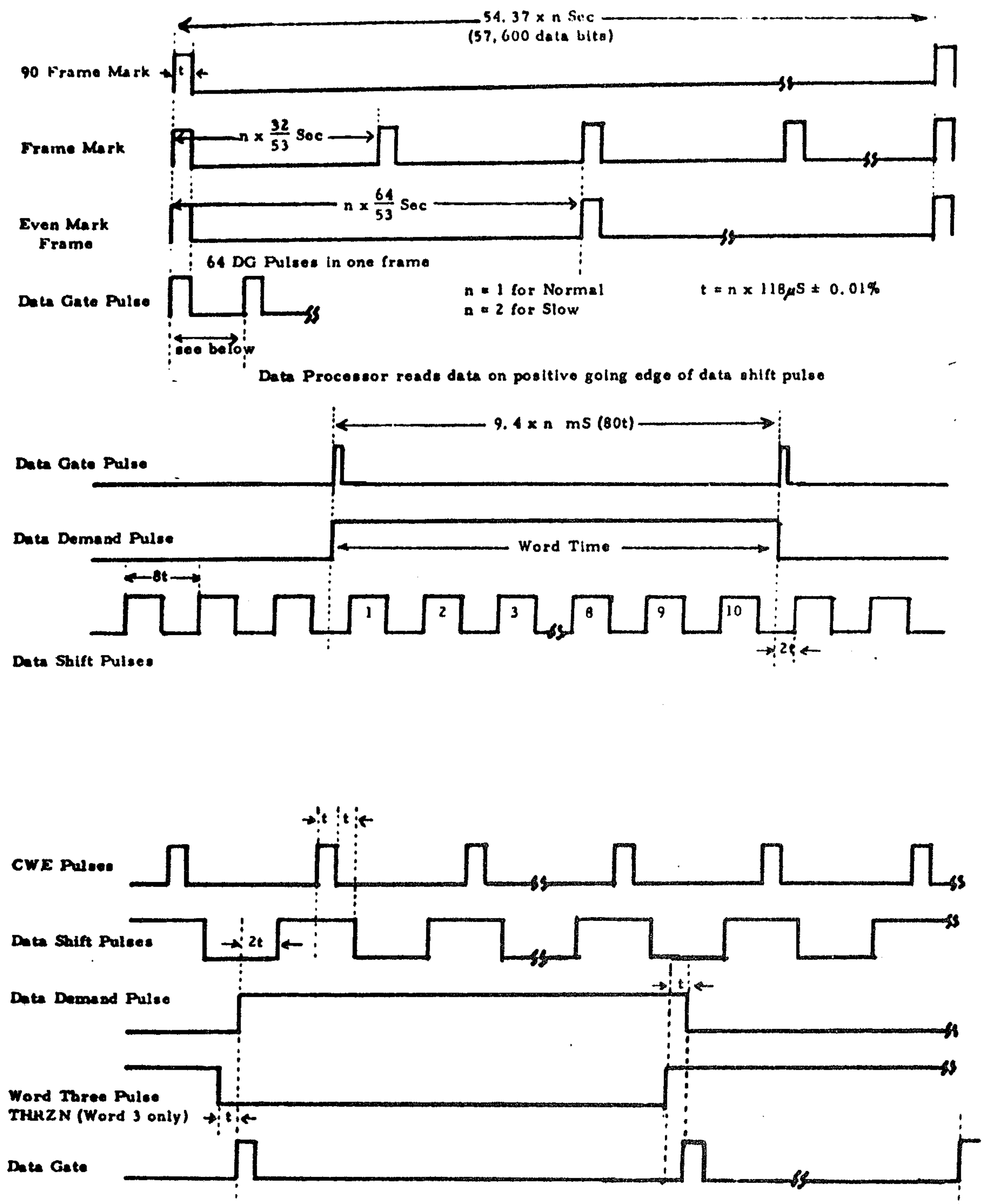


Figure 4-22 DDP Timing Pulses

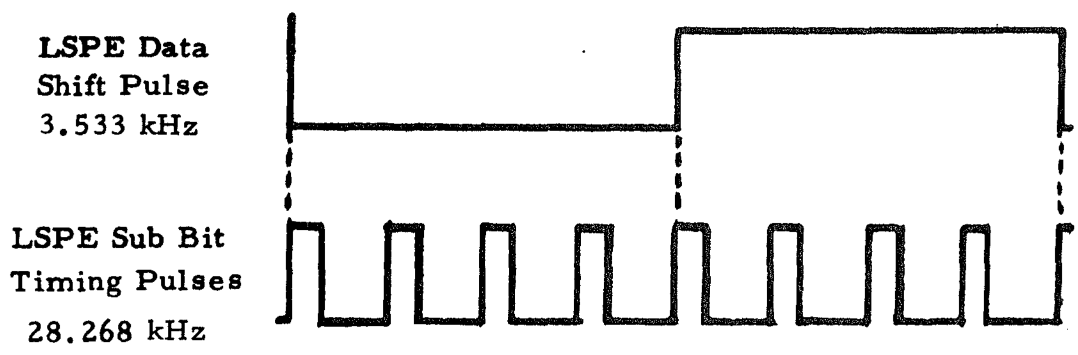


Figure 4-23 LSPE Timing Pulses

4.4 COMMAND RECEIVER

4.4.1 Introduction

The Command Receiver contains two complete receivers and redundancy combining devices as shown in Figure 4-24.

The receiver is manufactured by Motorola and makes extensive use of Linear Integrated Circuits.

Each individual receiver is capable of receiving either a baseband phase modulated carrier, Format 1, or a phase modulated subcarrier signal, Format 2. The receiver modulation format is selectable by means of a jumper wire at the receiver connector. Only Format 1 is used in Array E. The receiver circuits are described below.

4.4.2 The Hybrid Coupler

The hybrid coupler uses printed circuit strip line techniques to route the incoming r.f. to both receivers inputs.

4.4.3 The RF Converter

The RF Converter accepts an input signal at 2119 MHz and outputs it at the second IF frequency of 10.7 MHz. It is a double conversion unit with a first IF at about 60 MHz.

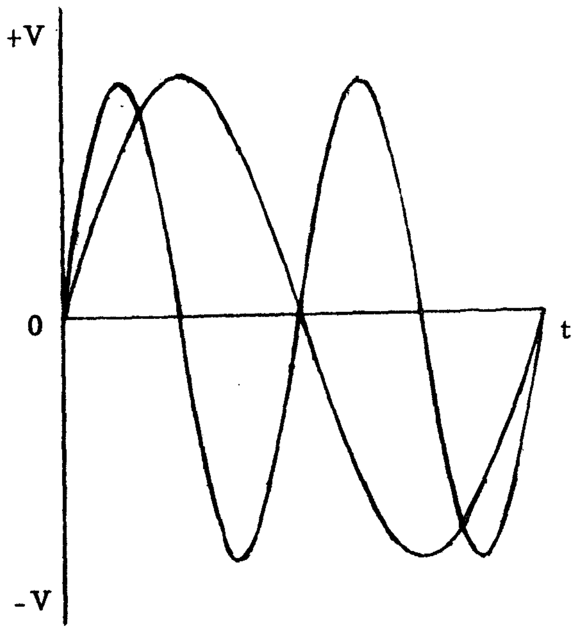
4.4.4 The IF and Audio Module

The IF and Audio Module accepts an input signal at 10.7 MHz, amplifiers and demodulates the signal. In Format 1, the output of the first discriminator is integrated and passed to the audio circuits. In Format 2, the output is passed to the 70 KHz subcarrier demodulating circuitry.

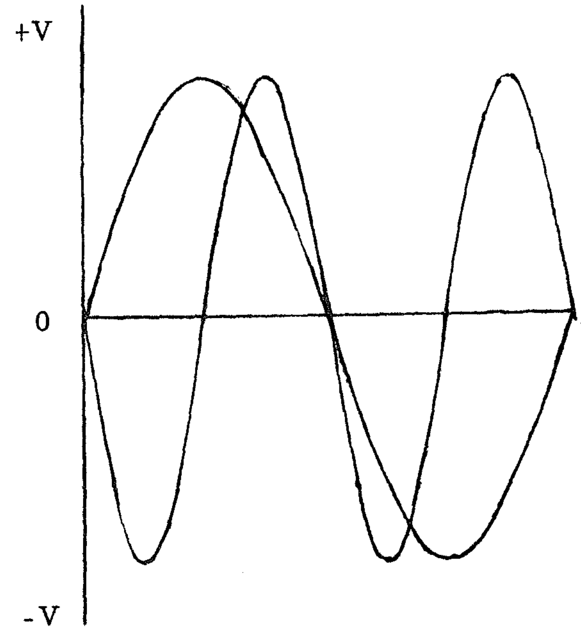
The format control circuitry controls the power supply to the 70 kHz subcarrier circuit which consists of a filter, a limitor and a second discriminator.

The received audio signals consists of a two phase modulated data tone (2 kHz) and a 1 kHz reference tone as shown in Figure 4-25. The 1 kHz signal is sensed in the audio section and a telemetry signal generated so as to provide engineering information regarding the presence or absence of the 1 kHz subcarrier.

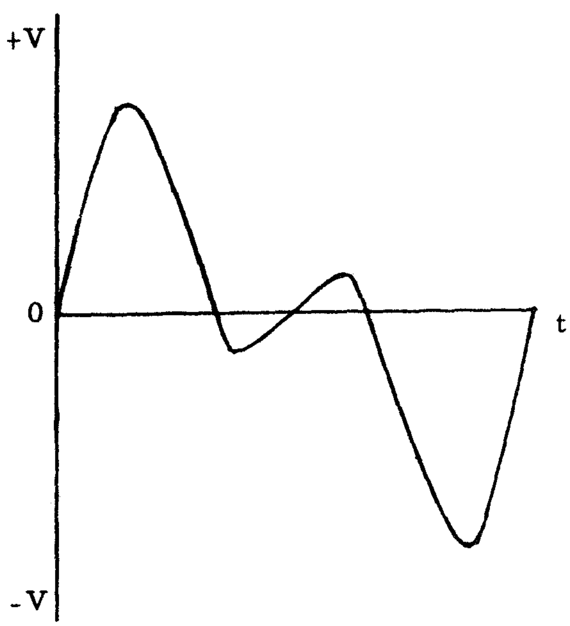
This page intentionally left blank - Page 4-46 was missing from this document.



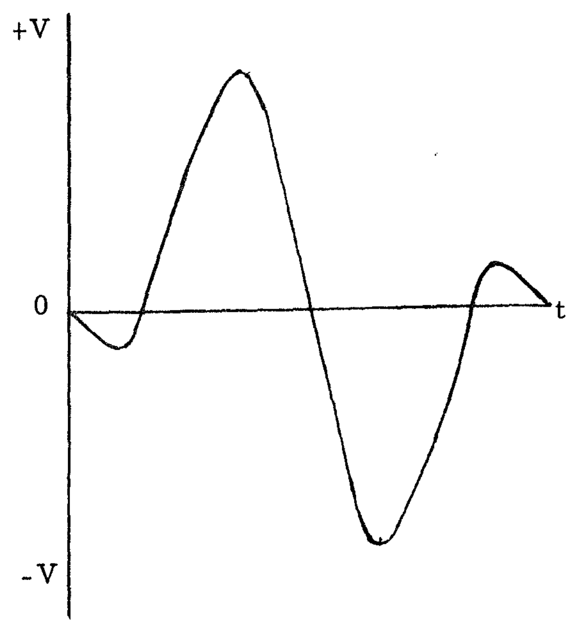
1 kHz Sync with 2 kHz
Bit 1 - Information In Phase



1 kHz Sync with 2 kHz
Bit 0 - Information 180°
Out-of-Phase



Composite Input Voltage
Waveform - Bit 1



Composite Input Voltage
Waveform - Bit 0

Figure 4-25 Command Receiver Output Signal Characteristics

4.4.4 (Cont.)

The AGC voltage is also brought out as a telemetry signal providing engineering information regarding the strength of the carrier of the signal.

4.4.5 Redundancy (Output) Combining Circuitry

The Power Line Isolator is a series surge regulator circuit with an output voltage of the order of +11V. The temperature of the receiver case is monitored by a thermistor and is outputed as a telemetry signal, if receiver A is in use.

The audio combiner circuits generates separate A and B outputs as well as an A or B audio output. The receiver may operate in either an active redundancy mode as used in Array D or in a standby redundancy mode as used here in Array E.

The Standby Redundancy mode of operation used in Array E treats the receiver as two separate units each able to operate independently with respect to the other. Redundancy is obtained by switching the power supply.

The power is obtained from the +12V supply lines to Uplink A and Uplink B. The audio output of Receiver A is routed to side A of the Command Decoder, the audio output of Receiver B is routed to side B of the Command Decoder. The A sides of both the receiver and the command decoder are known as uplink A. Similarly uplink B comprises the B sides of the units.

4.4.6 Signal Levels

In the Format 1 mode of operation, as in Array E, the receiver will provide 4.0 to 6.2 volts (peak to peak) of audio output, at 20 dB S/N ratio, for an RF input signal from -60 dBm to -92 dBm, with a phase deviation of ± 3.00 radians, peak. Practical tests have shown that the input signal has to fall to -94 to -97 dBm before the audio output degrades to the point where the command decoder will not accept it.

4.5 TRANSMITTER

5.4.1 Introduction

The Array contains two identical transmitters manufactured by the Teledyne Telemetry Company. Each unit accepts Manchester encoded digital data from the Data Processor and utilizes it to modulate a rf carrier. The modulated rf signal is amplified and frequency multiplied so as to provide an output signal of the order of one watt at an S-Band frequency of 2275. 5 MHz.

4.5.2 Operation

The block diagram of the transmitter is shown in Figure 4-26. The operation of the transmitter is considered in sections as described below.

4.5.3 RF Circuits

A crystal oscillator stage generates a 95 MHz rf signal which is phase modulated by the Manchester Coded Digital Data. The modulated signal is then amplified and passed through a two pole band pass filter. The filtered signal is then frequency quadrupled by a common emitter transistor stage. The 380 MHz signal is then passed through a third two pole band pass filter. The signal is then frequency doubled by a common emitter frequency multiplier and amplified. The 760 MHz signal is then power amplified. A signal of about 2-1/2 watts is then applied to a varactor diode frequency tripler. The resulting S-Band signal is filtered and outputted to the Diplexer and antenna.

The radiated rf signal from the antenna is of the order of one watt.

4.5.4 Power Supply Regulator

The +29V supply from the power subsystem is converted to two supply voltages. A +17V supply line powers the low power stages of the transmitter and the temperature telemetry sensor circuitry. A +23V supply line powers the power amplifier stages of the transmitter. The power supply regulator is a single encapsulated unit.

TRANSMITTER FUNCTIONS

SPECIFICATIONS:

OUTPUT: 1 WATT INTO A 50-OHM LOAD

FREQUENCY: +0.000, -0.0005% ON INITIAL SETTING
+0.0005%, -0.0000 DRIFT OVER TWO-YEAR PERIOD
± 0.002% DUE TO ENVIRONMENTAL EFFECTS

MODULATION INDEX: ± 1.25 RADIANS ± 5%

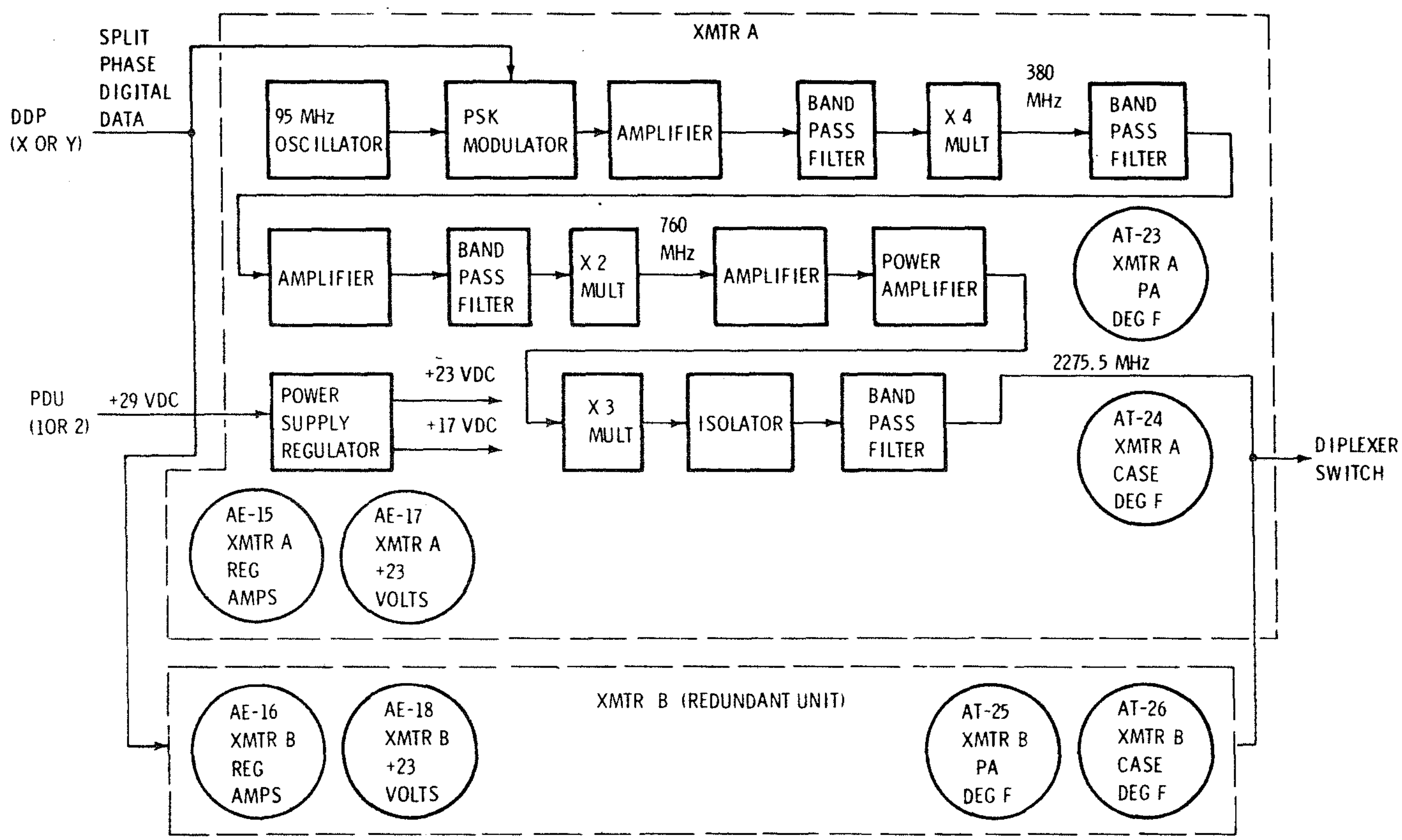


Figure 4-26

MAY 72 3270.2.42

4.5.5 Telemetry Signals. The following telemetry sensors are provided within the transmitter:

4.5.5.1 Transmitter +23V Regulator Output. This sensor monitors the output voltage of the regulator. The +23V line feeds the power amplifier stages.

4.5.5.2 Transmitter +17V Regulator Current. This sensor monitors the current flowing in the low power stages of the transmitter.

4.5.5.3 Transmitter Power Amplifier Temperature. This sensor monitors the temperature of the power amplifier.

4.5.5.4 Transmitter Case Temperature. This sensor monitors the case temperature of the transmitter.

All four sensor circuits contain protective networks to prevent excess voltage inputs to the ADP.

4.6 FILTER SECTION OF THE DIPLEXER

4.6.1 General Description

The Diplexer Filter contains a transmit frequency bandpass filter, a receiver frequency bandpass filter and a common path antenna low-pass filter. The low-pass filter augments the transmitter bandpass filter in suppressing the above-center-frequency spurious transmitter outputs. The three filters are tied together at a common junction at the end opposite to the circulator switch, receiver, and antenna ports. Figures 4-27 and 4-28 show a general outline and a block diagram of the Diplexer Filter.

4.6.2 Detailed Functional Description

The bandpass filters for the transmit and receive arms consist of five elements, adjusted to provide the response shown in Figure 4-29. These response characteristics provide the attenuation needed at the transmit frequencies, receive frequencies, and the image, LO, and transmitter spurious output frequencies. The filter elements consist of cavities, containing tuneable stubs. Figure 4-30 shows the equivalent circuit for the cavity resonator bandpass filters. The filter is of a Chebyshev ripple design, providing a low insertion loss and a low VSWR throughout the passband. The insertion loss is inherently controlled by the response specified and the allowable package size. The cavity cross sections are approximately 1.1 in. and provide an unloaded Q of 2400, resulting in an insertion loss of 0.52 db for the transmitter arm and 1.0 db for the receiver arms of the filter.

Cavity-type filters in the microwave region are inherently susceptible to wave guide mode propagation, resulting in spurious pass bands of various attenuation levels. The effects of this characteristic has been reduced in two ways: (1) the addition of a low-pass filter between the common junction of the bandpass filter and the antenna port and (2) the use of a common junction (coupling) external to the bandpass filter cavities.

The low-pass filter is an unbalanced ladder filter consisting of seven T sections. It is of coaxial construction in a tubular passage of approximately half an inch in diameter in the Diplexer body casting between the two bandpass filters. The filter cut-off frequency is 2.6 GHz, and provides at least 100 db of isolation between 4 GHz and 5 GHz, where the first spurious mode in the bandpass filter opens. The insertion loss of the low-pass filter alone, within the receiver-to-transmitter pass bands (2118 to 2180), is approximately 0.15 to 0.20 db.

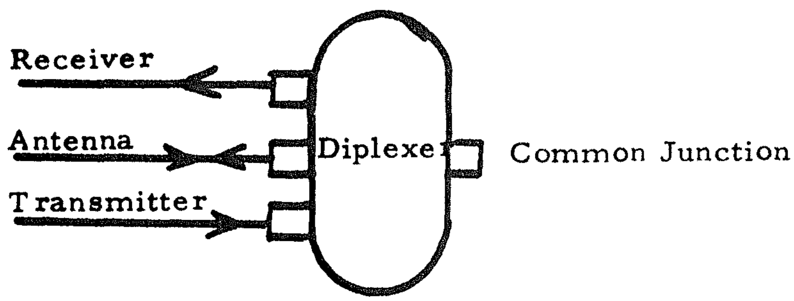


Figure 4-27 General Outline of Diplexer Filter

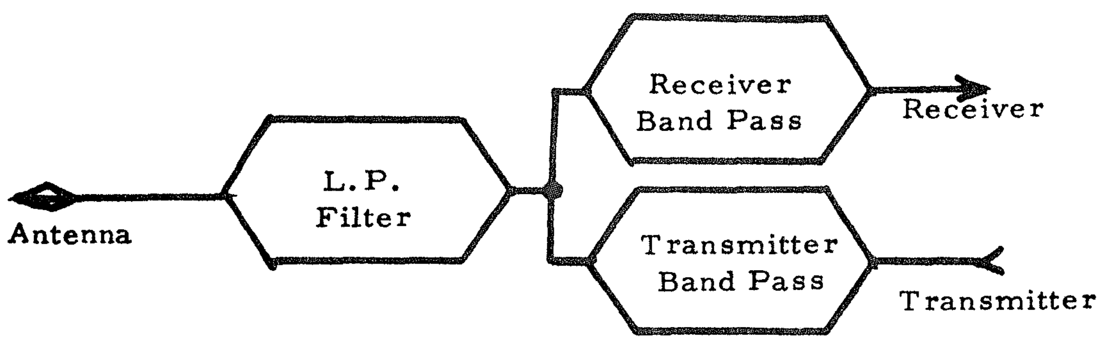
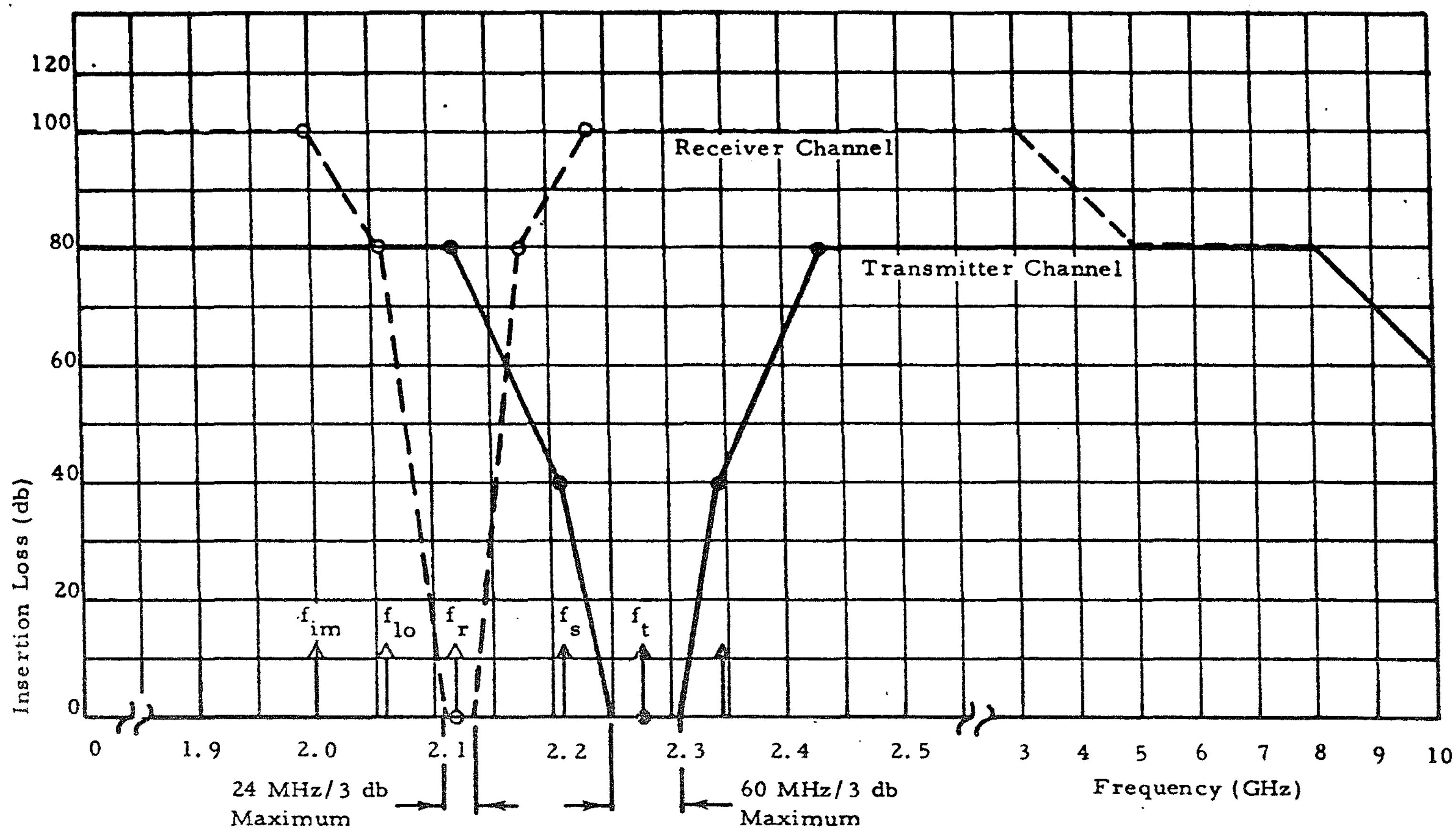


Figure 4-28 Block Diagram of Diplexer Filter



f_{im} = Receiver Image Freq = 1999 MHz

f_{lo} = Receiver Local Osc = 2059 MHz

f_r = Receiver Frequency = 2119 MHz

f_t = Transmit Freq = 2275 - 2280 MHz

f_s = 1st Transmitter Spurious Harmonids = $f_t \pm 70$ MHz

Figure 4-29 Diplexer Filter Minimum Rejection Requirements

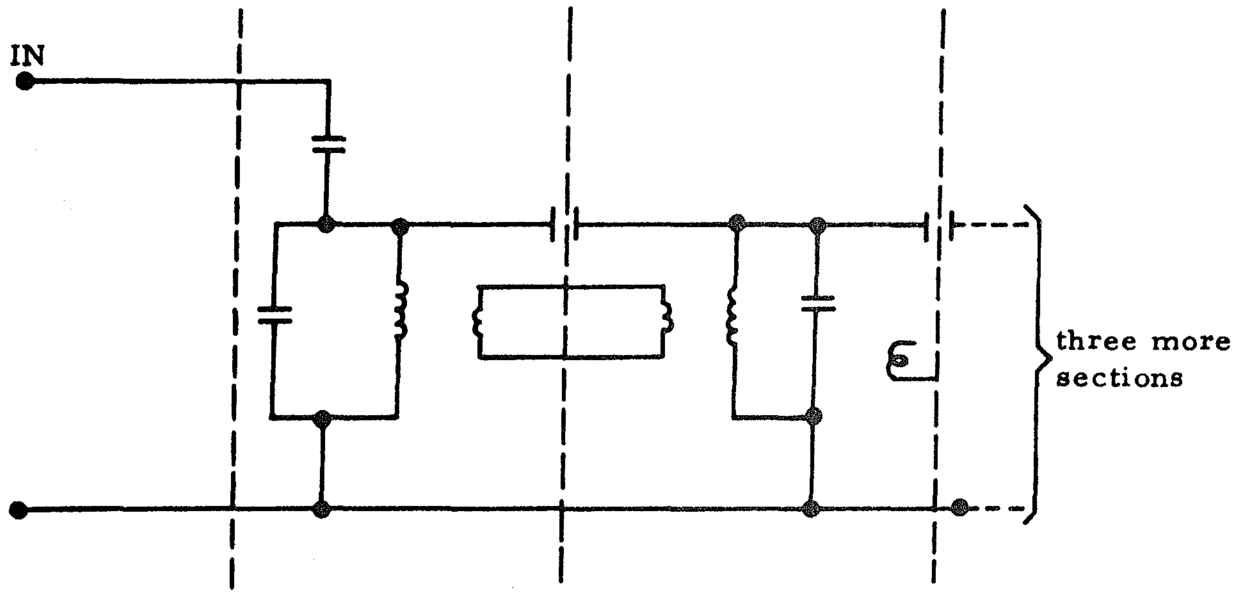


Figure 4-30 Bandpass Filter Equivalent Circuit

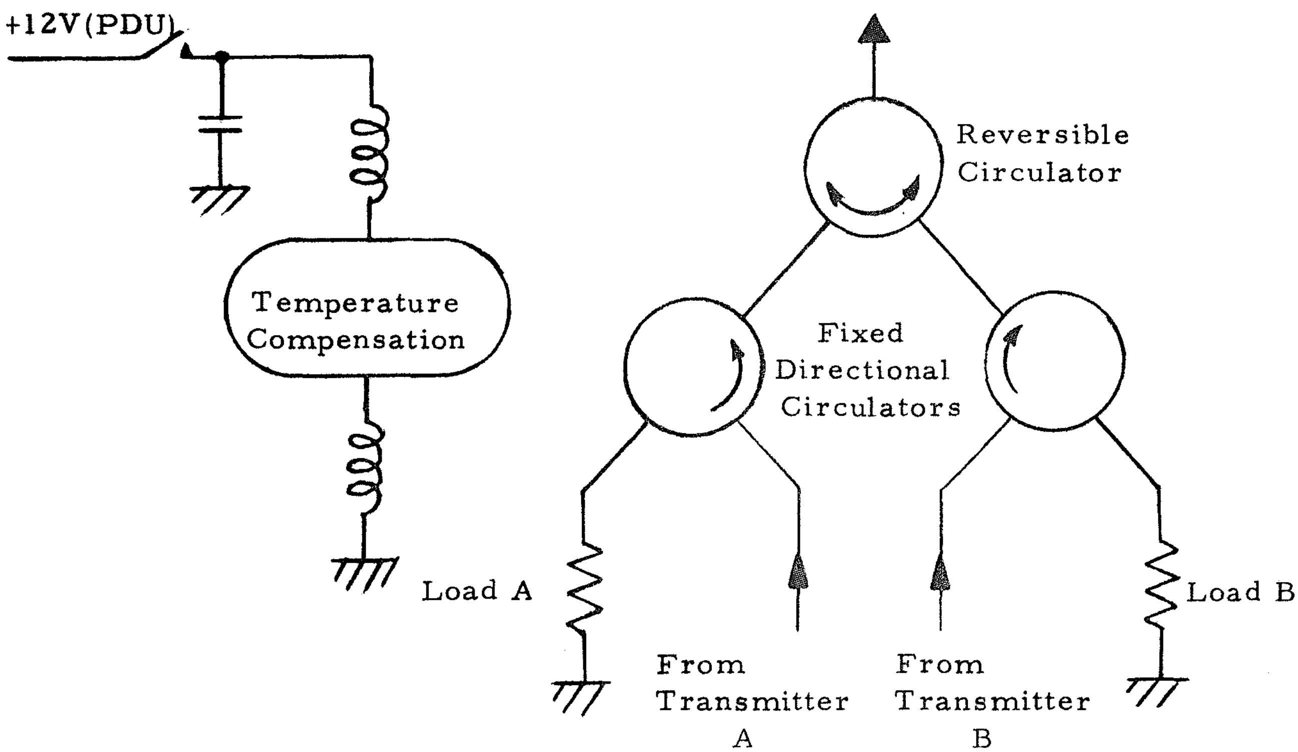


Figure 4-31 Circulator Switch Block Diagram

4.6.2 (Cont.)

The low-pass and bandpass combined attenuation characteristics are shown in Figure 4-29.

4.6.3 Input and Output Connections

The input and output connections are OSM-type 224 miniature coaxial connectors. The 224 is a right angle connector made of gold plated stainless steel. Three connectors are used: antenna, transmitter, and receiver. The matching impedances are 50 ohms.

4.6.4 Functional Parameters

The functional parameter of the diplexer filter are tabulated below:

Receiver Path (includes bandpass and low-pass filter)	Typical	Spec
Insertion Loss	1.30 db	2.5 db
VSWR	1.10:1	1.36:1
Center Frequency	2119	2118-2120 MHz
Max 3-db Bandwidth	11.0 MHz	24 MHz
Min 3-db Bandwidth	11.0 MHz	2.18 MHz
Rejection	Refer to Fig. 2-29	
Transmitter Path		
Insertion Loss	0.70 db	0.8 db
VSWR	1.10:1	1.36:1
Center Frequency	2275-2280 MHz	2275-2280 MHz
Max 3-db Bandwidth	45 MHz	60 MHz
Min 3-db Bandwidth	45 MHz	5.35 MHz
Power Handling Capability	20.0 w	1.5 w

4.7 DIPLEXER CIRCULATOR SWITCH

4.7.1 General Description

The Diplexer Circulator Switch is used to couple the selected transmitter through the Diplexer Filter section to the antenna. The circulator switch, in addition to the selecting transmitter output, provides protection for both transmitters and connecting equipment from opens, shorts, or simultaneous transmitter operation. The unit consists of three circulators, two loads, and three external ports in a single package. Two circulators are used for transmitter isolation and protection and one is reversible to serve as a switch (Figure 4-31). The unit requires DC power for switching purposes.

4.7.2 Detailed Functional Description

The circulator switch is composed of three-port circulators -- two fixed and one reversible. The circulator design uses copper-clad dielectric board stripline techniques.

The construction technique is not the usual symmetrical method of placing ferrite discs on each side of a strip-conductor junction. It uses only a single disc. The strip transmission line is photoetched on one board to the desired configuration. A magnetic coil structure is mounted in cut-out in the board. The other board in the sandwich has no photoetched strip conductor, but is modified to accept the ferrite disc and high dielectric constant ring for impedance matching from the ferrite junction to the 50-ohm output connectors.

A two-step transformer is used for this matching, each step being a quarter wavelength long. Multiple steps are used to obtain the bandwidth required for operation of the unit over the temperature range. The transformer adjacent to the ferrite consists of a quarter wavelength of line in material with a relative dielectric constant of 15. The second transformer is in the polyphenlene oxide board which has a 2.55 relative dielectric constant.

The use of dielectric boards results in a size reduction and greater ease of fabrication compared to the equivalent air stripline approach. In addition to the basic size reduction factor, the stripline circuitry has been designed for additional size reduction. The lines between the isolator junctions and external connectors have been bent within the high dielectric constant transformer to narrow down the package width. Quarter wavelength lines have been used between circulators, resulting in a reduction of thepackage size in both length and width compared with the more common half-wavelength coupling devices.

4.7.2 (Cont.)

The placement of the magnetic structure within one of the circuit boards results in a grounded junction circulator. The grounded junction results in smaller magnets and coils and shorter magnetic shunts and since the magnetic circuits can be bult with a single ferrite and no air gaps, the reduced gaps also minimize any magnetic leakage. This leakage is further reduced by using opposite circulation for the two identical isolator sections, thus tending to cause cancellation of the opposing leakage fields. As can be seen from the block diagram (Figure 4-31), loads are placed on the unused ports of each isolator to provide loads for the transmitters in event of power reflection. Also, if both transmitters were powered simultaneously, transmitter B will port to the filter whilst the output power of transmitter A will be circulated into a load.

Switching is provided by a DC-powered solenoid creating a magnetic field opposing the normal fixed magnet polarity. As the normal field is overriden, the circulator reverses, selecting the alternate input port. The switching time is dependent upon the field buildup as related to the solenoid inductance and the magnetic path characteristics. The switching time is approximately 130 msec, while the dc power requirement is 150 mW.

The isolation provided by the circulators in the non-energized sate is of the order of 30 db over a 200-MHz bandwidth centered around the nominal transmitter frequency. The switch isolation in the energized state is 16 db at 2777 MHz $\pm$ 100-MHz bandwidth, but is greater than 20 db at 2277 MHz $\pm$ 5-MHz bandwidth. To maintain the required rejection in the electromagnetic mode, temperature compensation of the coil current is required. The insertion loss is 0.25 db per circulator. Two circulators (one of which is the switch) are always in series whith the signal path resulting in a 0.5-db loss at ambient and 0.7 db at the temperature extremes.

4.7.3 Input and Output Connectors

The input and output connectors consist of three OSM-224 miniature coaxial right-angle connectors facing upward. One is for the interconnecting line to the diplexer filter section, and one each to the transmitters. Two solder terminals are provided for the +12-v switching power. All terminals are clearly labeled.

4.7.4 Functional Parameters

The functional parameters of the Diplexer Circulator Switch are tabulated below.

	Typical	Spec
Insertion Loss	0.5	0.7 db
VSWR	1.14	1.36:1
Center Frequency		2277 MHz
Isolation for 5MHz BW	30 to 40 db	20 db
Switching Voltage		12 VDC
DC Power (Position B)	150 mW	150 mW
DC Power (Position A)	0	0
Switching Time	120 msec	150 msec
RF Power Capability	1.5W	1.5W
Weight	1.28 lb	1.5 lb
Stray Magnetic Field (steady state)	10 gamma at 3 ft.	20 gamma at 3 ft.
Reliability	0.9998	0.9977 (goal)

4.8 ANTENNA

4.8.1 Description

The ALSEP antenna is a modified axial helix designed to receive and transmit a righ-hand circularly polarized signal at S-Band frequencies.

The antenna is formed by winding a flat, ribbon-like copper conductor into a helix around a fiberglass-epoxy tube and then bonding it in place. The helix is 23 in. long and 1.5 in. in diameter, with a pitch angle of 15°. The tubing provides a mechanical support for the copper helix. A five-inch ground plane with a two-inch wide cylindrical skirt is attached to one end of the helix and functions as a wave launcher to provide the transition from the coaxial transmission line to the helix.

An impedance matching transformer is located at the antenna feed point to match the typically higher impedance of the helical antenna to the 50-ohm coaxial transmission line.

The entire antenna is coated with a white, reflecting thermal paint for thermal protection.

The antenna is designed for easy attachment to the antenna pointing mechanism by the use of a quick-connect, spring-loaded detent mechanism. A circularly grooved shaft located below the ground plane is inserted into a mating part on the pointing mechanism. Spring loaded balls in the pointing mechanism fit into the grooved shaft of the antenna and hold the antenna securely in position. The antenna can be disconnected from the pointing mechanism by applying a moderate amount of force and pulling the two components apart.

4.8.2 Antenna Radiation Patterns

The antenna radiation patterns for both the transmitting and the receiving frequencies are shown in Figures 4-32 and 4-33.

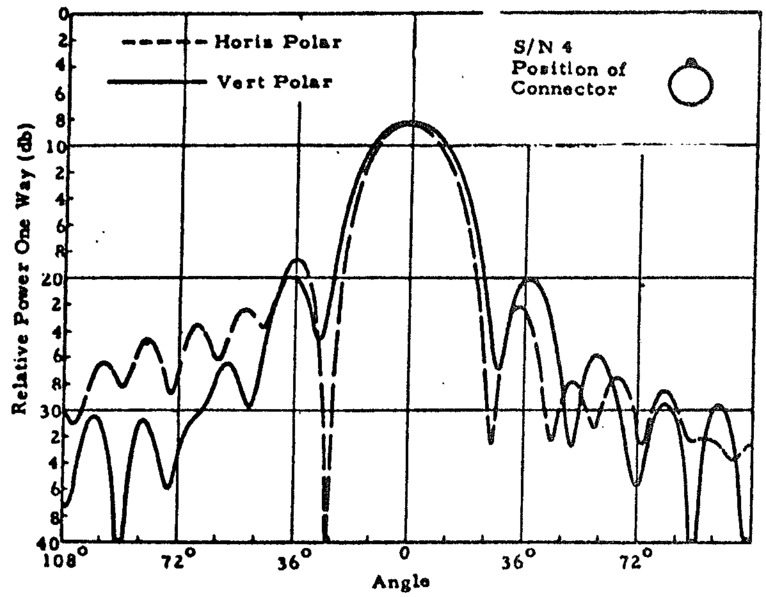


Figure 4-32 Typical Antenna Pattern, Transmit Frequency

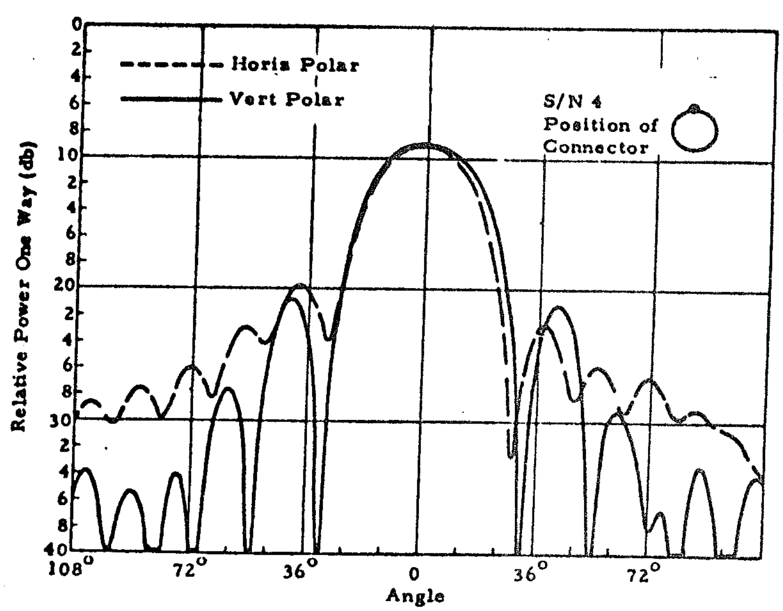


Figure 4-33 Typical Antenna Pattern, Receive Freq

4.8.3 Antenna Parameters

The antenna will receive command signals from the MSFN on earth on a frequency of 2119 MHz and will transmit data on any transmitter output frequency located within the frequency band of 2275 to 2280 MHz. The minimum allowable parameters for the antenna are shown below.

	Transmit		Receive	
	Spec	Typical	Spec	Typical
Gain*				
On Boresight	15.2 db	16.0 db	14.7 db	15.2 db
Beamwidth at 11.0 db gain			27°	36°
Beamwidth at 11.5 db gain	27°	33°		
Axial Ratio	3db	1.3 db	3 db	1.0 db
Input VSWR	1.25:1	1.20:1	1.5:1	1.20:1
Sidelobe Level	-10 db	-11 db	-10 db	-11.3 db
Weight (Actual)	1.28 lb (Including Cable)			

*The gain of the antenna is referenced to a right-hand circularly polarized isotropic level. It does not include coaxial cable loss, which is typically 1.0 db.

4.9 ANTENNA AIMING MECHANISM

4.9.1 Description

The antenna aiming mechanism supports the antenna and allows the astronaut to aim the antenna at the mean center of the apparent librations of the earth. The mechanism is shown in Figure 4-34.

The antenna aiming mechanism can be leveled (within a range of $\pm$ 10°) on two right angle horizontal axes. Tubular bubble levels indicate the degree of tilt of each axis. The bubble levels have a sensitivity of 15 minutes of arc per 0.10 inch of bubble movement and have reference marks indicating when each axis is within 15 minutes of arc of being level.

The Sun Compass adjustments have a minimum range of $\pm$ 15° about the vertical axis from the null position. A two way gnomon is attached to the latitude gimbal such that the proper latitude adjustment tilts the gnomon into the lunar equatorial plane, rendering the sun compass independent of the apparent sun angle. The latitude adjustments have a range of $\pm$ 45° from the vertical and adjustments are always made in a direction towards the lunar equator. Thus, the system only requires the matching of the gnomon shadow to the reference for the proper (east-west) alignment of the mechanism.

The longitude adjustments have a range of $\pm$ 60° from the gimbal center line. The longitude adjustment range is positioned such that longitude setting will not cause the antenna to cast a shadow over the sun compass or that the longitude adjustment shall not disturb the sun compass setting once the latitude setting and sun compass alignment have been made. No part of the aiming mechanism is above any part of the antenna ground plane at any setting.

The longitude, altitude and sun compass adjustments are provided with disengagement mechanisms allowing the astronaut to override the worm gear system. The disengagement or the engagement of the mechanism is accomplished with 90° of operating lever rotation. When disengaged and the antenna is being manually positioned, the dial angle indicator is used to indicate the proper setting. The mechanical accuracy of the antenna positioning in the override operation mode is 5° or better in each axis. If the override mode of operation is employed, the indexing on the position indicators may be destroyed. The override mode is a contingency mode of operation and is not to be employed during the normal setting up of the ALSEP antenna system.

ANTENNA AND AIMING MECHANISM

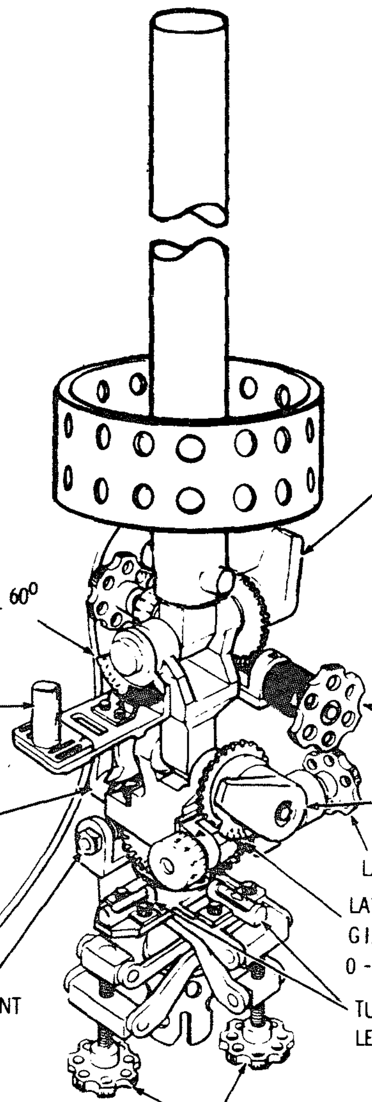


Figure 4-34

4.9.1 (Cont.)

All visual indicators on the aiming mechanism are easily readable at a distance of at least 34 inches. The astronaut should be able to assemble the aiming mechanism, the antenna and the antenna mast within two minutes. He should be able to correctly aim the antenna within another four minutes. The total time for the assembly and aiming of the ALSEP antenna system is thus less than six minutes.

4.10 WIRE HARNESS

4.10.1 Wiring Harness Assembly

The Central Station contains a multiconductor wiring harness assembly interconnecting the various components of the Data and Power Subsystems and providing interface points on the Central Station for each experiment. The wiring harness assembly for the Central Station consists of the cabling and connectors to interconnect the Data and Power Subsystems, terminals boards, and Central Station bulkhead connectors.

The harness is composed of single conductor stranded insulated wires except for twisted shielded pair connections on the LSPE geophone input leads between the LSP Electronics and the Central Station Connector and shielded clock lines between the LSPE and Data Processor.

The large differential between the lunar surface and the internal Central Station temperatures necessitate precautions being taken to restrict the heat flow through the experiment power and signal lines which must penetrate the thermal bag. Electric services are taken through the thermal bag via conductors of manganin wire. This design provides acceptably low thermal conduction together with acceptable electrical resistance of these lines.

Two printed-circuit terminal boards provide the points at which the copper wire used in the Data and Power Subsystem harness and the manganin wire used to carry the electric services through the thermal gradient area are joined. Ground strips on the terminal boards are used to interconnect the multiple ground lines from the experiments. The ground strips are returned to the thermal plate via the terminal board fixings.

Copper wires are used to carry the large current from the RTG through the interface. The resistive losses of manganin wire would be large enough to prohibit its use in this application.

4.11 ASTRONAUT SWITCHES

In view of the greatly increased uplink reliability there is no requirement for experiment switches and they have been excluded from the design of Array E. There are thus only two switches in the Array; namely -

4.11.1 Astronaut Switch S1: PC #2 Select

This is a contingency switch to enable the astronaut to switch PCU's in ALSEP should PCU #1 fail to start.

This function is implemented as shown in Figure 4-35.

The use of the relay, which is already in the system (to allow a PCU change over by command) enables the function to be implemented with a minimum heat leak.

The switch and relay contacts are flown in the position shown. Should the PCU fail to start, the switch is rotated. The circuit to the PCU is opened (a low impedance on this line would not let the RTG voltage rise to a sufficient value to operate the relay) and the PC2 Select relay circuit is energized. The relay operates and selects PC #2. The switch is then returned to its initial position and power is supplied to PC #2.

The switch is a double-pole-double-throw device to avoid a single point failure.

4.11.2 Astronaut Switch S2 : LSPE Inhibit Switch

The requirement here is to disable the LSPE transmitter prior to the ALSEP turn on. This is an operation guarding against the possibility of ALSEP turning on in the "LSPE transmitter On" mode, a necessary feature on Array E since the order of deployment is such that ALSEP is deployed before the explosive packages.

The LSPE is inhibited by having the +29V supply line open during the deployment. The outline schematic for implementing this function is shown in Figure 4-36.

The astronaut performs a visual check to ensure that the switch is in the open position. This ensures that when ALSEP is turned on no power is applied to the LSPE.

The switch is closed by the astronaut during the deployment sequence.

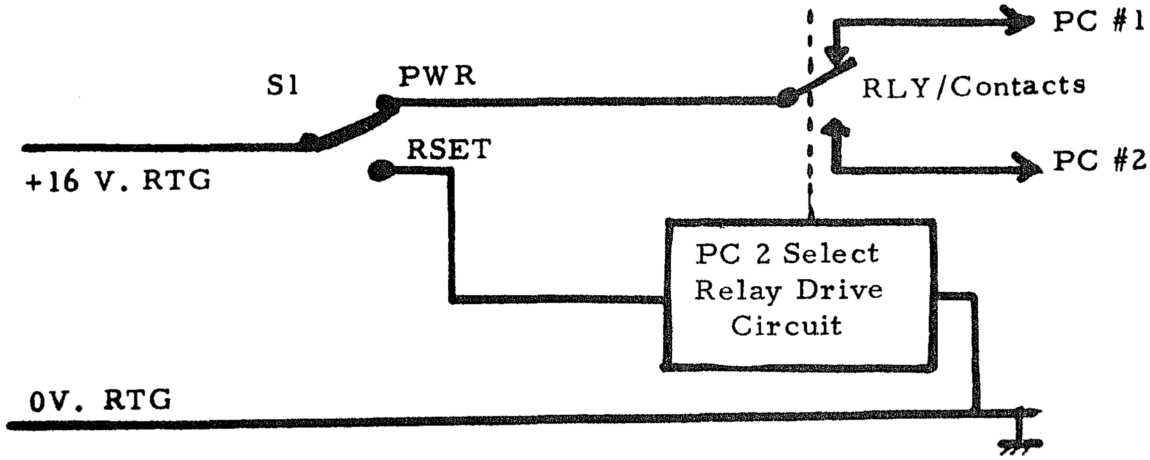


Figure 4-35 Astronaut Switch S1

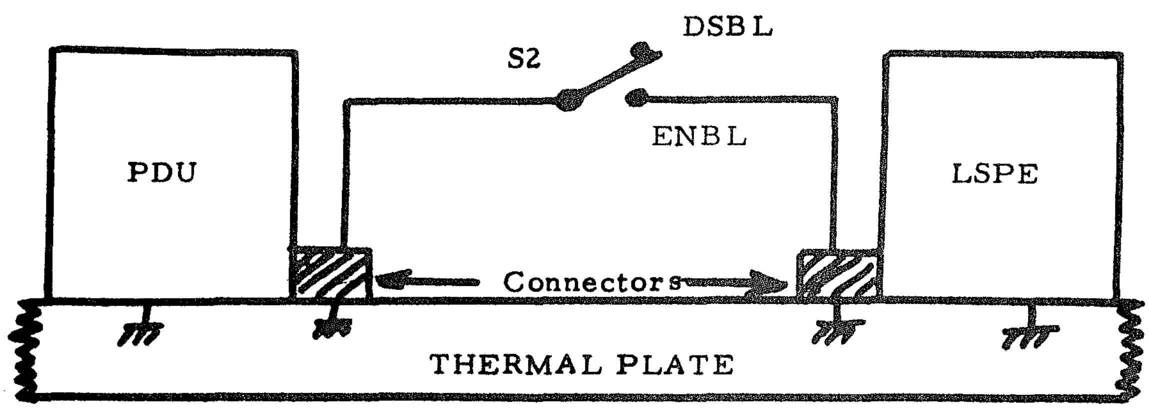


Figure 4-36 Astronaut Switch S2

4.12 EXPERIMENT INTERFACES

Each experiment is supplied with operating on standby power, as required. The Command and Data Interfaces are at standard TTL interface voltage interface levels. The timing pulses supplied to each experiment are shown in Figure 4-37.

Timing Pulse	Experiment			
	LMS	LEAM	LSG	HFE
Frame Mark	1	1	1	1
90 Frame Mark	1	1	1	1
Data Demand	1	1	1	1
Data Shift Clock	1	1	1	1
Even Frame Mark	0	0	0	0
Data Gate	0	0	1	0

LSPE utilizes Clock Pulses at 3.533/1.060 kHz and 28.666 kHz sub-Bit Timing Pulses.

Figure 4-37 Experiment Timing Pulses

5.0 ARRAY 'E' SCIENTIFIC INSTRUMENTS

This ALSEP system includes an array of the following five scientific instruments.

Sensor			
ALSEP No.	NASA No.		
1	S-205	Lunar Mass Spectrometer*	Dr. J. H. Hoffman Univ. of Texas (Dallas)
2	S-202	Lunar Ejecta and Meteorites	Mr. Otto Berg Goddard Space Flight Center
3	S-037	Heat Flow Experiment	Dr. M. G. Langseth Columbia University
4	S-207	Lunar Surface Gravimeter	Dr. Joseph Weber University of Maryland
5	S-203	Lunar Seismic Profiling	Dr. Robert L. Kovach Stanford University

*Also known as Lunar Atmospheric Composition Experiment

Sensors 1, 2, 4 and 5 have never flown before on an ALSEP mission. The Heat Flow Experiment was part of the ALSEP systems flown on Apollos 13, 15 and 16.

The general construction of the first four sensors is similar in that each instrument packages the sensor and associated electronics in a unit to be deployed at the end of a ribbon cable remote from the Central Station. The nature of the Lunar Seismic Profiling experiment is such that the components are widely distributed. The four geophone seismic sensors and the antenna are deployed at the end of cables connected to the Central Station which houses the instrument electronics. The explosive charge packages are deployed from 500 to 7900 feet (150m to 3.5 Km) from the Central Station and are operationally coupled to it by an RF link.

The following sections provide a brief description of the objectives, configuration and operation of each instrument. More detailed information is provided in the Array E Familiarization Handout (BSR 3270) and the Array E Operational Data Book (MP-07).

5.1 THE LUNAR MASS SPECTROMETER EXPERIMENT

5.1.1 The Experiment Measurements

The purpose of the Lunar Mass Spectrometer is to provide measurements which will enable scientists to determine the global distributions and the diurnal variations of the lunar atmosphere and thus to test theories of planetary exosphere dynamics. Since the lunar atmosphere is a classical exosphere, these gas distributions can provide a reasonable check on exospheric transport theories, which play an important part in terrestrial exospheric problems. In addition, the LMS will provide valuable clues as to the origin of the lunar atmosphere and, by simultaneously monitoring the carbon monoxide (28 atomic mass units) and the sulfur dioxide (64 atomic mass units) constituents, will isolate volcanic activity.

The LMS is basically a magnetic-deflection mass spectrometer with three ion detection systems covering mass ranges 1 to 4 atomic mass units, 12 to 48 atomic mass units, and 27 to 110 atomic mass units, respectively. It is capable of detecting partial pressures ranging from 10^{-8} to 10^{-13} Torr. The overall instrument sensitivity is greater than 1×10^{-5} ion amperes per Torr, with unit resolution at 82 atomic mass units.

The LMS is delivered to the moon and deployed in the configuration shown in Figure 5-1. Before the astronaut completes its deployment he releases the pull-cord to vent the sensor and removes the seal at the inlet to the analyzer. After the LEM leaves the lunar surface, the dust cover over the thermal control mirrors is removed by ground command.

5.1.2 The Mass Spectrometer Design

Atmospheric gas molecules collected by the inlet aperture of the mass spectrometer are ionized by electron impact in an open ion source, using a Nier-type electron source. Thermionic electrons, produced by passing about 1 ampere through a tungsten/rhenium filament, are collimated by a small 350-gauss permanent magnet. A positive voltage is applied to a second tungsten/rhenium filament assembly which acts as an electron trap; this filament can be switched to become the thermionic emitter in case the other filament experiences burnout. The current detected by the electron trap is used to provide active emission control of the filament current. The differential voltage applied to the filament assemblies

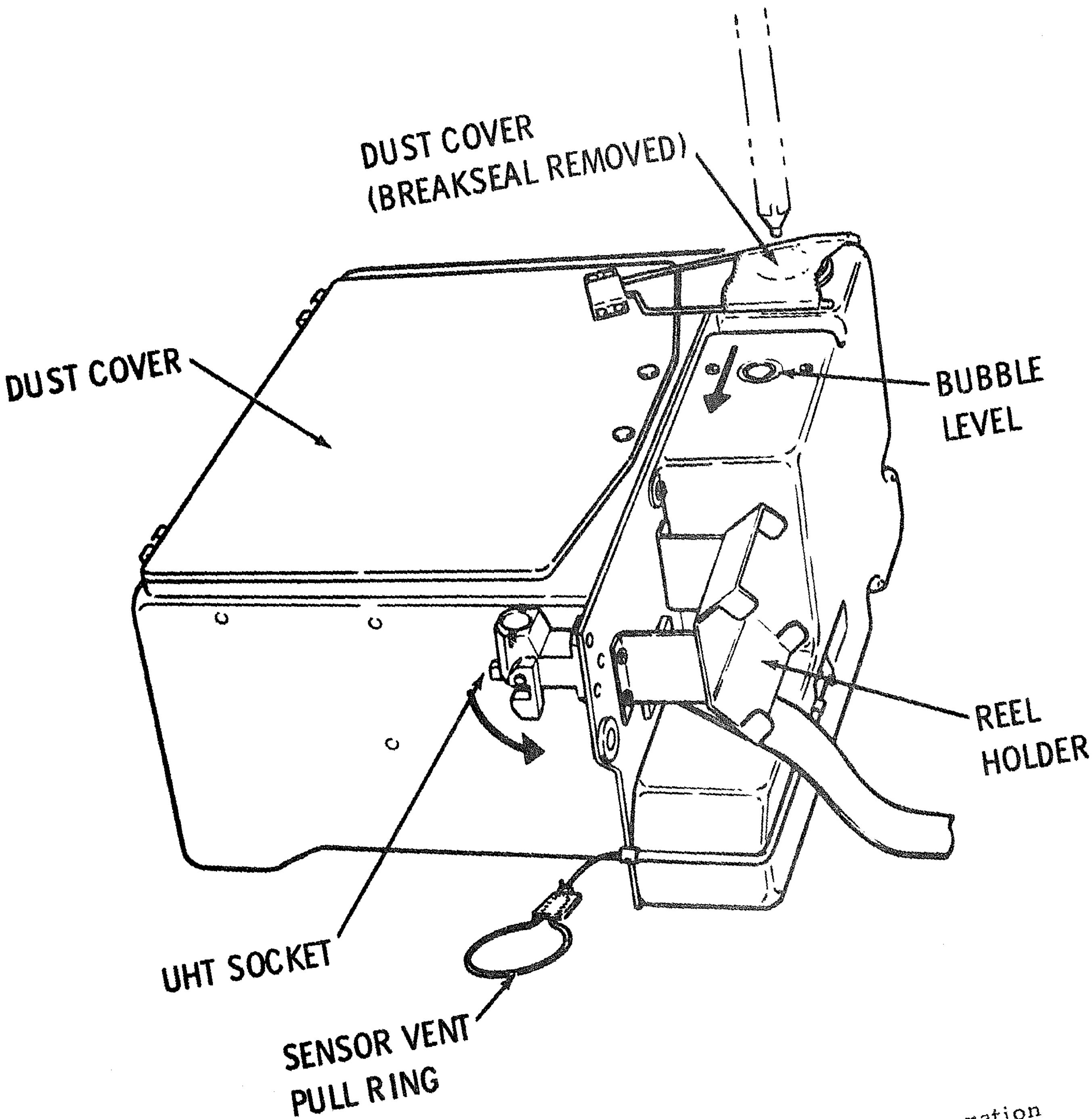


Figure 5-1 Lunar Mass Spectrometer Deployed Configuration

provides the force necessary to accelerate the electrons through the ion source, to develop a maximum energy level of approximately 80 electron volts. One mode of operation steps the differential filament voltage through four levels in order to distinguish between molecules of the same mass but of different ionization energies.

After the gas molecules are ionized, they are drawn out of the ion source past a series of slits, as illustrated in Figure 5-2. This is accomplished by placing a positive voltage on the entire ion source and providing an opening in it to permit the positively charged ions to accelerate toward a ground-potential slit; this slit is called the object slit since it also serves as the object for the ion optics of the mass spectrometer. Between the object slit and the ion source is a second slit called a J-plate; this slit is analogous to an optical lens and is used for fine-focusing of the ion beam.

A third slit, called the alpha slit, is between the object slit and the drift tube and serves to limit the ion optic aberrations. The object slit and the alpha slit are at ground potential; the J-plate potential is 90 to 95 percent of the ion source voltage. In order for the instrument to sweep the mass range, the ion source voltage is varied in a stepwise manner to impart different momenta to the ions as they leave the ion source and pass into the drift tube. The voltage sweep starts with a pedestal voltage of +320 volts and increase to +1420 volts in 1330 steps.

After the ion beam passes through the slit assembly, it enters the analyzer portion of the instrument, see Figure 5-2 where it is deflected by a 4300-gauss permanent magnet in accord with the following equation,

$$M/E = KB^2R^2/V$$

where B is magnetic field strength, R is ion-trajectory radius of curvature in the magnetic field, V is ion accelerating voltage, K is a constant, M is ion mass in atomic mass units, and E is electronic charge. Exit slits with ion detectors are located on three circular trajectories having radii of 0.478 inch, 1.653 inches, and 2.500 inches, as illustrated in Figure 5-2. This combination provides for the simultaneous monitoring of carbon monoxide and sulfur dioxide on the medium and high mass ranges, respectively.

LMS DETECTION SYSTEM

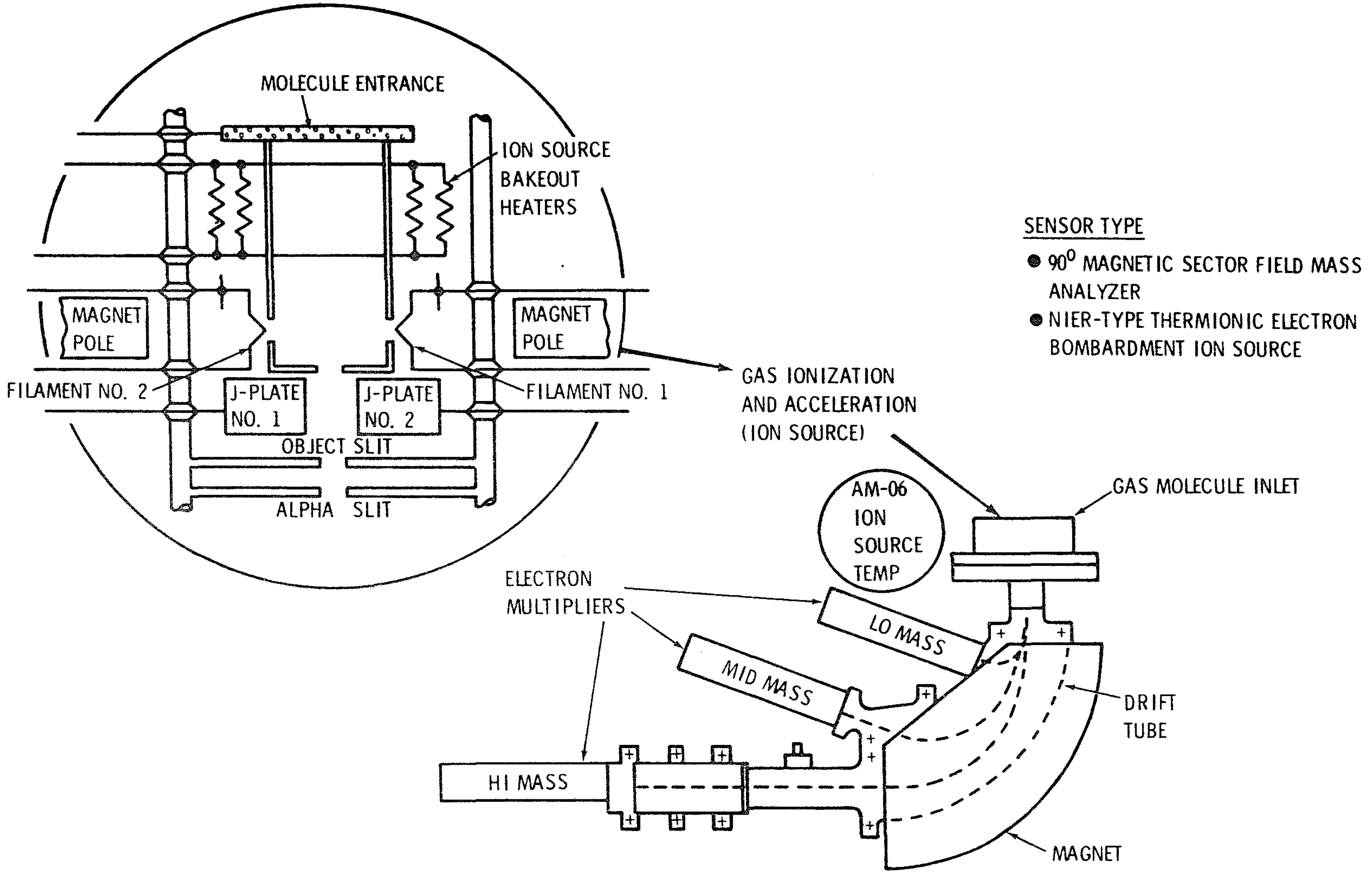


Figure 5-2

JUNE 72 3270.4.9

LMS PERFORMANCE CHARACTERISTICS

- MODE OF OPERATION: AUTOMATIC CONTINUOUS SWEEP WITH COMMANDABLE LOCK AT ANY AMU
- SCAN TECHNIQUE: VARY ACCELERATING VOLTAGE FROM 320 TO 1420 VOLTS IN A SERIES OF 1350 STEPS
- MEASUREMENT: THREE DETECTORS DETERMINE THE DENSITY (ABUNDANCE) OF EACH CONSTITUENT IN THE LUNAR ATMOSPHERE BY COUNTING PARTICLES AT EACH STEP FOR A PERIOD OF 0.6 SECONDS
- RESOLUTION: 10%
- SENSITIVITY: 1.0×10^{-5} TORR
- DYNAMIC RANGE: 1×10^{5}
- TYPICAL RECORD FOR ONE SWEEP IS SHOWN BELOW

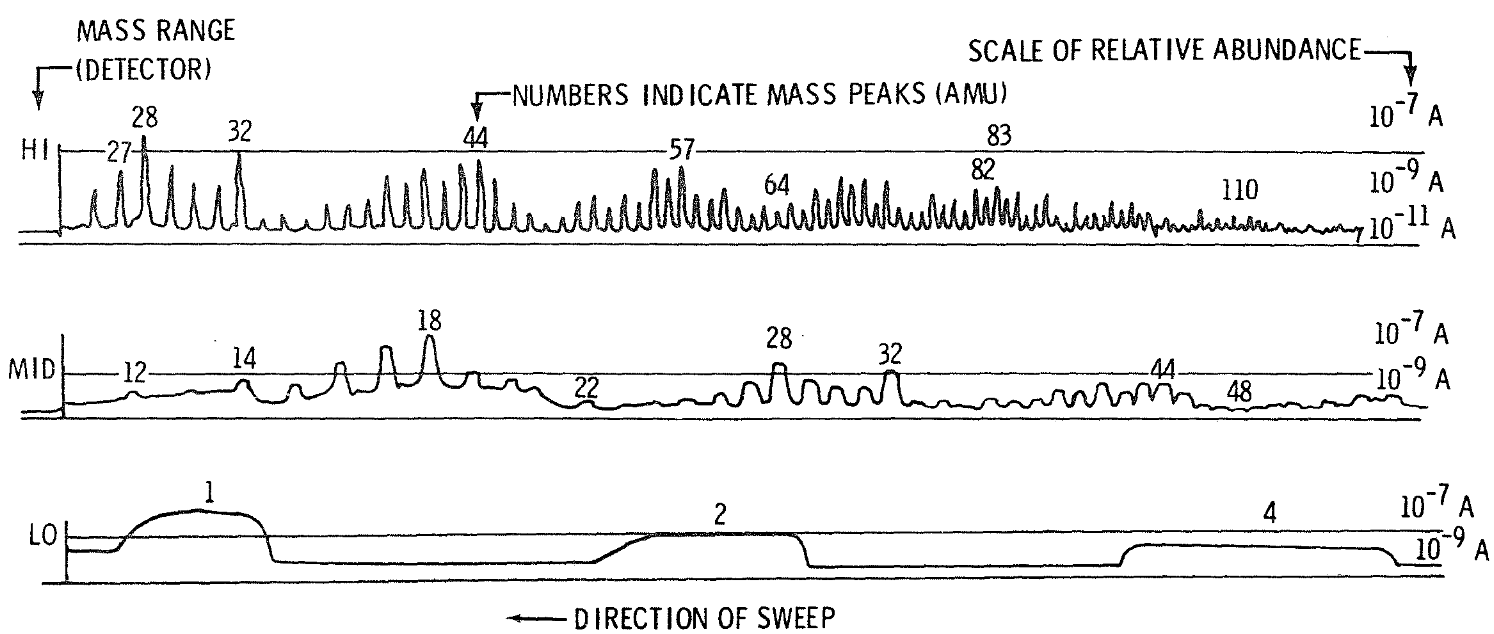


Figure 5-3

JUNE 72 3270.4.7

The density of each gas species is a function of the number of ions detected at each voltage step. Electron multipliers provide an output pulse for each ion input. This output is the input to a charge-sensitive amplifier, in series with a discriminator and a 21-bit counter. Since electron multipliers cannot be operated safely at pressures above 1×10^{-5} Torr, the pressure in the analyzer is determined prior to electron-multiplier turn-on by monitoring the current of a 0.15-liter/second appendage ion pump.

Upon command from the Central Station, the data in the counter are compressed and relayed to the Central Station for telemetry back to earth. The magnitude of the ion count indicates the partial pressure of the gas species at each voltage step. The instrument is calibrated to relate ion count to gas pressure and voltage step to gas being detected. A typical representation of the data provided by the LMS is shown in Figure 5-3.

5.2 THE LUNAR EJECTA AND METEORITES EXPERIMENT

The Lunar Ejecta and Meteorites (LEAM) instrument will provide measurements of the speed, direction, mass and flux density of cosmic dust particles at the Apollo 17 landing site. It will also yield information pertaining to the flux density and orbital parameters of lunar material ejected whenever meteorites strike the lunar surface. The ALSEP instrument has been developed from a similar unit flown successfully on the Pioneer 8 spacecraft.

The LEAM configuration, both stowed and deployed, is shown in Figure 5-4. The heart of the instrument is contained in three special particle detectors which are deployed facing northeast, southwest and up. The geometrical arrangement of the sensing elements of one of these detectors is shown in Figure 5-5.

The operation of the detector is illustrated in Figure 5-6. If a particle striking the front film has sufficient momentum, it will penetrate the very thin film and continue on toward the rear impact plate. As the metallized thin film is penetrated, an ionized plasma is produced and the particle loses some of its kinetic energy. The positive ions and electrons in the plasma are collected by the electrically biased films and grids, respectively, producing two coincident pulses. These are individually amplified and processed in the experiment electronics to identify the area of impact, to

LEAM EQUIPMENT

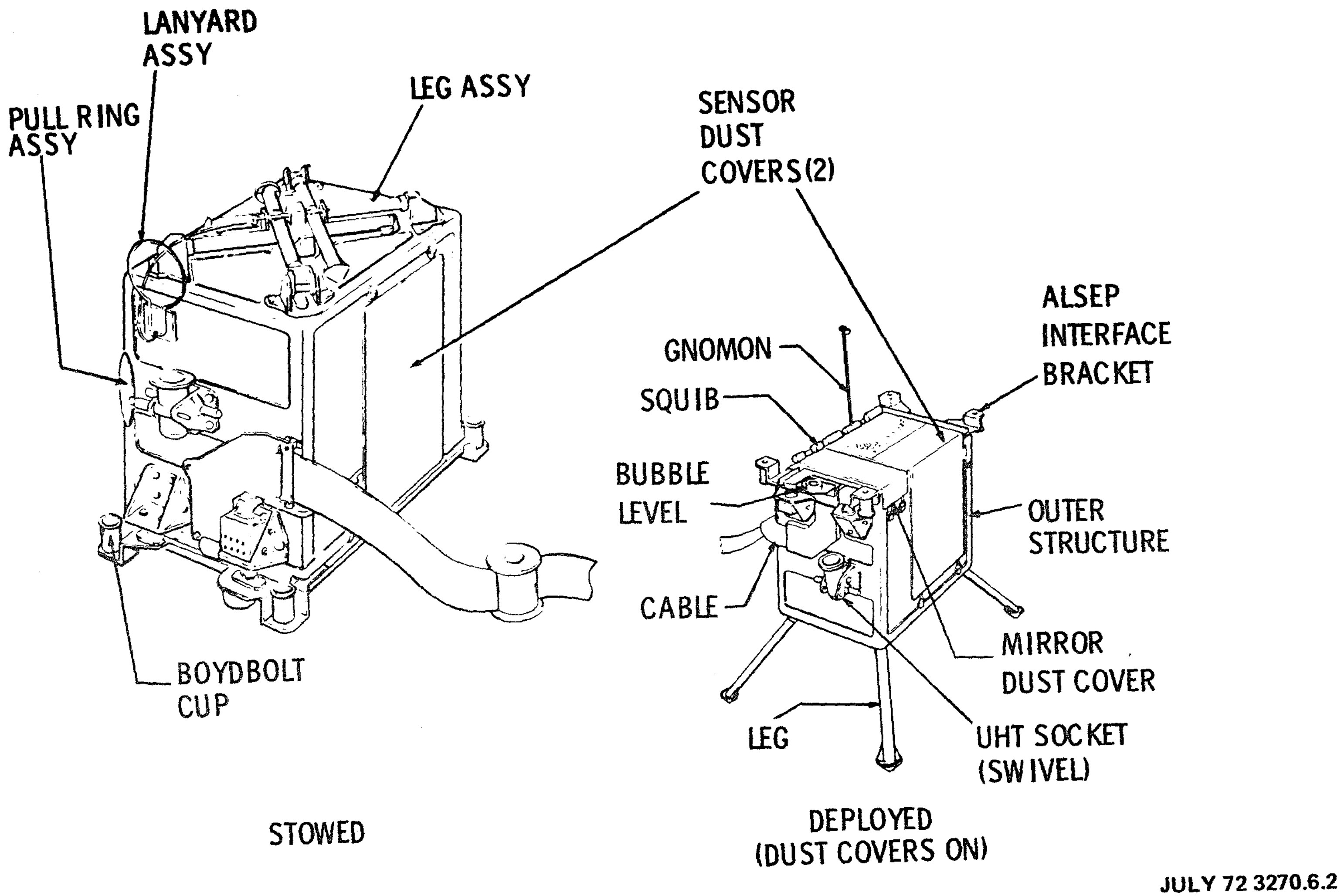


Figure 5-4

LEAM SENSOR GEOMETRY

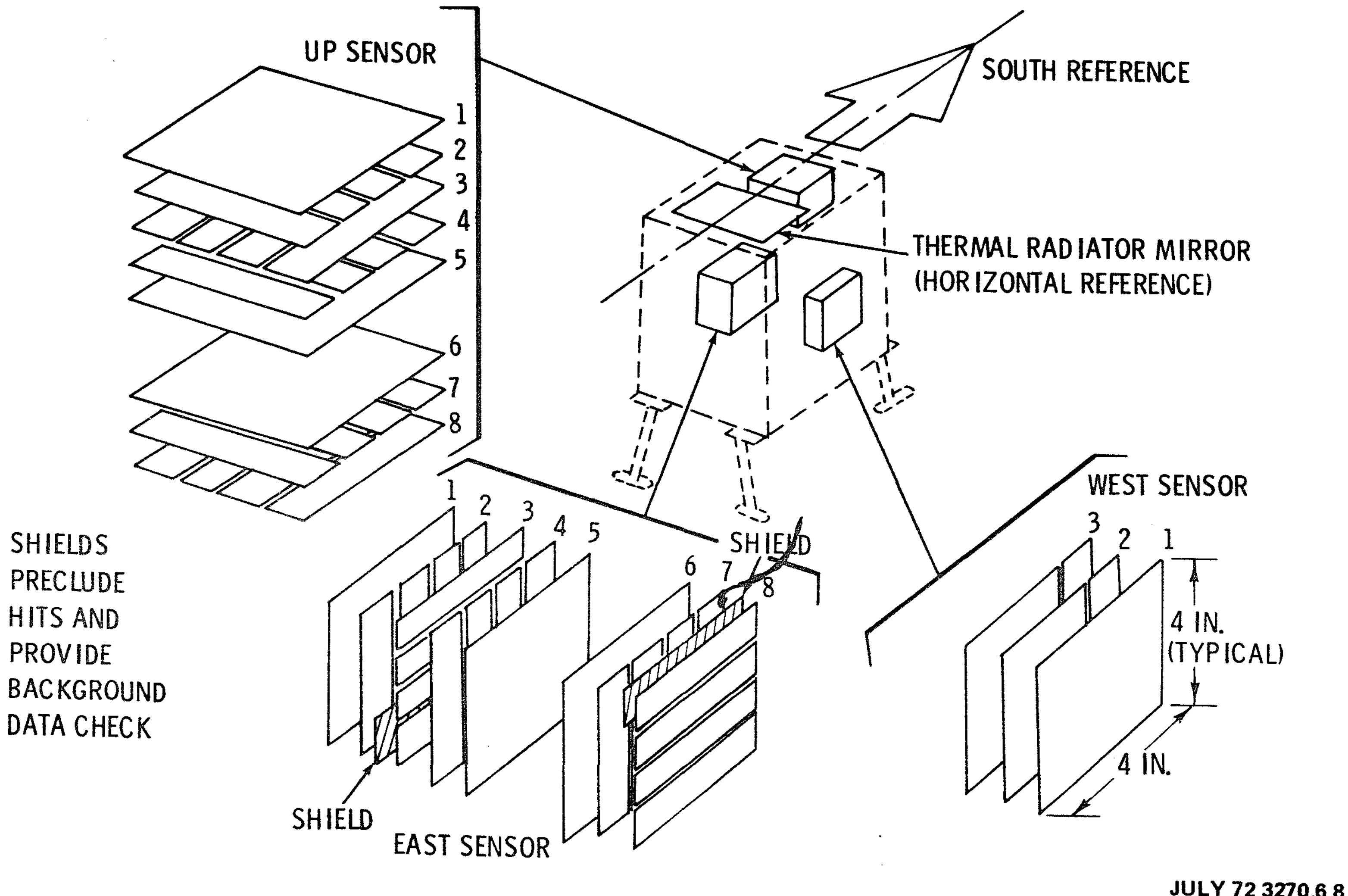
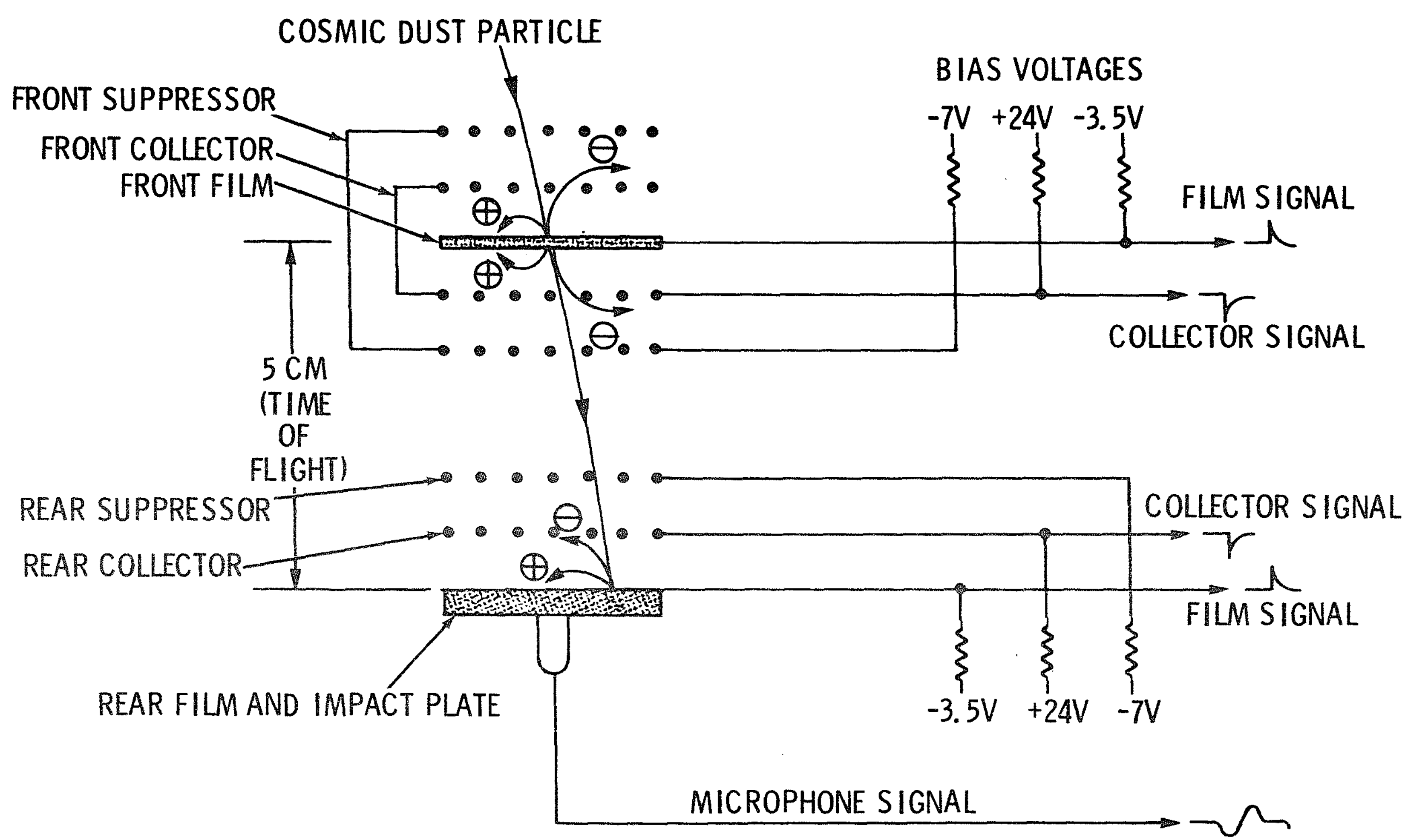


Figure 5-5

LEAM DUAL SENSOR FUNCTION



JULY 72 3270.6.9

Figure 5-6

This page intentionally left blank - Page 5-11 was missing from this document.

Precision measurement of absolute temperature sounds deceptively simple but is a formidable task, even in an Earth-based laboratory. The HFE is designed to provide lunar thermal measurements with the ranges and precision shown in Table 5-1. The instrument is constructed with the primary sensor elements mounted on meter-long probes which are placed in specially-drilled holes in the lunar surface. There are two probes and they are placed 2 1/2 meters below the surface. The measurement and control circuits are packaged in a small, temperature-controlled unit located between the probes as shown in Figure 5-7.

Table 5-1 Heat-Flow-Instrument Performance Requirements

Measurement	Requirement			
	Range	Resolution	Accuracy[a]	Minimum Stability
Temperature Difference across 0.5-Meter Probe Section in Lowest Meter of Hole	±2°K (high sensitivity) ±20°K (low sensitivity)	0.0005°K (high sensitivity) 0.005°K (low sensitivity)	±0.003°K	0.003°K/year
Ambient Temperature of Probe in Lowest Meter of Hole	200–250°K	0.02–0.08°K	±0.1°K	0.05°K/year
Temperature of Thermocouples in Upper 2 Meters of Hole	90–350°K	±0.17°K	±0.5°K	0.5°K/year
Thermal Conductivity of Material Surrounding Probes	0.002–0.4 watt/meter°K	±20%	±20%	——

[a]Maximum probable error.

During normal operation of the experiment (Mode 1) temperatures of all gradient bridges, thermocouples and the reference bridge (as well as temperature differences of all gradient bridges) are sampled every 7.2 minutes. When a heater is turned on at 0.002 watt to enable measurements to be made in the lower thermal conductivity range, the experiment is said to be operating in Mode 2. The Mode 3 operation is designed for the measurement of conductivities in the higher range. In this mode temperature and temperature difference at a selected ring bridge are read every 54 seconds. These modes of measurement and heater selection are controlled by ground command.

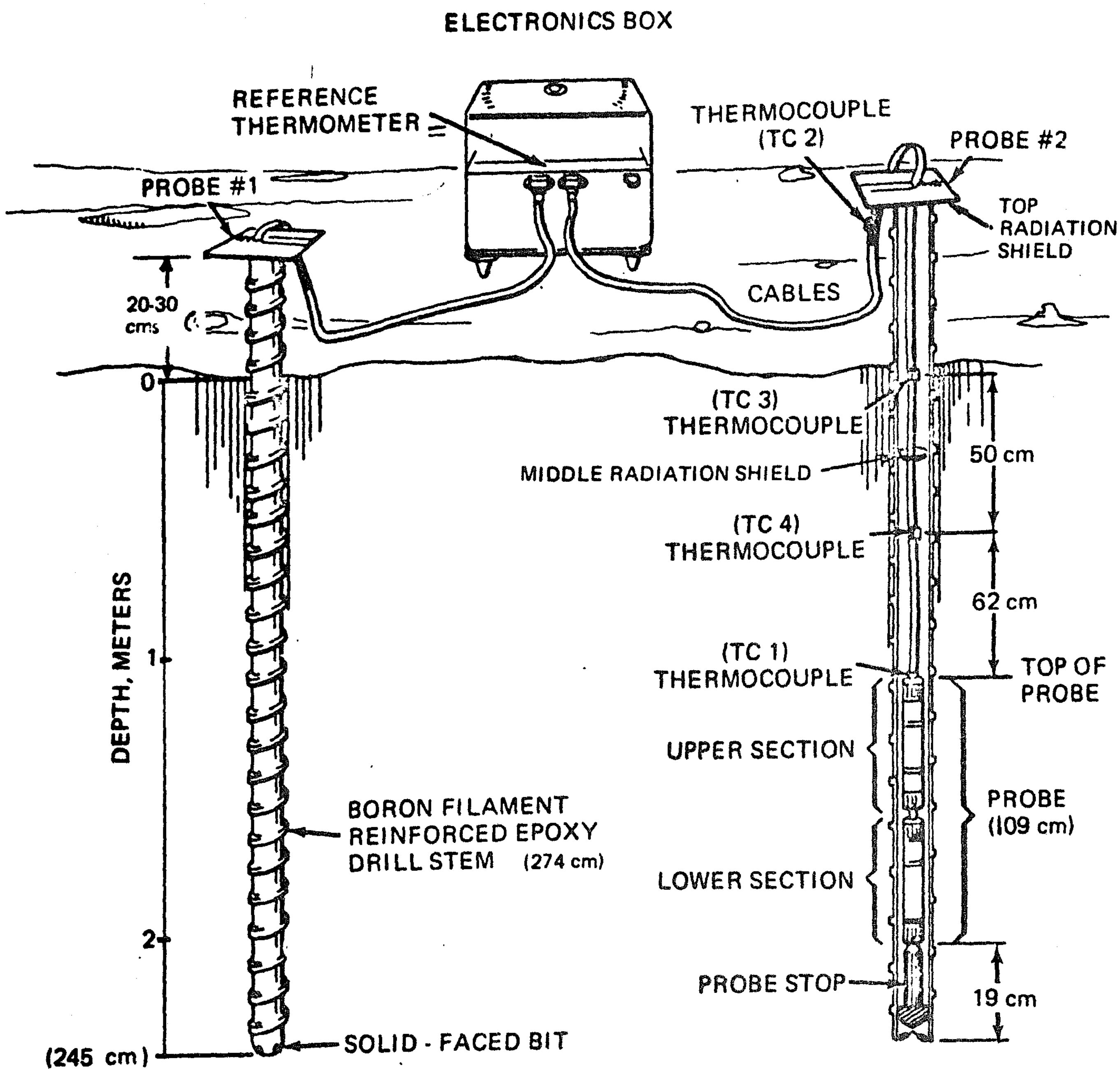


Figure 5-7 Heat Flow Experiment Deployed Configuration

5.4 THE LUNAR SURFACE GRAVIMETER EXPERIMENT

5.4.1 The Design and Construction of the Experiment

The Lunar Surface Gravimeter (LSG) is an extremely sensitive and versatile instrument designed:

a) To search for evidence of gravitational radiation from cosmic sources, which may excite low-frequency free oscillations of the moon, in the frequency range upward from 1 cycle every 15 minutes.

b) To obtain information on the internal structure of the moon by measurement of lunar deformations associated with tidal forces.

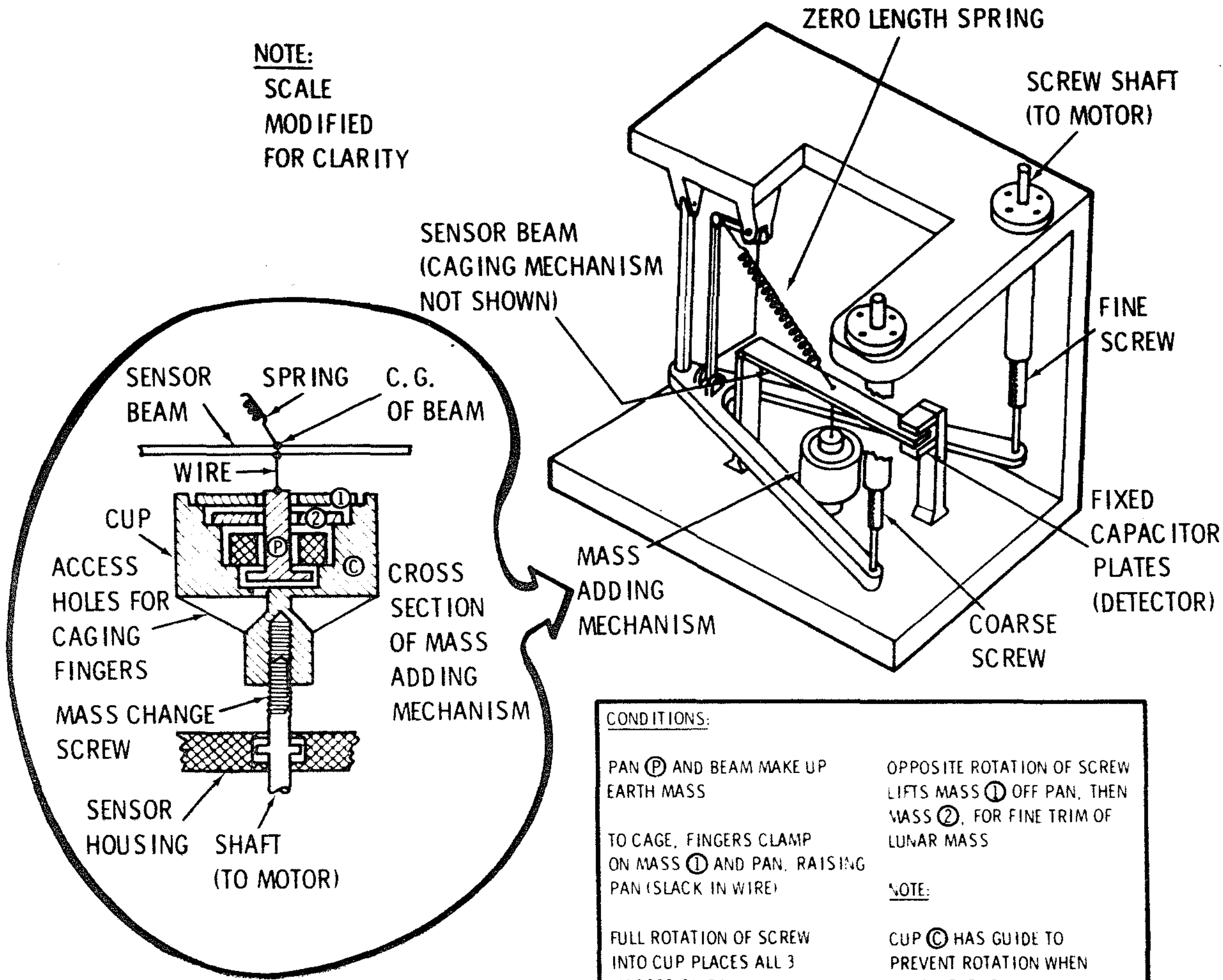
c) To obtain vertical-axis seismic data up to frequencies of 16 hertz.

d) To determine the ratio of lunar gravitational force to earth gravity with a precision of 1 part in 10^5.

The Lunar Surface Gravimeter detects and measures the vertical component of gravity at three different frequency levels-tidal (d. c. to 0.008 hertz), free-modes (0.0008 hertz to 0.12 hertz), and seismic (0.5 hertz to 16 hertz). These signals are detected with an accuracy of 1 part in 1000, with a resolution of 2 microgals for the tidal signal, 0.008 microgal for the free-modes signal, and 0.001 micron for the seismic signal.

The basic gravity sensor uses the LaCoste-Romberg type of spring-mass suspension to sense changes in the vertical component of local gravity. The sensor is shown diagrammatically in Figure 5-8. In the LaCoste-Romberg instrument, the major fraction of the force supporting the sensor mass (beam) against the local gravitational field is provided by the zero-length spring. (A zero-length spring is one in which the restoring force is directly proportional to the spring length.) Small changes in force tend to displace the beam up or down. This imbalance is adjusted to the null position by repositioning the spring pivot points by means of micrometer screws.

LSG SENSOR DETAILS



JUNE 72 3270.3.9

Figure 5-8

The sensor mass can be modified by the addition or removal of small weights, permitting the range of the sensor to be extended from earth to lunar operation.

The electronic sensing portion of the instrument consists of a set of capacitor plates. Two plates are fixed to the frame of the sensor, geometrically concentric with a third plate of similar size which is attached to the movable beam of the sensor. The plates are so arranged that the center plate is located exactly between the two outer plates when the beam is exactly horizontal.

The LSG has two servo systems. A null-seeking servo system provides an electrostatically-generated restoring force to balance the change in gravitational forces and recenter the beam to its reference position, equidistant between the two outer capacitor plates. The spring suspension point is adjusted by means of a motor-driven micrometer-screw servo system and is so set up that the center plate is zeroed when the input perturbation signal is midway between its extreme values. Micrometer-screw position is detected by readout of shaft encoders coupled to the screws.

The sensor-spring constant, and thus the restoring force, is affected by temperature. However, there is a point of inflection on the spring-constant-versus-temperature curve at which the spring constant is least sensitive to temperature changes; this point is called the spring inversion temperature point. To minimize the effects of temperature on the data output, the sensor will be operated near this temperature ($50^{o}C$) and its setpoint will be maintained with a short-term (30-minute) stability of $\pm 0.001^{o}C$ and a long-term (one-lunation) drift of $\pm 0.01^{o}C$.

To operate properly, the gravimeter sensor must be finely leveled and its temperature and pressure must be maintained within very close limits. A cutaway view of the instrument design to satisfy these requirements is shown in Figure 5-9.

In essence, the sensor is surrounded by three containers. The innermost is the heater box, which contains in addition to the gravimeter sensor the basic heating elements and drive mechanisms. Located on the outside of the heater box are motors for driving the micrometer screws, for mass adding, and for adjustment of tilt angle. The box is suspended in the sealed instrument housing, which is evacuated and back-filled with nitrogen

LSGE/CUTAWAY

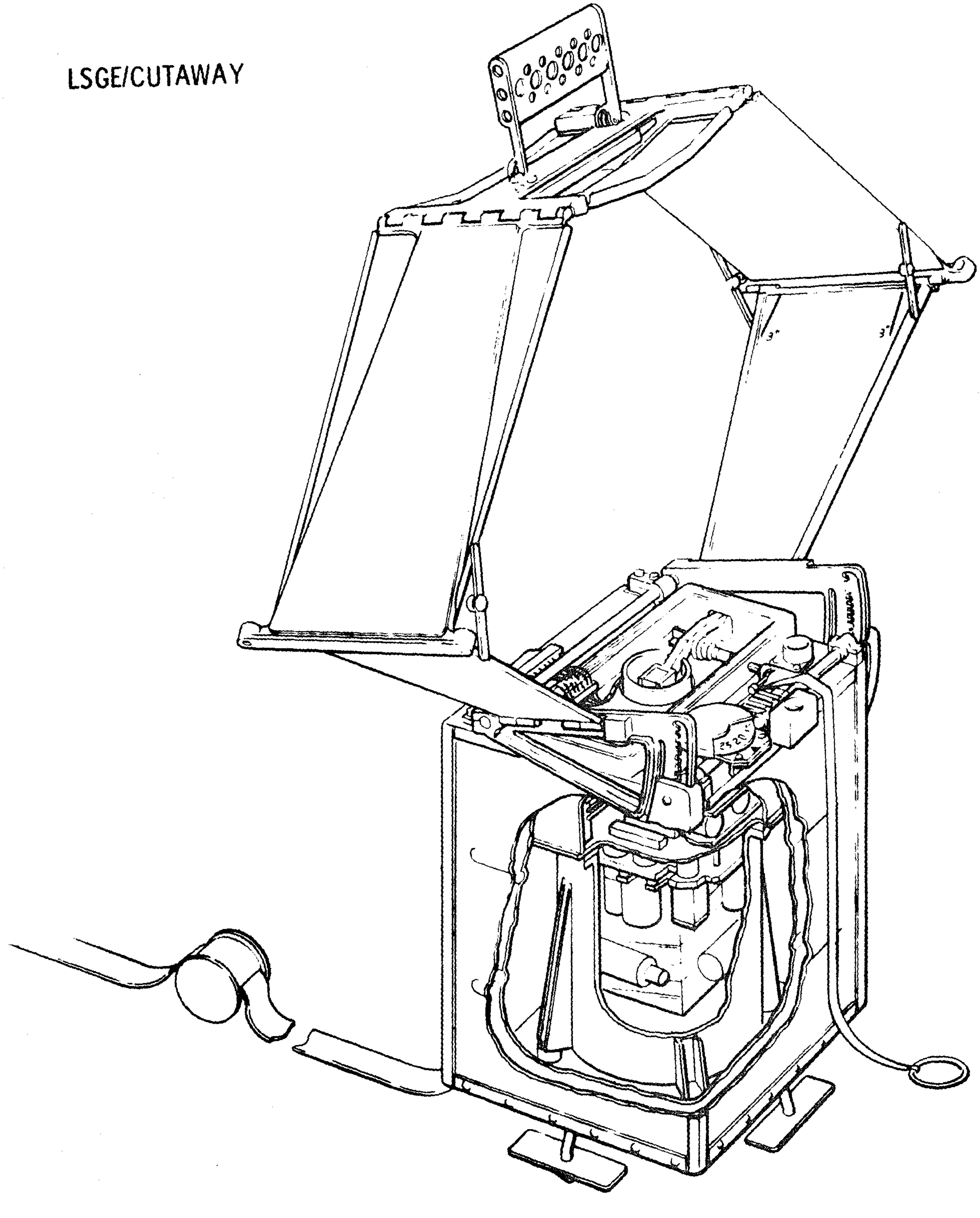


Figure 5-9

to a nominal pressure of 10 Torr. This small amount of gas provides the damping necessary for operating the sensor and the servo systems. The four fiberglass straps by which the box is suspended provide conductive thermal isolation from the instrument housing. The electronics package is mounted on top of the instrument housing. A pressure sensor for monitoring internal pressure is located in the instrument-housing cover. Power and signal connections between the pressure sensor, the heater box, and the electronics package pass through two hermetically sealed connectors in the cover.

The total instrument-housing and electronics-package assembly is suspended from a gimbal for self-leveling. For fine adjustment, the center of gravity of the gimball-suspended mass is adjusted by driving small, weighted motors attached to the heater box along a screw to a new position. The clearance between the instrument housing and the outer container permits a swing of slightly more than 3 degrees in all directions without interference. In the stowed configuration, the gimbal is locked and the entire suspended mass and gimbal are depressed into small cones located in the insulation between the two outer containers.

The container that encloses the entire suspended mass is composed of insulation between two aluminum shells. Four feet, used for lunar emplacement, project from the bottom of the container. The top has a cavity that contains the thermal radiator and the gimbal-actuator mechanism. Also located on the top of the unit are a bubble level, the handling-tool socket, the sunshade with its tilt mechanism, the tilt indicator, and detents for locking in a tilted position. On the side of the outer container is a bracket that retains the cable spool and cable linking the unit to the ALSEP Central Station.

The sunshade prevents direct solar radiation from impinging on the cavity. The top element of the sunshade has an astronaut handle to facilitate deployment. This handle is hanged to fold down flat during transit. A gnomon or sun-angle indicator is marked on the sunshade for azimuth alignment. The sunshade tilt indicator is marked on the sunshade for azimuth alignment. The sunshade tilt indicator is calibrated in degrees of latitude, permitting the astronaut to tilt the sunshade to accomodate landing-site latitude variations of $\pm$ 25 degrees from the lunar equator.

This page intentionally left blank - Page 5-19 was missing from this document.

In order to operate over a wide input range and to make the operation independent of small changes in the electronics, a dc feedback voltage applied to the capacitor plates balances the input force and brings the beam back to a near-center position. The restoring force is obtained by modulating a constant voltage bias across the plates. The electrostatic force generated is directly proportional to the feedback voltage, which is obtained by integrating the beam position signal from the demodulator. At low frequencies (tidal and free-modes motions), where the integrator has sufficient time to follow, the output is directly proportional to the gravity change. The output of the integrator is of sufficient amplitude to provide an accurate measurement of the tidal data; the free-modes data have a much lower intensity, however, and require that the integrator output be further amplified and filtered.

The seismic signals are of a higher frequency than the tidal or free-modes signals. Since these input frequencies are higher than the natural frequency of the sensor, the beam will remain fixed in space because of its inertia. The detection of seismic signals is based on the motion of the fixed plates relative to the beam. The error signal generated as a result of this motion is a direct indication of the seismic input.

5.5 THE LUNAR SEISMIC PROFILING EXPERIMENT

5.5.1 Description of the Experiment

The experiment will determine the Lunar Surface and Near-Surface response to artificially induced seismic energy and to natural seismic phenomena.

This data will be analyzed to obtain the following lunar surface characteristics.

(a) the degree of induration and bearing strength of the lunar surface

(b) the thickness and line structure of the surface layer

(c) the type and character of the surface and near surface rocks

(d) the relationship between Marias and Highland areas

(e) an understanding of the origin of the primordial lunar surface

The LSPE consists of a central electronics package mounted on the central station thermal plate, a special transmitting antenna, four geophones and eight explosive packages. These items are illustrated in Figure 5-10, which shows the four geophones packaged into a module from which they will be deployed by the astronaut, the electronics, the deployed antenna, and one explosive package transport frame with two mounted and one deployed package.

The geophones will be deployed in the pattern which is shown in Figure 1-3. This provides known multiple direct paths from the geophone array to an explosive package source.

The explosive packages will be transported on the LRV and deployed by the astronauts at known locations which are between 160 and 3500 meters from the ALSEP Central Station. The charge weights are in the range of 1/8 lb. to 6 lb., the heavier charges being deployed at the greater distances.

The explosive package design is shown in Figure 5-11. Each explosive package is designed to be detonated by a radio link from the LSPE Central Electronics during a one minute period of time. The astronaut "arms" each package upon deployment. Approximately ninety hours after the deployment of each package the "detonation window" of that package opens. Power is supplied to the Package Electronics by a thermal battery with a one minute minimum lifetime. If an "fire" signal is not received by the package, the thermal battery power runs out and the package electronics are no longer powered. About one hour later the Explosive Package is disarmed so that it will not be a potential hazard to any future lunar exploration missions.

The timing relationships for a typical deployment sequence are illustrated in Figure 5-12. In this sequence, four explosive packages are deployed on the 2nd EVA and four on the 3rd EVA. The actual deployment sequence may differ from this typical sequence. The timing of the explosives is deferred until after LEM lift-off, by means of timers delaying the arming for either 90, 91, 92 or 93 hours after deployment.

LSP EQUIPMENT

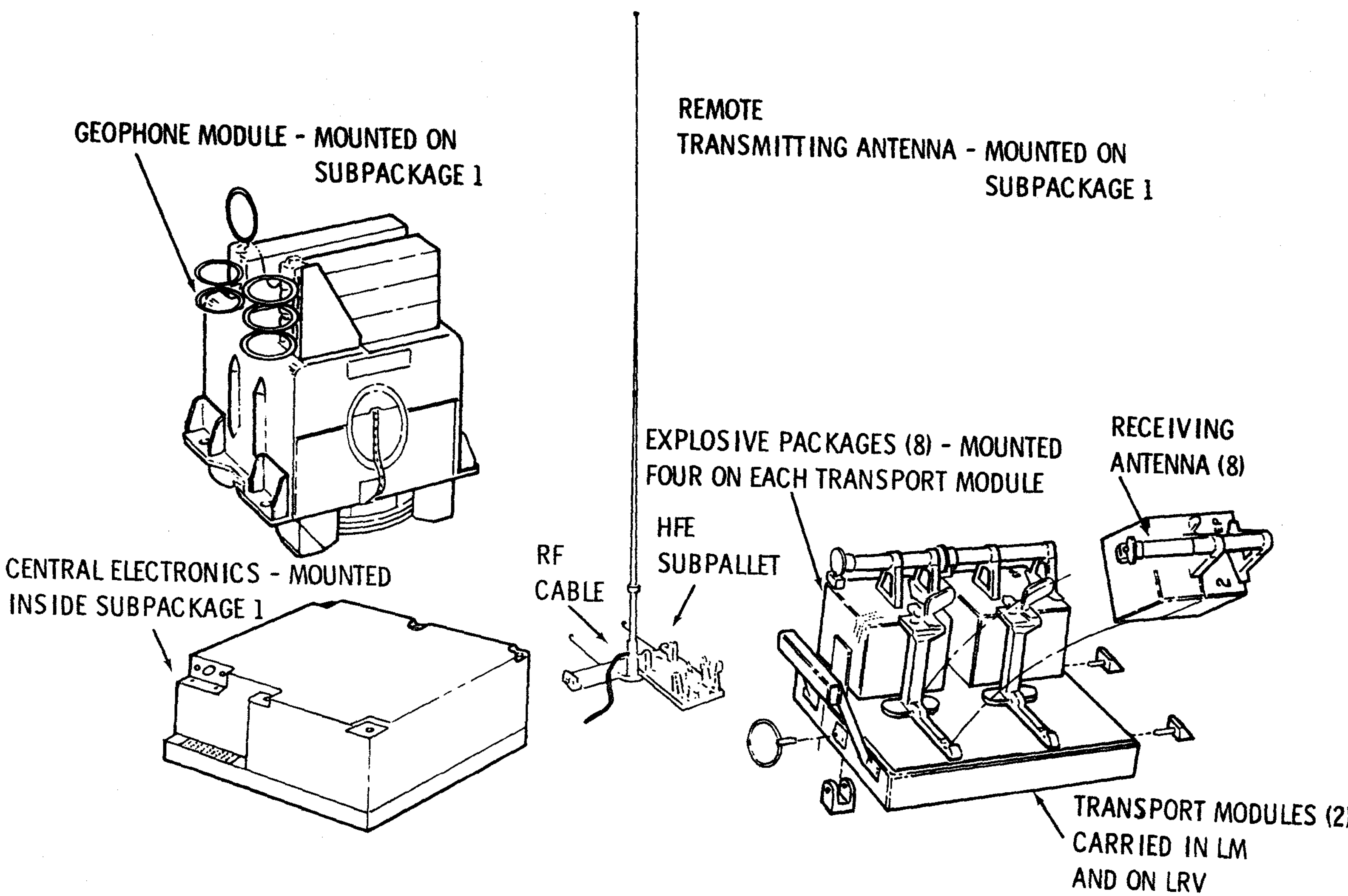


Figure 5-10

JULY 72 3270.5.2

LSP EXPLOSIVE PACKAGE DESIGN

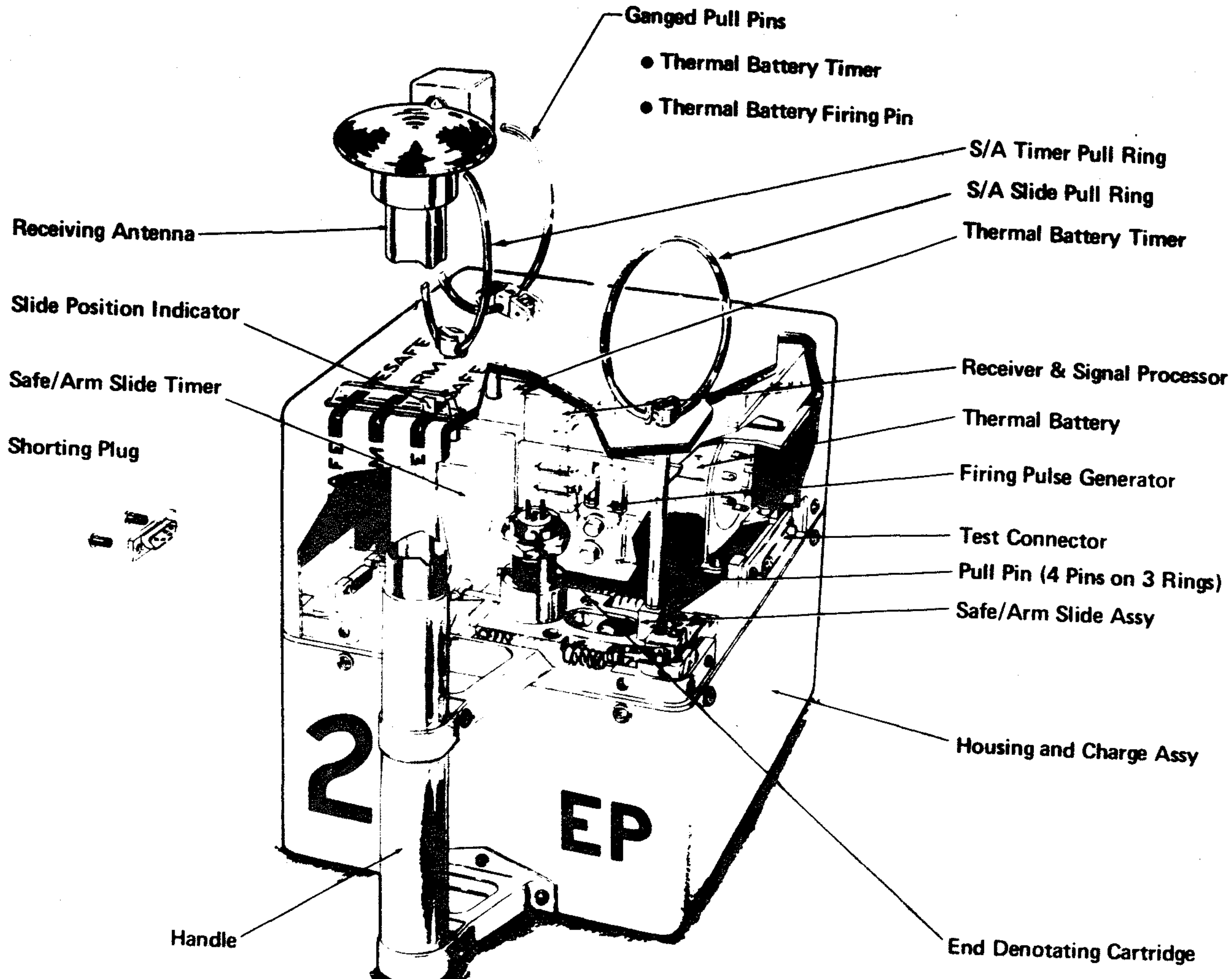


Figure 5-11

JULY 72 3270.5.9

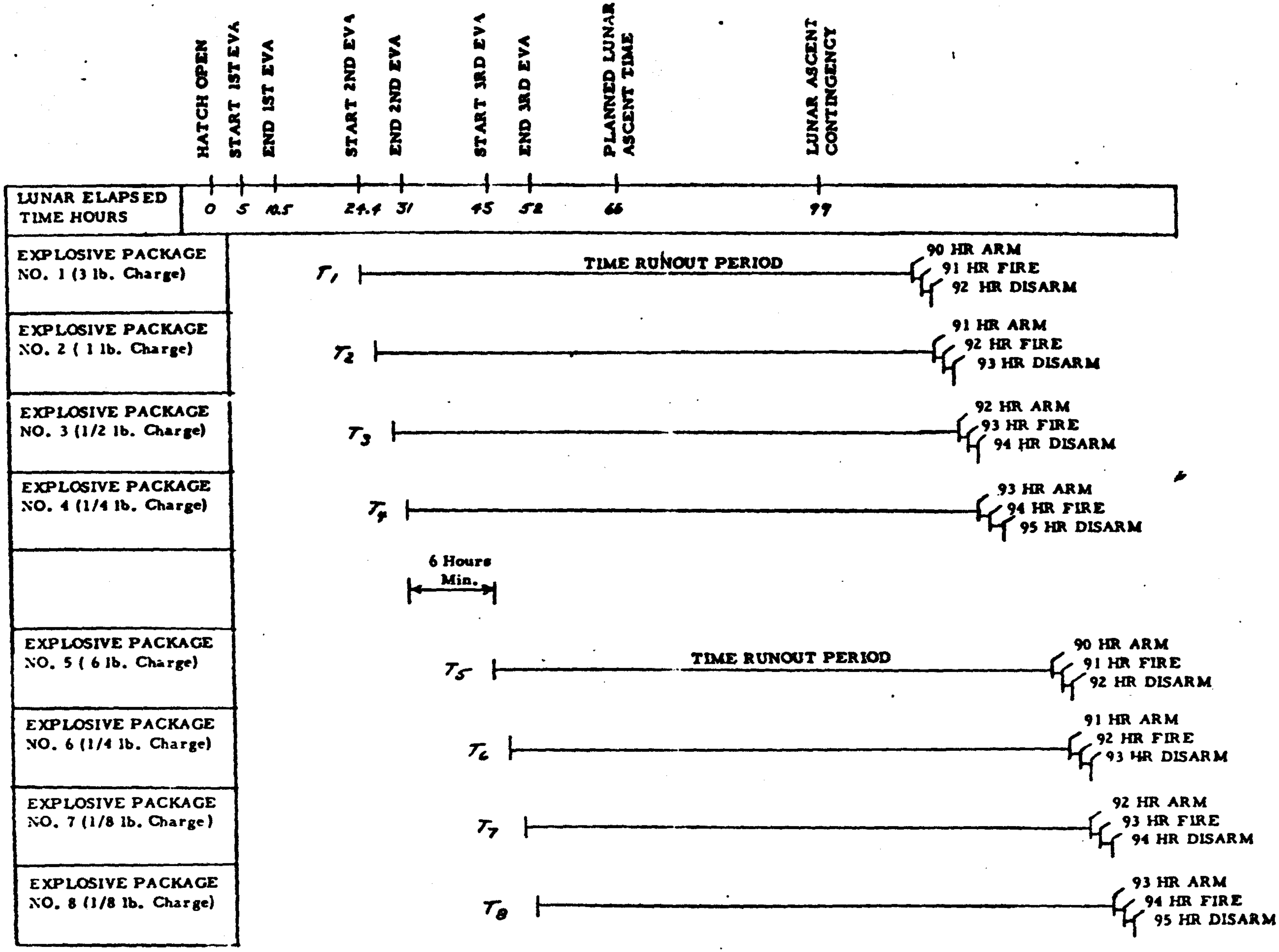


Figure 5-12 Explosive Package Deployment Time and Sequence

The ALSEP is commanded into the "LSPE Formatting" mode of operation shortly before the first "detonate window" is expected to open. The LSP transmitter is turned on so as to transmit "fire" pulses at intervals of thirty seconds. When a package's "detonate window" opens at least one "fire" signal pulse will be received by the package. The first "fire" pulse received will initiate the explosion of the package.

The time of transmission of the "fire" pulses is synchronized with the LSPE downlink telemetry frame. This permits the geophone output signals recorded at the ground stations to be related the actual instant of the explosion, so the velocity of the seismic waves may be deduced.

After all the explosions have been recorded, or in the event of a misfire the "detonate windows" have closed, the ALSEP is commanded to the "DP formatting" mode of operation.

The ALSEP retains the facility to operate the LSPE geophone seismic sensors in a passive listening mode when required.

5.4.2 Experiment Control

The operation of the experiment is controlled by commands from the MSFN. A total of five commands are allocated to the LSPE. These commands are utilized on a one command one function basis, thus giving the LSPE a total command capability of 5. Two commands are allocated to the Data Processor so as to switch the ALSEP into and out of the LSP Formatting" mode of operation.