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LANDSAT-D FLIGHT SEGMENT OPERATIONS MANUAL

VOLUME I

(E83-10285) LANDSAT-D FLIGHT SEGMENT OPERATIONS MANUAL, VOLUME 1 (General Electric Co.) 749 p HC A99/MF A01 CSCL 12B

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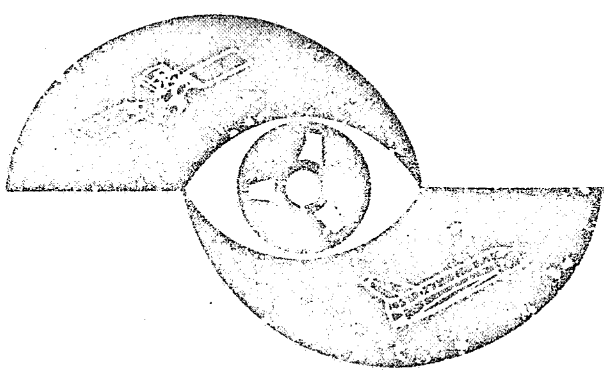

SPACE SYSTEMS DIVISION

CONTRACT NO.
NAS 5-25300

GENERAL ELECTRIC

SVS-10266
Rev. B
August, 1982

LANDSAT-D

FLIGHT SEGMENT

OPERATIONS MANUAL

Prepared For

Goddard Space Flight Center
Greenbelt, Maryland 20771
Under
Contract No. NAS5-25300

General Electric Company
Space Systems Division
Valley Forge Space Center
P. O. Box 8555
Philadelphia, Pennsylvania 19101

LSD-WPC-263

SVS-10266
Rev. B
August, 1982

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LSD-WPC-263

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REVISION LOG

This log identifies those portions of this specification which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Paragraph Number(s) Affected	Rev. Date
A	AN-2 Cancels AN-1, CHG PER AN-2, Redefine Document Structure	June 1982 JCR 6/10/82 dj
B	Revise SVS-10266/3 to Rev. A inc. SVS-10266/3 AN-1	8/5/82 PCR 8-10-82 J.H.

REVISION STATUS AND INDEX PAGE

Document Number	Volume Number	Contents	Revision Status	Index Page
SVS-10266/1	I	Sections 1-13 (INTRO, REF's, MACS, C&DH, NBTR, OBC, PM, SC&CU, MPS, SADAPTA, PDU, DPU, WCS)	Ø	1-1 thru 13-41
SVS-10266/2	II	Section 14 (TM, GPS, DASB, MSS, PCD, TCS, SARDJA, BARDJA, STRUCTURE)	Ø	14-1 thru 22-40
SVS-10266/3	III	Appendix A (Coefficients/Calibration Data)	A	A-1 thru A-40
SVS-10266/4	IV	Appendix B (OBC Software Users' Manual)	Ø	B.1-1 thru B.3-450

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GENERAL ELECTRIC SPACE SYSTEMS PHILA., PA. **ALTERATION NOTICE**	SECURITY CLASS. NONE	CONTRACT NAS5-25300	ALTERATION NO. SVS 10266/1 -1
	INITIATOR J. VARHOLA	RM. NO. U7035 EXT. NO 2648 OPER. NO. 1040	REG AN DWG X PL — CHGD AN DWG PL — SHEET 1 OF 8 — GEN AN EMER
DRAWING OR SPECIFICATION TITLE LANDSAT-D FLIGHT SEGMENT OPERATIONS MANUAL		ORG NO. —	NEXT ASSEMBLY NO. —
NATURE OF CHANGE ADD, DELETE AND REVISE TEXT; CORRECT AND ADD INFORMATION TO TABLES AND FIGURES			AREA OR END ITEM —
			EPR NO. —
REASON FOR CHANGE TO REFLECT REVIEW COMMENTS AND LATEST SPACECRAFT INFORMATION.			ECP NO. —
			CONTROL NO. —

P. iii WAS 1. Instruction to Landsat-D
NOW 1. Introduction to Landsat-D

P. 1-5, LINE 22 WAS 48 x 48 x 12
NOW 48 x 48 x 18

P. 3-25, PARA. 3.1.12, LINE 1 WAS Instrument Module (IM)
NOW Multimission Modular Spacecraft (MMS)

P. 3-28, PARA. 3.2, LINE 5 WAS Instrument Module (IM)
NOW Multimission Modular Spacecraft (MMS)

P. 4-13, PARA. 4.11.2.3, LINE 7 DELETE: "except when transmitting high data rate telemetry signals." ADD: "NOTE: During emergency TDRS link service (SSA) via Landsat-D Omni antenna, the coherent turn-around mode and ranging should be turned OFF, since Omni forward link nulls in the antenna pattern will result in the switching of PN codes, causing WSGT to lose the return link."

PROGRAM AND/OR MODEL NO. LANDSAT-D	EFFECTIVITY ALL UNITS	CLASS 2	CODE — TYPE —

DISPOSITION OF MATERIAL	IN PROC.	IN STOCK	COMPL'D	INSTLD.	IN TEST	QUAL.	IN FIELD	NONE
REWORK								
SCRAP								
RETROFIT								
RET TO STOCK								
REQUALIFY								
RETEST								X

EXPLAN. FOR MAT'L. DISP. NONE

CHANGE AFFECTS					
SPEC.		INTCHG		RETROFIT	
PERFRMNCE		COST			
SAFETY		DELIVERY			
RFI		SPARES		NONE	X
Δ WEIGHT —		Δ POWER —		Δ RFM —	

OTHER OPERATIONS AFFECTED —

DISTRIBUTION CODE SVS-10266
DIST LIST VERIFIED [signature]

SECURITY CLASS. NONE [signature] 6/10/82

APPROVALS AND DATE	
WRITTEN BY J. VARHOLA	
CHECKED BY [signature]	R.E. Clayton FORB 6/8/82
DRAWING CHGD BY	[signature] 6/8/82 by R.E. Clayton
DESIGN ENG.	[signature] 6/8/82 by R.E. Clayton
QC & T [signature] 6/8/82	[signature] for W. [illegible] 6/9/82
PROD. CONTROL	CUSTOMER
DCB REP.	DCB CHAIRMAN [signature] 6/10/82

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GENERAL ELECTRIC
MISSILE AND SPACE DIVISION
ALTERATION NOTICE

CLASSIFICATION	SHEET
NONE	2 OF 8
DRAWING NO. SVS-10266/1	ALTERATION NO. -1

P. 1-58 ADD BRACKETS AS SHOWN:

	Destination	Type
Unregulated	Transponder Receiver A	- Continuous
	Transponder Receiver B	- Continuous
	R.F. Switch #1	- Continuous
	R.F. Switch #2	- Continuous
	PMP-A	- Continuous
	PMP-B	- Continuous
	STACC CU-A	- Continuous
	STACC CU-B	- Continuous
	STACC RIU-A	- Continuous
	STACC RIU-B	- Continuous
	Transponder Transmitter-A	- Switched
	Transponder Transmitter-B	- Switched
	R.F. Switch BUS-A	- Switched
	R.F. Switch BUS-B	- Switched
	Module Heater #1	- Switched
	Module Heater #2	- Switched
	NBTR A	- Continuous
	NBTR B	- Continuous
Conditioned	STINT A	- Dedicated
	STINT B	- Dedicated
	Memories	- Switched

P. 1-5, para. 3, line 2 WAS centered about the roll axis
NOW centered on the pitch axis.

P. 1-6, para. 2, line 9 WAS attitude which without use
NOW attitude without use

FORM 1037A REV. (5-65) TISSUE

CLASSIFICATION	ENGINEER
NONE	J. VARHOLA

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GENERAL ELECTRIC
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ALTERATION NOTICE

CLASSIFICATION	SHEET
NONE	3 of 8
DRAWING NO.	ALTERATION NO.
SVS-10266/1	1

P. 4-95, PARA. 4.6.1.3.3 ADD ASTERISKS AND NOTE AS FOLLOWS:

Mode E – external data to [illegible] *
Mode F – Real time telemetry to TDRSS *
Mode I – Real time telemetry and external data to TDRSS *

* This mode not used for Landsat-D

P. 4-97, Figure 4.6-2 ADD ASTERISKS AND NOTE AS FOLLOWS:

Mode
E *
F *
I *

* This mode not used for Landsat-D

P. 4-99 ADD ASTERISKS AND NOTE AS FOLLOWS:

AMP/XPNDR. Configuration

Mode E normal *
Mode F normal *
Mode I normal *

Mode E reverse *
Mode F reverse *
Mode I reverse *

* This mode not used for Landsat-D

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NONE	VARMOLA

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ALTERATION NOTICE

CLASSIFICATION	SHEET
NONE	4 OF 8
DRAWING NO. SVS-10266/1	ALTERATION NO. 1

P. 5-16, PARA. 5.4 ADD THE FOLLOWING AFTER ITEM 4:

5. If power is to be turned OFF, the current state of the tape position, BOT, and EOT indicators should be logged.

Explanation:

The Narrowband Tape Recorders (NBTR) use digital logic and logic latches to collect and transmit digital telemetry signals. As a result, these signals are lost from memory (i.e., latching is cancelled) when NBTR power is removed.

It is important to be aware that tape position, BOT, and EOT indicators do not return to their former values when power is turned OFF and then ON. As a result, if power is to be turned OFF, the current state of those indicators should be logged.

When the recorders are turned on, the tape position will not read correctly until the tab on the lower reel has made two successive passes between the LED and phototransistor to initialize the tape position counter.

Similarly, if recorder power is turned OFF while that recorder is at BOT or EOT, when recorder power is later turned ON it will not indicate BOT or EOT, and will move in the direction commanded, and will indicate BOT or EOT only after the lower reel tab has passed between its LED and phototransistor sufficient times to indicate a tape position indicator value equal to or less than 70 (BOT) or equal to or greater than 180 (EOT). 70 and 180 are in decimal notation. The recorder will indicate BOT or EOT and stop the recorder (put it into STANDBY mode) only after 3 successive tape position indications of ≤ 70 or ≥ 180.

(continued)

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NONE	VARHOLA

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CLASSIFICATION	SHEET
NONE	5 OF 8
DRAWING NO.	ALTERATION NO.
SVS-10266/1	1

The above applies to primary BOT and primary EOT. Secondary BOT and EOT are implemented as windows in the tape which pass between a LED and phototransistor. As with primary BOT and EOT, secondary BOT and EOT are logic latches, and will not be retained with power OFF. When power is later turned ON, the recorder will move as commanded, and will indicate secondary BOT or EOT only if the appropriate window is passed between the LED and phototransistor again.

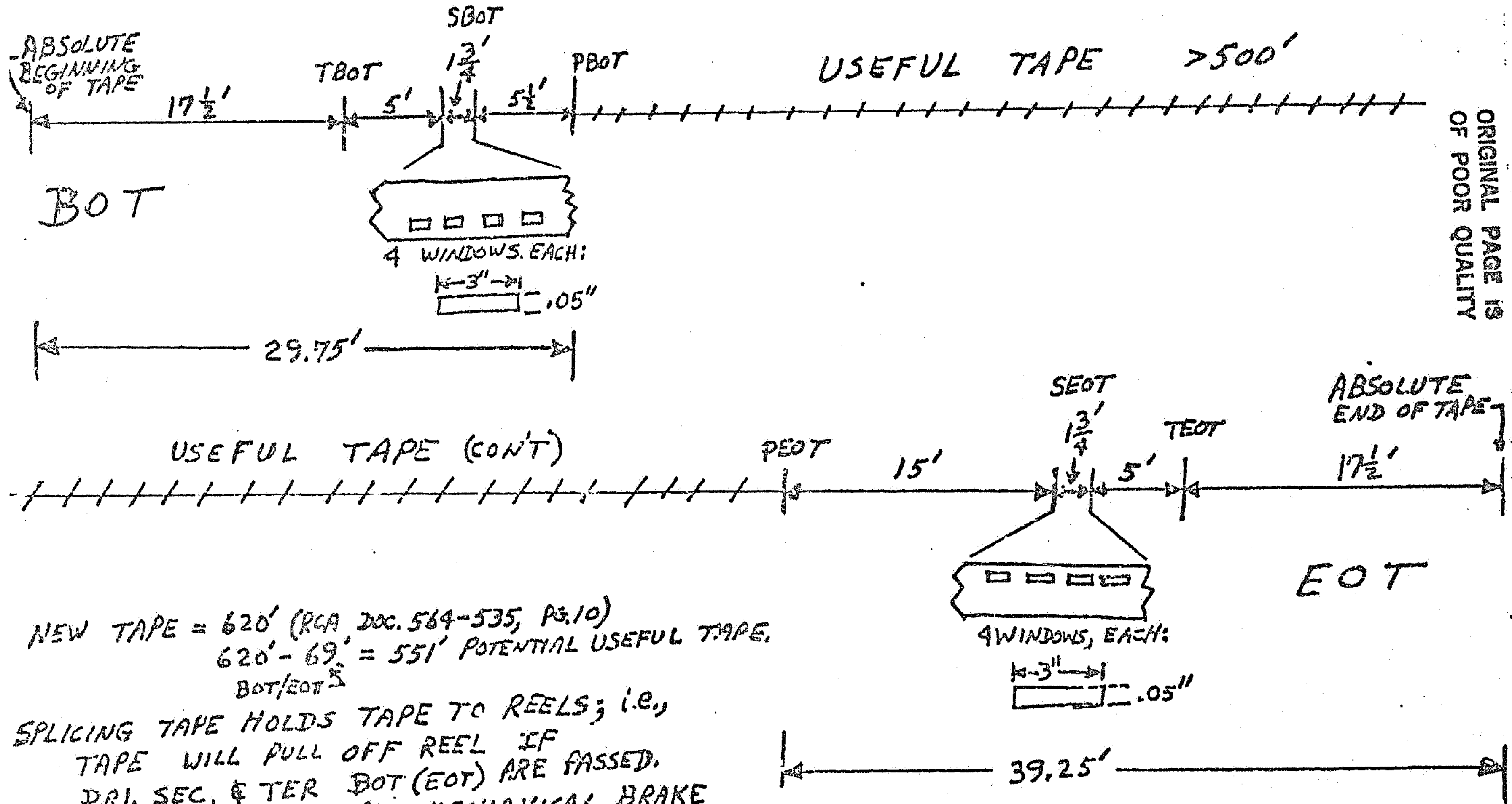
Tertiary BOT and EOT will be retained during power OFF, since each is a mechanical brake and also a switch mechanism which prevents the motor from moving tape farther into BOT or EOT.

It should be noted that all of the above applies only to primary power OFF. BOT, EOT and tape position indications are retained when the recorder is in Standby (Stop).

Figure 5.4-1 indicates the tape layout including design primary, secondary, and tertiary BOT and EOT locations.

FORM 1037-A REV. (6-65) TISSUE

CLASSIFICATION	ENGINEER
NONE	VARHOLA



NEW TAPE = 620' (RCA DOC. 564-535, PG.10)
620' - 69.5' (BOT/EOT) = 551' POTENTIAL USEFUL TAPE.

SPLICING TAPE HOLDS TAPE TO REELS; i.e.,
TAPE WILL PULL OFF REEL IF
PRI, SEC, & TER BOT (EOT) ARE PASSED.
TERTIARY IS HARD MECHANICAL BRAKE
ON REELS & MOTOR DISCONNECT.

FIGURE 5.4-1 LANDSAT D TAPE RECORDERS
BOT/EOT LOCATIONS

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ALTERATION NOTICE

CLASSIFICATION	SHEET
NONE	7 OF 8
DRAWING NO.	ALTERATION NO.
SVS-10266/1	1

P. 7-7/8 REVISE LINE 8 AS FOLLOWS:

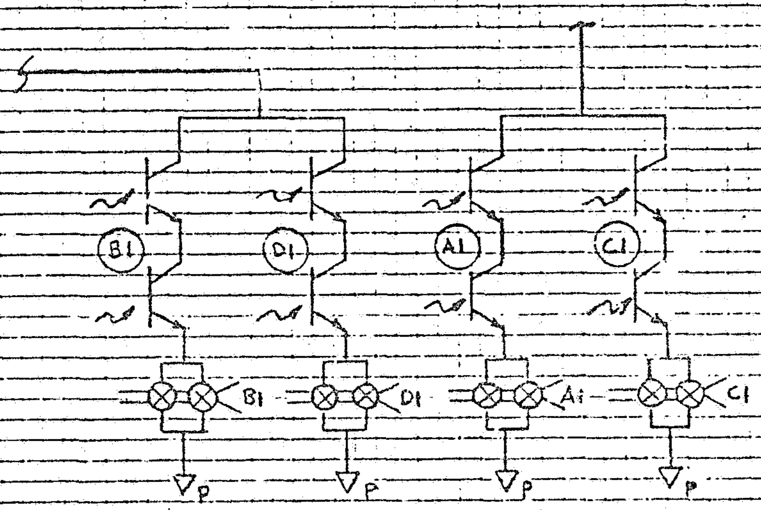
Capability exists to fire only two of the four 5-pound thrusters for translation, but this mode will normally be used for drag makeup maneuvers.

P. 7-7/8 ADD THE FOLLOWING TO THE LAST PARAGRAPH:

NOTE: when a translation thruster OFF-pulses, the corresponding attitude control thruster(s) ON-pulse.

P. 7-13, LINE 3	WAS	756 milliseconds
	NOW	256 milliseconds
P. 7-13, LINE 5	WAS	756 milliseconds
	NOW	256 milliseconds
P. 7-13, LINE 22	WAS	undesired torque
	NOW	desired torque

P. 7-19 REVISE FIG. 7.3-1 AS FOLLOWS:



5 LB$_F$ THRUSTERS

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NONE	VARHOLA

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CLASSIFICATION	SHEET
NONE	8 OF 8
DRAWING NO.	ALTERATION NO.
SVS-10266/1	1

P. 7-21, PARA. 7.4.3, ITEM 2 REVISE AS FOLLOWS:

WAS Following Coarse Sun Acquisition,
NOW Following orbit adjust in normal orbit operations,

P. 7-23, PARA. 7.4.7 ADD THE FOLLOWING ITEM:

6. In order to use the translation thruster OFF-pulsing capability either or both PME's must be enabled for attitude control.

P. 7-25, LINE 2 WAS withtout
NOW without

P. 8-7, PARA. 8.2.3.2, LINE 3 WAS resupply operations
NOW retrieval operations

P. 9-7, PARA. 9.2.2, LINE 2 WAS This shall be implemented
NOW This is implemented

P. 9-7, PARA. 9.2.3.1, ITEM 2, LINE 1

WAS The SC/CU shall provide
NOW The SC/CU provides

P. 13-3, PARA. 13.1.1, LINE 10 WAS Figure 13-2
NOW Figure 13.1-2

FORM 1037A REV. (6-65) TISSUE

CLASSIFICATION	ENGINEER
NONE	VARHOLA

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	INITIATOR J. VARILULA	RM. NO. 47035 EXT. NO. 2648 OPER. NO. 1040	REQ AN DWG PL / CHGD AN DWG PL / SHEET 1 OF 3
DRAWING OR SPECIFICATION TITLE LANDSAT-D FLIGHT SEGMENT OPERATIONS MANUAL		P OR G NO. 2 —	X / GEN AN / EMEP
NATURE OF CHANGE TO CORRECT & UPDATE FIGURES			NEXT ASSEMBLY NO. —
			AREA OR END ITEM —
			EPR NO. —
REASON FOR CHANGE TO REFLECT NEW COMMENTS AND LATEST SPACECRAFT INFORMATION			ECP NO. —
			CONTROL NO. —

SECTION 16 WAS PAGE 6-19
NOW PAGE 16-19

PROGRAM AND/OR MODEL NO.	EFFECTIVITY	CLASS	CODE	TYPE
LANDSAT-D	ALL UNITS	2	—	—

DISPOSITION OF MATERIAL	IN PROC.	IN STOCK	COMPLETED	INSTLD.	IN TEST	QUAL.	IN FIELD	N.R.S.
REWORK								
SCRAP								
RETROFIT								
RET TO STOCK								
REQUALIFY								
RETEST								
NONE								X

EXPLAN. FOR MAT'L. DISP.: NONE

CHANGE AFFECTS

SPEC.		INTCHG		RETROFIT	
PERFRMNCE		COST			
SAFETY		DELIVERY			
RFI		SPARES		NONE	X
Δ WEIGHT —		Δ POWER —		Δ RFM —	

OTHER OPERATIONS AFFECTED

DISTRIBUTION CODE: SVS-10266

SECURITY CLASS.: U

APPROVALS AND DATE

WRITTEN BY: J. VARILULA	
CHECKED BY: [signature] 6/4/82	R.E. Clayton FOR E 6/8/82
DRAWING CHGD BY	G.A. Acpli 6/8/82 by R.E. Clayton
DESIGN ENG.	D.E. Plante 6/8/82 by R.E. Clayton
QC & T [signature] 6-8-82	[signature] 6-9-82 for W. [signature]
PROD. CONTROL	CUSTOMER
DCB REP. [signature] 6/10/82	DCB CHAIRMAN [signature] 6/10/82

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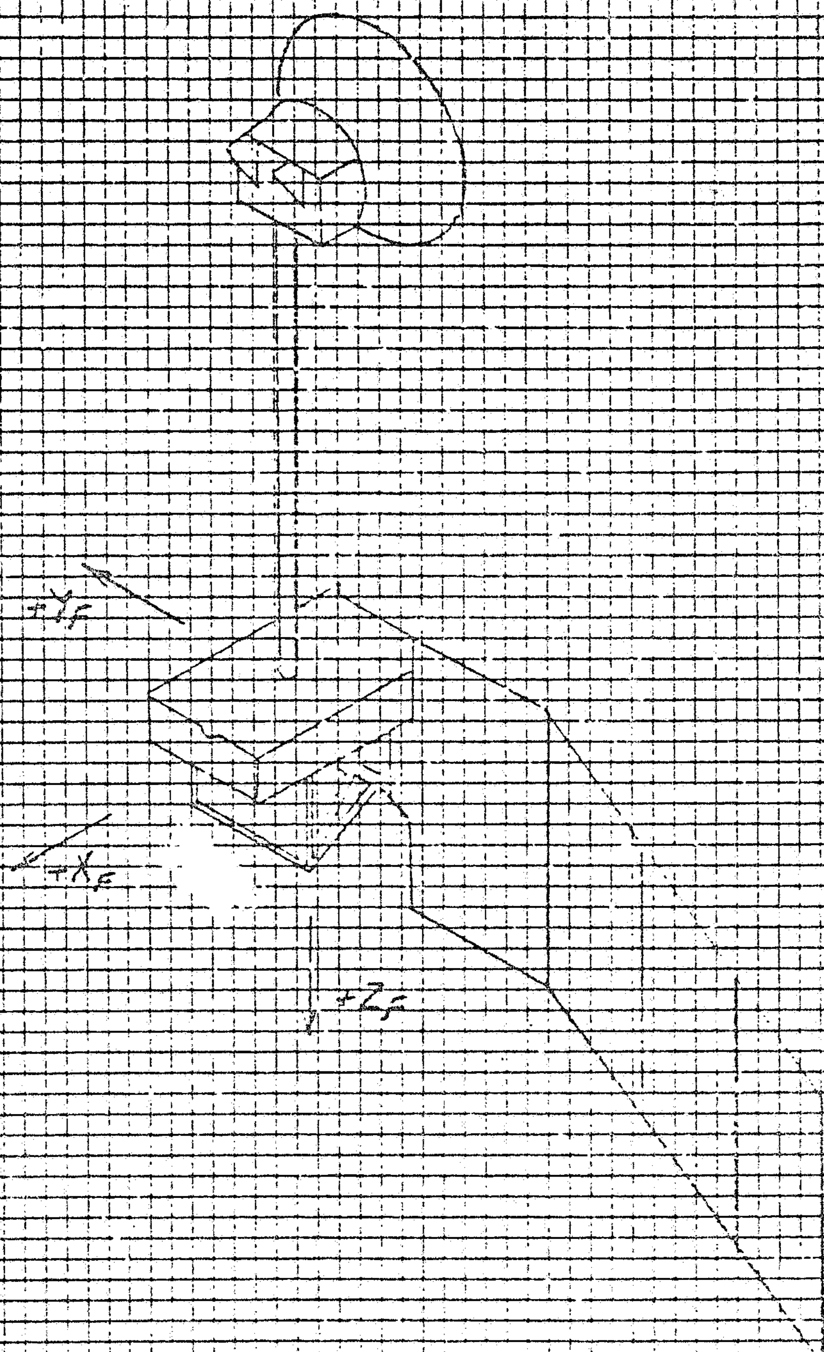
CLASSIFICATION	SHEET
NONE	2 OF 3
DRAWING NO.	ALTERATION NO.
SVS-10266/2	1

P 20-2, Figure 20.1-1 ADD DIRECTIONAL ARROWS AS SHOWN.



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CLASSIFICATION	ENGINEER
NONE	VARHOLA

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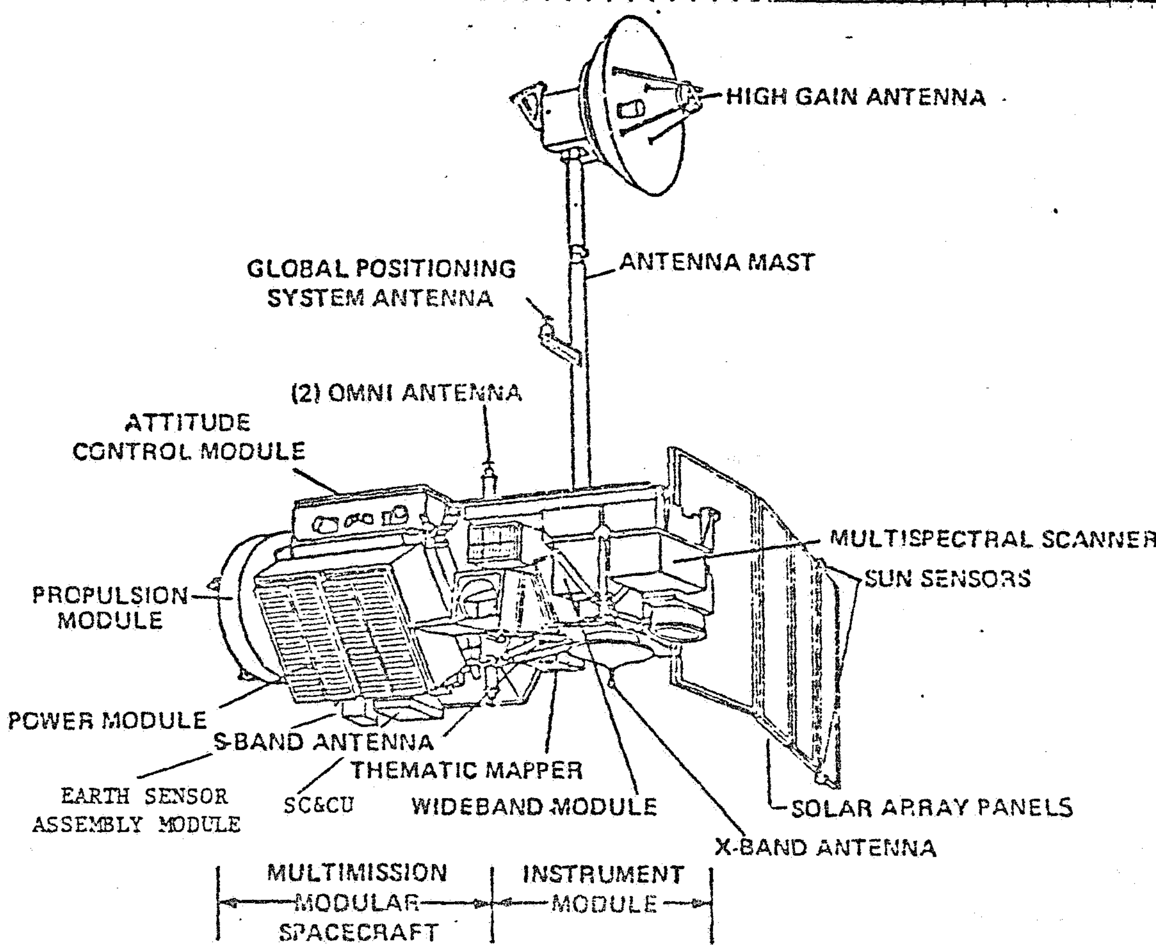
CLASSIFICATION	SHEET
NONE	3 OF 3
DRAWING NO.	ALTERATION NO.
SVS-10266/2	1

P. 22-2 WAS Figure 22-1
NOW Figure 22.1-1

ADD EARTH SENSOR ASSEMBLY MODULE I.D. AND
SC&CU I.D. AS SHOWN BELOW:



P. 22-23, Figure 22.2-5 WAS See Figure 22.2-4 for configuration
NOW See Figure 22.2-6 for configuration

FORM 1031A REV. (6-63) TISSUE

CLASSIFICATION	ENGINEER
NONE	VARHOLA

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LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATION (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

1.0 INTRODUCTION

1.0 INTRODUCTION

SECTION 1.0

INTRODUCTION TO LANDSAT-D

The Landsat program had its origin in conceptual studies and planning performed in the late 1960's, culminating with the launch of Landsat 1 in July of 1972. The program has focused on the development and application of remote sensing technology from space to assist man in his understanding and management of the earth's resources. The program, by a variety of measures, has been an unqualified success. The number of data applications has been steadily expanding, with estimates of the potential annual economic benefit to this nation alone in the hundreds of millions of dollars. By early 1978, the number of organizations making practical use of Landsat imagery had grown to over 600, spread over 100 nations. Seven countries have installed and are operating their own data receiving and processing stations; at least three more are currently planning installations. Formal recognition of the program's significance came in 1974 with the award of the Collier Trophy.

1.1 LANDSAT-D PROJECT OBJECTIVES

The Landsat-D project is a major step in the orderly development and application of remotely sensed data from space to management of the earth's resources. It will provide enhanced remote sensing capabilities relative to earlier Landsats through improved sensors, wider acquisition of global data, and more rapid processing of the data for users.

An instrument named the Thematic Mapper will provide the new sensing capability. It is a mechanically scanned radiometer, operating in seven spectral bands, with 30-meter spatial resolution. Previous Landsat spacecraft carry radiometers with 80-meter resolution and operate in four or five spectral bands.

The project will also develop a new, highly automated ground data system that will calibrate and geometrically correct the sensor data to subpixel accuracies, and make it available to users only a few days after observation.

The three major objectives of the Landsat-D project are to:

1. Assess the capability for the Thematic Mapper (TM) to provide improved information for Earth Resources Management.

2. Provide system-level feasibility demonstrations that will aid federal agencies in decisions on the need for an operational system. It will define the essential features of such a system and the probable cost.

3. Continue foreign support and investment in the program.

The project is being developed by NASA and will eventually be transferred to the National Oceanic and Atmospheric Administration (NOAA).

The Landsat-D observatory operates from a nominal 705 km circular sun-synchronous orbit, imaging the same 185 km swath of the earth surface every 16 days. As illustrated in Figure 1-1, image data is transmitted in real time at Ku-band via the Tracking and Data Relay Satellite (TDRS) to its ground terminal at White Sands, New Mexico. TM data is recorded and then relayed via a domestic communications satellite (DOMSAT) to the Goddard Space Flight Center (GSFC) in Maryland for processing. MSS data can either be recorded and relayed or relayed in realtime to GSFC for processing.

Image data may also be transmitted directly to foreign or domestic ground stations at X-band in addition to, or in lieu of, transmission via TDRS. A separate S-band direct link compatible with the Landsat 1, 2 and 3 is also provided to transmit MSS data to those stations only equipped for receiving at S-band. This S-band link will serve as the primary communication path prior to the availability of TDRS. Spacecraft telemetry and command communications paths are via TDRSS at S-band, and through the NASA-GSTDN stations.

Tracking data for Landsat-D is obtained via TDRSS or the GSTDN stations. Ephemeris data, required by the spacecraft for attitude control and by the ground segment for both mission planning and image correction processing are computed at the Goddard Space Flight Center. However, the Landsat-D spacecraft is equipped with a Global Positioning System (GPS) receiver/processor which, after checkout and calibration, can provide the spacecraft ephemerides.

1.2 FLIGHT SEGMENT

The Landsat-D Flight Segment, shown in its orbital configuration in Figure 1-2, is characterized by by its large deployed mast supporting the TDRS antenna and by its single-wing solar array.

The main body of the spacecraft is comprised of NASA's standard Multimission Modular Spacecraft (MMS) and the Landsat Instrument Module (IM). The long dimension of the spacecraft body (the roll axis) lies in the plane of the orbit; the yaw axis is oriented to the local vertical (parallel to the antenna mast); and the pitch axis is normal to the orbit plane and parallel to the axis of rotation of the solar array.

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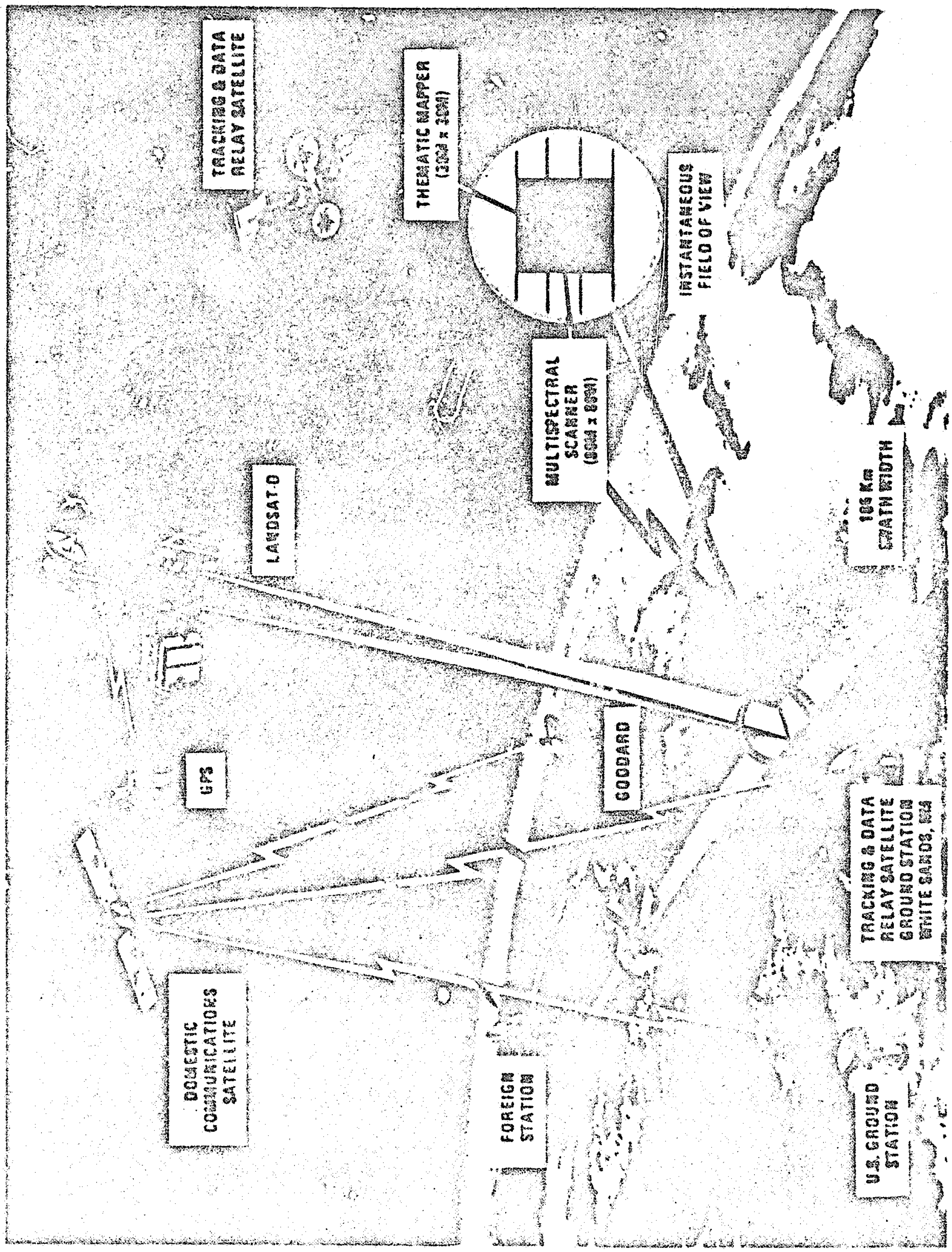

Figure 1-1. Landsat-D System

LSD-WPC-263

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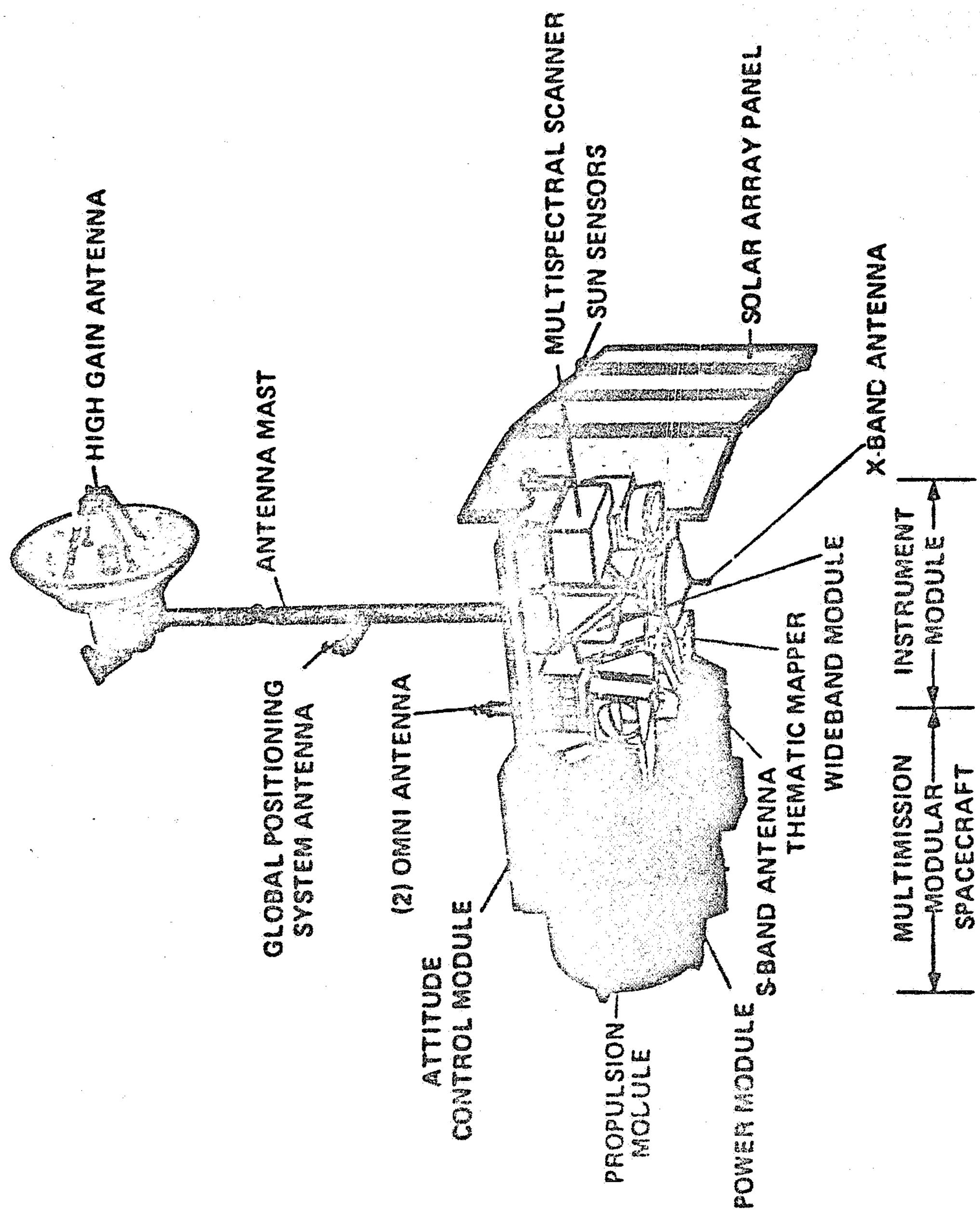

Figure 1-2. Landsat-D Flight Segment Configuration

The principle sensing instruments are: 1) the Thematic Mapper, located at the transition adapter between the Instrument Module and the MMS, 2) and the Multispectral Scanner (MSS), located at the forward end of the Instrument Module. Each instrument uses a moving mirror assembly to scan in the cross-track direction (perpendicular to the spacecraft ground track) and depends upon the relative motion of the spacecraft to achieve the along-track scan. The Thematic Mapper uses a multistage passive radiative cooler for temperature control of the thermal band detectors (which require a large unobstructed space view). The cooler is oriented to the anti-sun side of the spacecraft.

The mast mount for the TDRS communications assembly extends about 13 feet above the spacecraft body to provide a clear field-of-view to the TDRS from horizon-to-horizon. An L-band antenna, mounted on this mast, provides nearly hemispherical contact with the Global Positioning System satellites.

From the sun-synchronous Landsat-D orbit, the relative motion of the sunline traverses a cone centered about the roll axis. The solar array, with its single-axis-of-rotation drive, moves at orbital rate to track the sun and incorporates a fixed cant or bend to orient the array nominally perpendicular to the sun line.

Multimission Modular Spacecraft

The multimission modular spacecraft provides four subsystems; power, attitude control, communications and data handling, and propulsion. They are all mounted on a triangular structure. Each subsystem is modularized, with the former three subsystems housed in identical 48 x 48 x 12 inch structures. The forward end of the structure provides the mating surface for the mission-unique portion of the flight segment, and the aft end contains the propulsion module. For Delta launches, the structure also provides the mechanical interface to the launch vehicle, using an adapter mated to the aft end of the spacecraft. For retrieval, three trunions at the forward end mate to a support cradle which is connected to the Shuttle cargo bay.

The Power Subsystem utilizes a Peak Power Tracker to optimize the transfer of power from the mission unique solar array. It includes three 50-ampere-hour nickel-cadmium batteries, with the necessary provisions for temperature comparison charge control. The power bus operates at a nominal 28 volts dc.

The Communications and Data Handling Subsystem provides telemetry data output at two data rates: 8 kbps during normal operations (with a 1 Kbps backup for use during launch and in case of contingencies), and a 32 Kbps transmission mode for on-board computer memory dump and Payload Correction Data transmission. Two standard tape recorders are included for recording and subsequent playback of telemetry data. Transmission of recorded telemetry data may be directed to GSTDN Stations, or to the ground via TDRSS.

The command portion of the subsystem provides serial and pulse command capability. Landsat-D will utilize three command rates: 125, 1000, and 2000 bps , depending on the uplink command path. All communications between Landsat-D and the ground take place via the C&DH module, with the exception of wideband instrument data. The Communication and Data Handlng Module also contains an on-board computer with 64,000 words of memory. The capability exists to fully reload the memory via command uplink from the ground, and to dump the memory via telemetry. The computer is used for a variety of functions including attitude control, high gain antenna pointing/control, spacecraft/TDRS/solar ephemeris computation, failure detection and correction, and housekeeping telemetry monitoring.

The Attitude Control Subsystem is a high-precision, zero-momentum system with three-axis pointing accuracy of 0.01 degree and a stability of 10^{-6} degree per second. It achieves this precision using an inertial reference unit with attitude updates from two star trackers. A three-axis magnetometer and torquer magnets continuously unload the momentum wheels. Backup wheel unloading is provided by the propulsion module. Since the specific pointing modes are mission-unique, all control algorithms are implemented in software executed in the on-board computer. A Safehold mode is provided which maintains an earth pointing attitude which without use of the on-board computer. It utilizes redundant scanning earth horizon sensors as a two-axis (pitch/roll) reference with a gyrocompass reference in yaw.

The Propulsion Module is mounted at the aft end of the spacecraft and uses hydrazine fuel. It includes both 5-lbf (11N) thrusters and 0.2 lbf (0.5N) thrusters. The large thrusters are used to make orbit adjustments to maintain the 16-day-repeating Landsat-D ground swath. The large thrusters are also used for the orbit altitude changes needed for Shuttle rendezvous. The small thrusters are used for initial stabilization and for backup attitude control system momentum wheel unloading.

Multispectral Scanner

The Multispectral Scanner (MSS) is very similar to that flown on Landsats 1 and 2. The optics and the scan mechanism have been modified to account for the lower altitude of the Landsat-D orbit. The optics are a Ritchey-Cretien type, focusing the scanned earth image on a set of detectors. The instrument includes four spectral bands in the visable and very near IR. Bands one through three use photomultiplier tubes as detectors, while band 4 uses silicon photo diodes.

Twenty-four detectors (six in each of the four spectral bands) are scanned across the flight segment ground track every 73.4 milliseconds. The velocity of the flight segment in orbit is such that the ground track advances the equivalent of six scan lines once each mirror scan cycle. The 15.06 megabit-per-second output data stream contains a continuous 185 km (100 nautical miles) swath of image data on the ground, plus calibration information inserted during the inactive portion of the scan mirror cycle.

Flight segment time code is included in the data stream, with a complete code occurring every other mirror scan. Time information is used to correlate the MSS image data with flight segment ephemeris and attitude during geometric correction processing on the ground.

Thematic Mapper

The Thematic Mapper is a new instrument with improved resolution and spectral coverage. It operates in seven spectral bands. Bands one through five and sevenband cover the visible and near-infrared, while band six provides coverage in the thermal infrared portion of the spectrum. Bands one through five and band seven have an instantaneous field-of-view (IFOV) equivalent to a 30- meter square when projected on the ground; band six has an IFOV equivalent to a 120-meter square on the ground. The output data rate is 84.9 megabits per second. The downlinked data stream includes the imagery data and time code for correlation with attitude and ephemeris data during ground processing.

The Thematic Mapper employs a bidirectional scanning system; i.e., it scans in both directions across the ground track, yielding an 85 percent scan efficiency. The optics are a Ritchey-Cretien type projecting the ground scene onto two focal plane detector arrays. Bands one through four are on one focal plane, while bands five through seven are on the other. Sixteen detectors are employed at the focal plane for the high resolution bands, while four are utilized for the thermal band. Sixteen scan lines are therefore generated for each high-resolution band, and four are generated for the thermal band during each scan mirror sweep.

Global Positioning System

The GPS on the flight segment includes an antenna for receipt of two L-band signals from the Navigation Satellites, a preamplifier, an oscillator, and a receiver/processor assembly. The GPS system receives messages which are continuously transmitted from a constellation of Navigation Satellites, selects the optimum subset of satellites from which to utilize the data, and calculates three-dimensional position and velocity data of the host (Landsat-D) satellite. GPS time is also calculated; this time is offset from Universal Time Coordinated (UTC) by a known amount.

Every six seconds, nominally, updated position and velocity data is output from the receiver/processor assembly to the on-board computer in the Communications and Data Handling Subsystem. These updates are transformed in the computer into the proper coordinate systems and utilized for attitude control and the computation of high-gain antenna pointing angles. The position and velocity data is also downlinked on telemetry for later use in geometric correction of Thematic Mapper and Multispectral Scanner imagery on the ground.

In the early 1980s, only six of the planned 18 Navigation Satellites will be in orbit. Consequently, there will be periods when no Navigation Satellites are in view of the Landsat GPS antenna. During these periods, the receiver/processor operates in a "propagate" mode, estimating position and velocity of the host satellite based on past data.

Since Landsat-D is one of the first NASA spacecraft to carry the GPS, an experimental period extending over the first several months of the mission is planned. During this period, ephemeris accuracies will be validated and overall performance of the subsystem will be assessed. The receiver/processor assembly can output a series of data files and the contents of its entire memory for downlink via telemetry; this data is used for validation as well as for diagnostic purposes in the event of contigencies. The memory can also be reloaded by command uplink from the ground.

1.3 FLIGHT SEGMENT DESIGN

The Flight Segment configuration is a result of extensive trade-off studies to establish a simple design that makes maximum use of flight-proven designs and hardware. The key design features for the selected configuration are:

1. Modular design (utilizing the MMS spacecraft) allowing parallel integration and test of subsystems prior to overall spacecraft integration.

2. Earth referencing, acquisition, and Safe Hold control modes to provide a cone of sun avoidance about the optical axes of both the TM and MSS.

3. Rigid four-panel solar array of 150 ft^2. The outer three panels are canted at 22^o to maximize solar collection capability and the axis of rotation is offset to minimize interference with the TDRS antenna field of view.

4. Aluminum bifold boom to provide stable support for the TDRSS antenna, located to avoid daytime blockage of the communication link to TDRSS.

5. Jettison capability for the TDRSS antenna and solar array assemblies to satisfy Shuttle retrieval requirements.

6. GPS antenna mounted on the TDRSS antenna boom to provide the required coverage without a separate deployment. Electronics are mounted in the upper support structure near the antenna boom with a pre-amplifier mounted on the boom adjacent to the GPS antenna.

7. Thermal control at the module level with near-adiabatic interfaces to the primary structure, using passive thermal control augmented by thermostatically controlled heaters.

8. A three-axis angular displacement sensor assembly to provide, in conjunction with the inertial gyros, payload correction data to the TM Ground Processing System to allow for compensation of the micro-motion of the TM optical axis.

Communication Links

Landsat-D uses a wide variety of communications links in order to fulfill its mission. There are three kinds of links:

1. Narrowband--for housekeeping telemetry, command and tracking.

2. Wideband--for earth observation (MSS and TM) data.

3. Global positioning system (GPS)--for navigation and time data.

S-band and Ku-band links are used by Landsat-D for narrowband and wideband communications, respectively. Both bands are transmitted through the high-gain antenna to TDRS. The S-band link can be achieved through either the single access (SSA) or the multiple access (SMA) services that TDRS provides. The S-band data is also transmitted through omni-directional antennas for GSTDN or TDRS single-access use.

Existing foreign ground stations are equipped to receive 15 Mbps MSS data on S-band. However, the bandwidth available on the S-band allocation is inadequate to handle the 84.9 Mbps data from the Thematic Mapper. An X-band link is provided to permit TM or MSS data to be received by upgraded foreign ground stations.

The links to GPS are at L-band and are Receive-Only.

Wideband Communication Subsystem

The Wideband Communication Subsystem enables the Flight Segment to transmit MSS and TM instrument data to both TDRSS and ground-based users. It further enables the spacecraft to acquire and track TDRSS forward link emissions at Ku-band. The subsystem consists of the RF compartment, wideband module, and gimbal drive assembly. The RF compartment is integrally mounted on a 1.8 meter (6 feet), Ku-band high-gain antenna, and contains the Ku-band autotrack receiver front-end components and all other Ku-band RF components required to transmit to TDRSS. The wideband module contains the mode selection and modulation equipment; this equipment is used for both the KSA and X-band links in addition to all the X-band RF equipment required for direct communications with ground stations. The S-band transmitters are mounted in the instrument module structure above the wideband module, and the S-band antenna is mounted on the wideband module, adjacent to the X-band antenna.

All RF, dc power, and signal lines required for interconnection between the RF compartment and the wideband module are contained in a redundant cable bundle. RF signals are at S-band to prevent excessive coaxial cable attenutation. A cable wrap-up arrangement is utilized in the gimbal drive assembly. The cable bundle, on the inboard side of the gimbals, is routed down the mast to the wideband module.

1.4 FLIGHT SEGMENT LAUNCH CONFIGURATION

The Flight Segment launch configuration, shown in Figure 1-3, is constrained by the Delta 86-inch diameter shroud envelope. The six-foot diameter TDRSS antenna is stowed in the forward shroud area extending into the conical portion of the shroud. The rear of the antenna assembly is preloaded to the antenna boom and forward portion of the primary structure to provide a rigid tie during launch.

The bifold boom antenna assembly has one end supported from the primary structure at a hinge joint just forward of the Thematic Mapper. The primary structure has a cutout to allow the antenna boom to be stowed directly under the solar array assembly. The boom extends forward where the second hinge joint occurs. A short boom segment extends back from the forward hinge to mate with the TDRSS antenna gimbal assembly. A launch lock is also provided between the upper boom segment and the TDRSS antenna RF compartment to cage the gimbal assembly during launch and powered flight.

The solar array assembly is stowed for launch between the upper support structure and the Delta shroud envelope. The panels are rigidly tied to the primary structure at four locations during launch.

The Thematic Mapper (TM) is mounted directly on the mission adapter, which in turn is attached to the forward portion of the MMS. Graphite-epoxy truss tubes are provided to assist in the distribution of the launch loads around the TM.

The payload attach fitting ties into the three corners of the MMS module support structure; the volume provided within allows for the mounting of the propulsion system. The aft end of the payload attach fitting ties to the Delta second stage.

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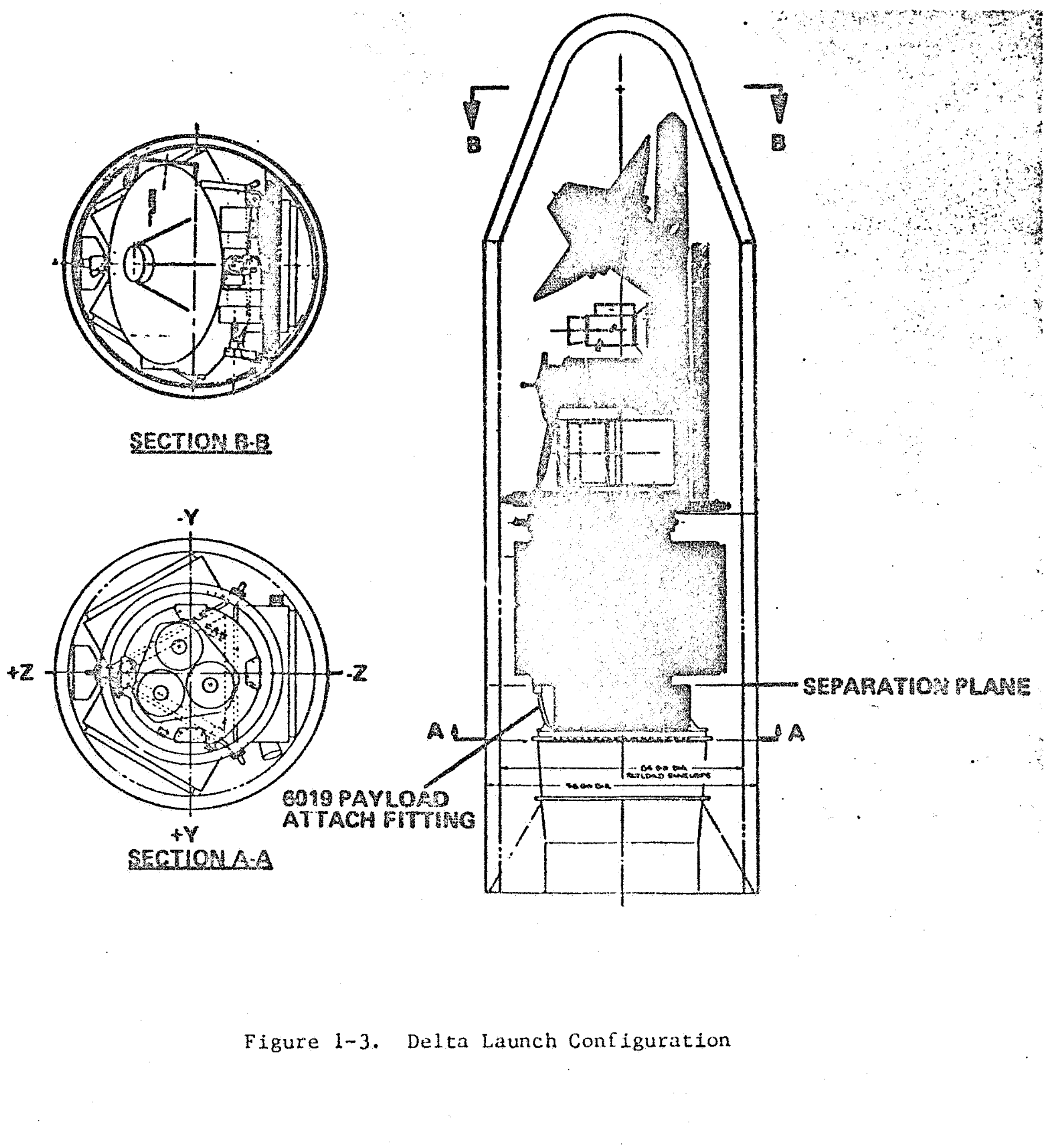

Figure 1-3. Delta Launch Configuration

2.0 APPLICABLE DOCUMENTS

SECTION 2

REFERENCES

1. "Landsat-D Data Format Control Book" Volume I (Data Acquisition Plan), SVS-10122, 31 July 1981.

2. "Landsat-D Data Format Control Book", Volume II (Telemetry) SVS-10123, 31 July 1981.

3. "Landsat-D Data Format Control Book," Volume III, (Command), SVS-10124, 31 July 1981.

4. "Landsat-D Data Format Control Book," Volume IV, (GPS), SVS-10125, 31 July 1981.

5. "Landsat-D Data Format Control Book", Volume V, (Payload), SVS-10126, 31 July 1981.

6. "MMS Flight Executive Users Guide," July 21, 1977, prepared by DAO.

7. S-700-56 Rev B MMS Onboard Computer Flight Executive Technical Description, February 1980.

8. Drawing Number 47J249400AZ Diagram, Schematic, Elec, Landsat-D System.

9. "Landsat-D Observatory System Restraints Manual," SVS-10264.

3.0 MAC

3.0 MODULAR ATTITUDE CONTROL

SECTION 3.0

MODULAR ATTITUDE CONTROL SYSTEM

The Modular Attitude Control Subsystem (MACS) is the attitude control module for NASA's Multimission Modular Spacecraft (MMS). The MMS configuration is adaptable for earth pointing missions including Landsat-D and Landsat-D Prime. The MACS is compatible with either the Space Transport System (Shuttle) or the ground launch vehicle. Figure 3-1 shows a MACS module integrated into the Landsat-D spacecraft. Figure 3-2 shows the specific modules that makeup the MMS subsystems.

The Communications and Data Handling (C&DH) Module handles all MACS commands. The On-Board Computer (OBC) is a component of the C&DH module. In the normal mode of operation of the MACS the OBC becomes a part of attitude control function.

A MACS is comprised of sensors, actuators and associated electronics, see Figure 3-3. In addition, the attitude control requires data from an Earth Sensor Assembly (ESA1 or ESA2) which is located in the Earth Sensor Assembly Module (ESAM) located on the MMS Module Support Structure and also from a Coarse Sun Sensor (CSS1 or CSS2) which is mounted on the Solar Array. The MACS Attitude Control Electronics (ACE) can issue logic commands directly to the thrusters which are part of the Propulsion Module (PM).

Figure 3-4 shows the Functional Block Diagram of the MACS including the sensors not physically a part of the MACS module.

Figure 3-5 shows the orientation of the MACS actuators relative to the MACS rectangular coordinate frame.

The Modular Power Subsystem (MPS) supplies 28 VDC to the Power Switching Unit. One of the redundant Attitude Control Electronics (ACE A or ACE B) and both Remote Interfaces Units to the C&DH module are powered ON when MPS power is applied to the MACS. Power to the remaining MACS components is controlled by specific Discrete Commands.

The Fixed Head Star Tracker (FHST) and the Inertial Reference Unit (IRU) supply the data required for the OBC to determine the real time attitude of the spacecraft in terms of the Earth Centered Inertial (ECI) coordinate reference frame. The desired ECI reference frame requires a knowledge of the spacecraft ephemeris data.

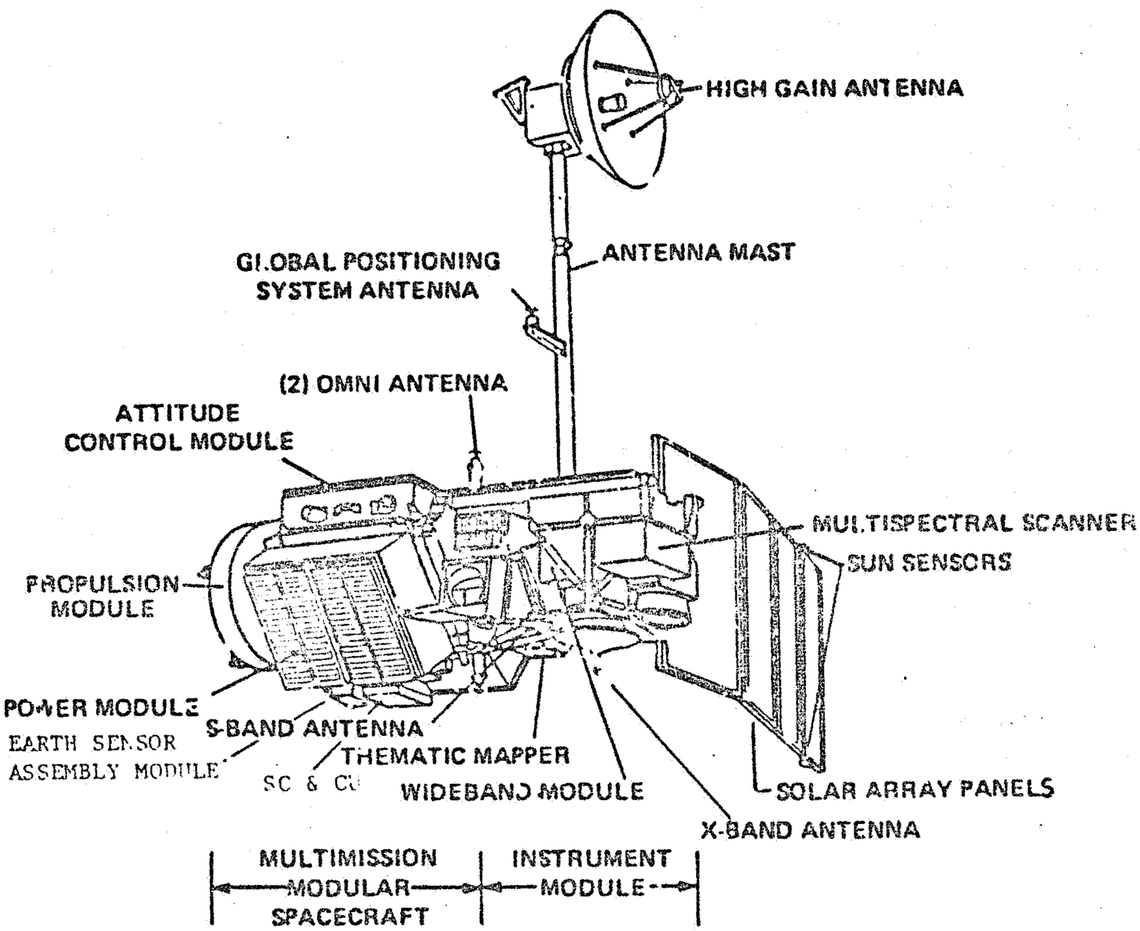

Figure 3-1. MMS Integrated to the Landsat-D Spacecraft

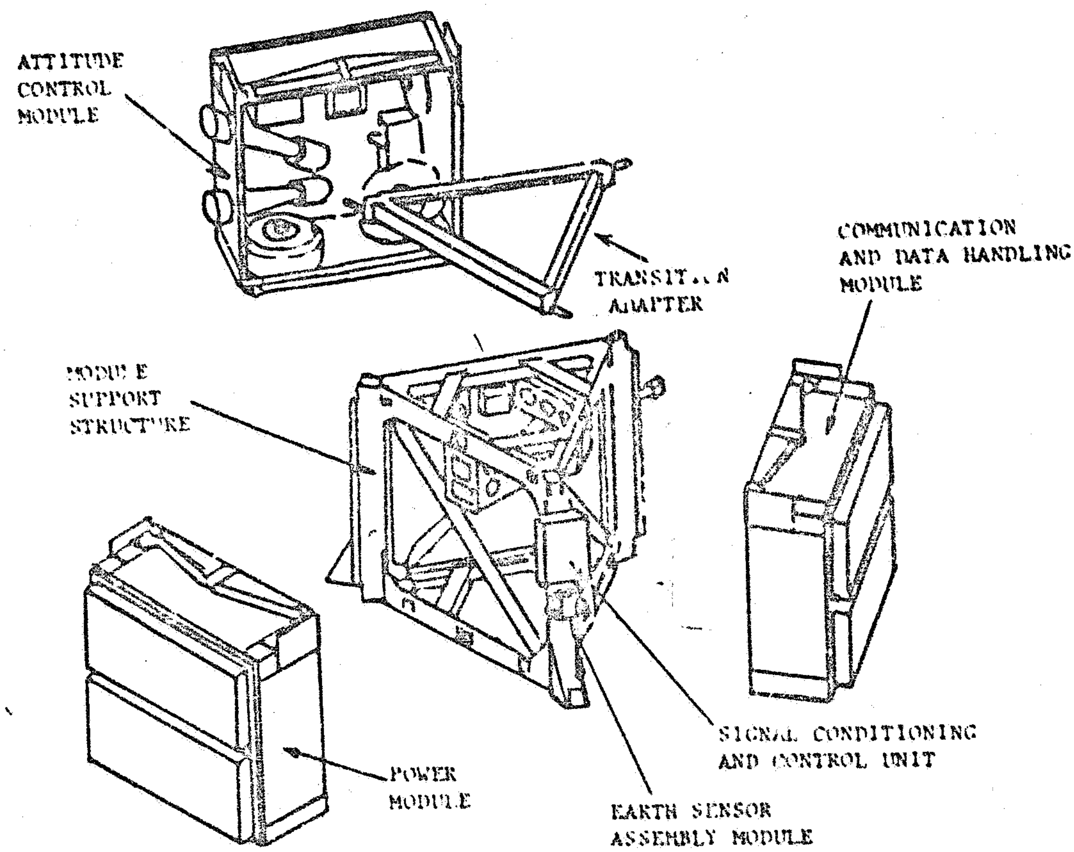

Figure 3-2. MMS Subsystems

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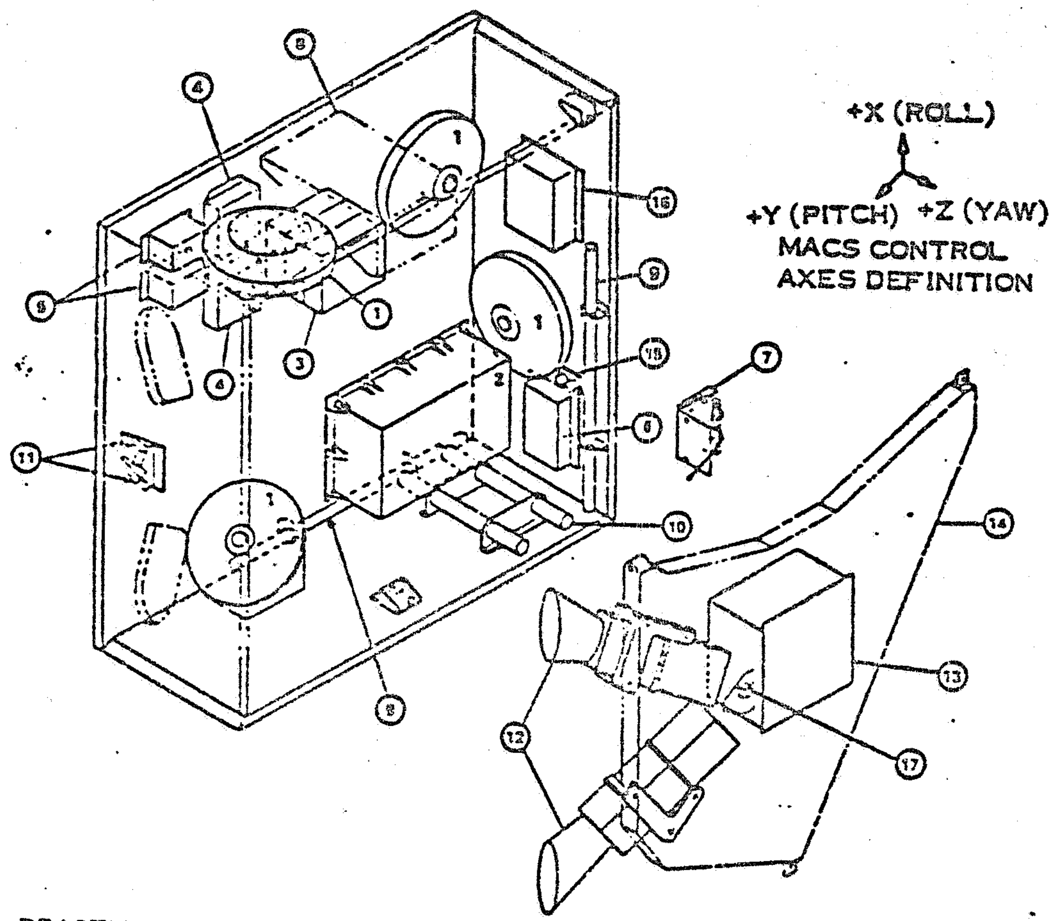

1. REACTION WHEEL (4)
2. ATTITUDE CONTROL ELECTRONICS
3. REMOTE INTERFACE UNIT (2)
4. MAGNETOMETER ELECTRONICS (2)
5. MAGNETOMETER SENSOR (2)
6. FINE SUN SENSOR ELECTRONICS
7. FINE SUN SENSOR
8. MODULE I/F CONNECTOR BRACKET
9. MAGNETIC TORQUER (2)
10. MAGNETIC TORQUER (2)
11. BRIGHT OBJECT SENSOR (2)
12. FIXED HEAD STARTRACKER (2)
13. INERTIAL REFERENCE UNIT
14. OPTICAL BENCH
15. TEST CONNECTORS
16. POWER SWITCHING UNIT
17. OPTICAL CUBE

Figure 3-3. MACS Components and Packaging Arrangement

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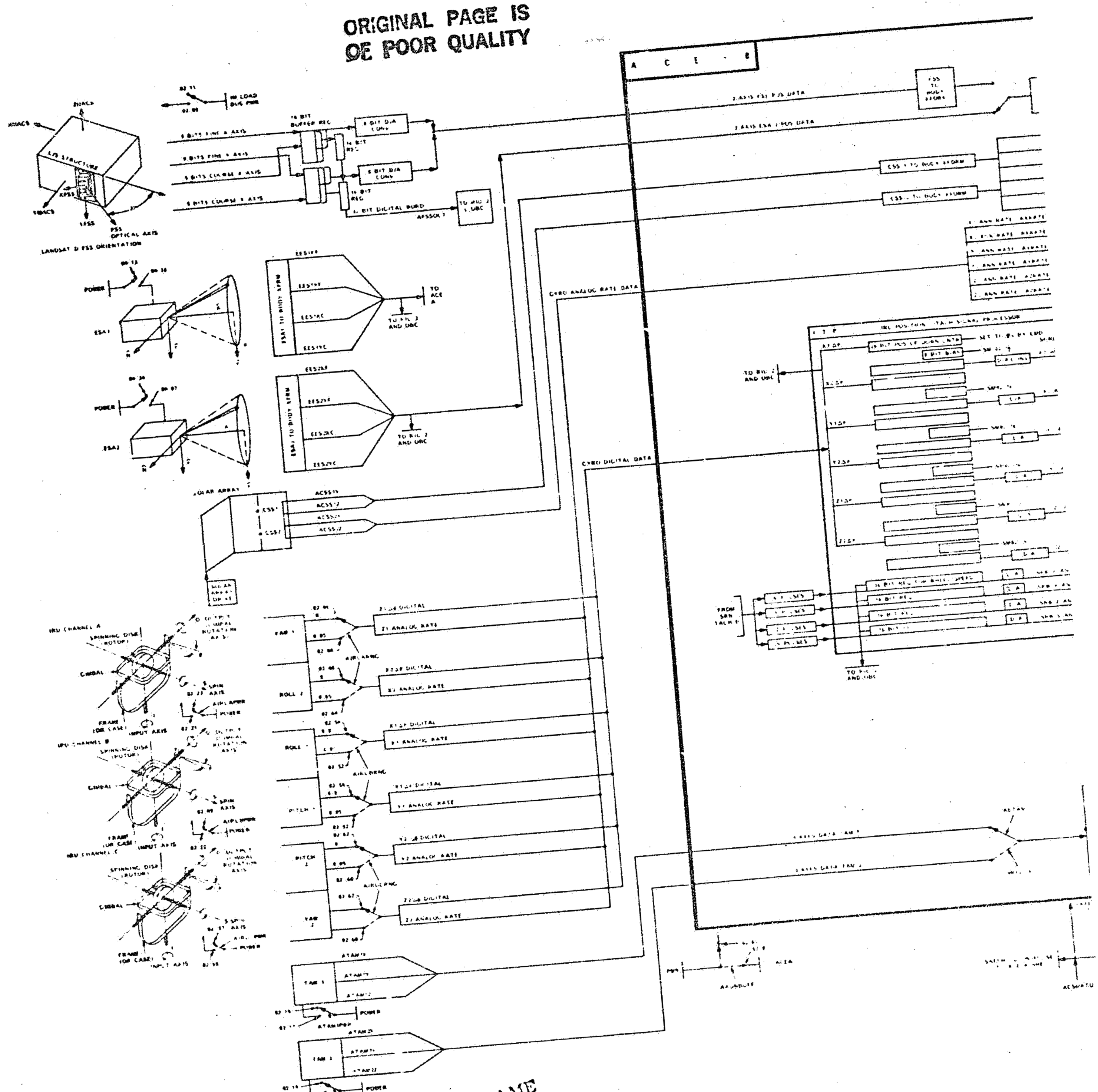

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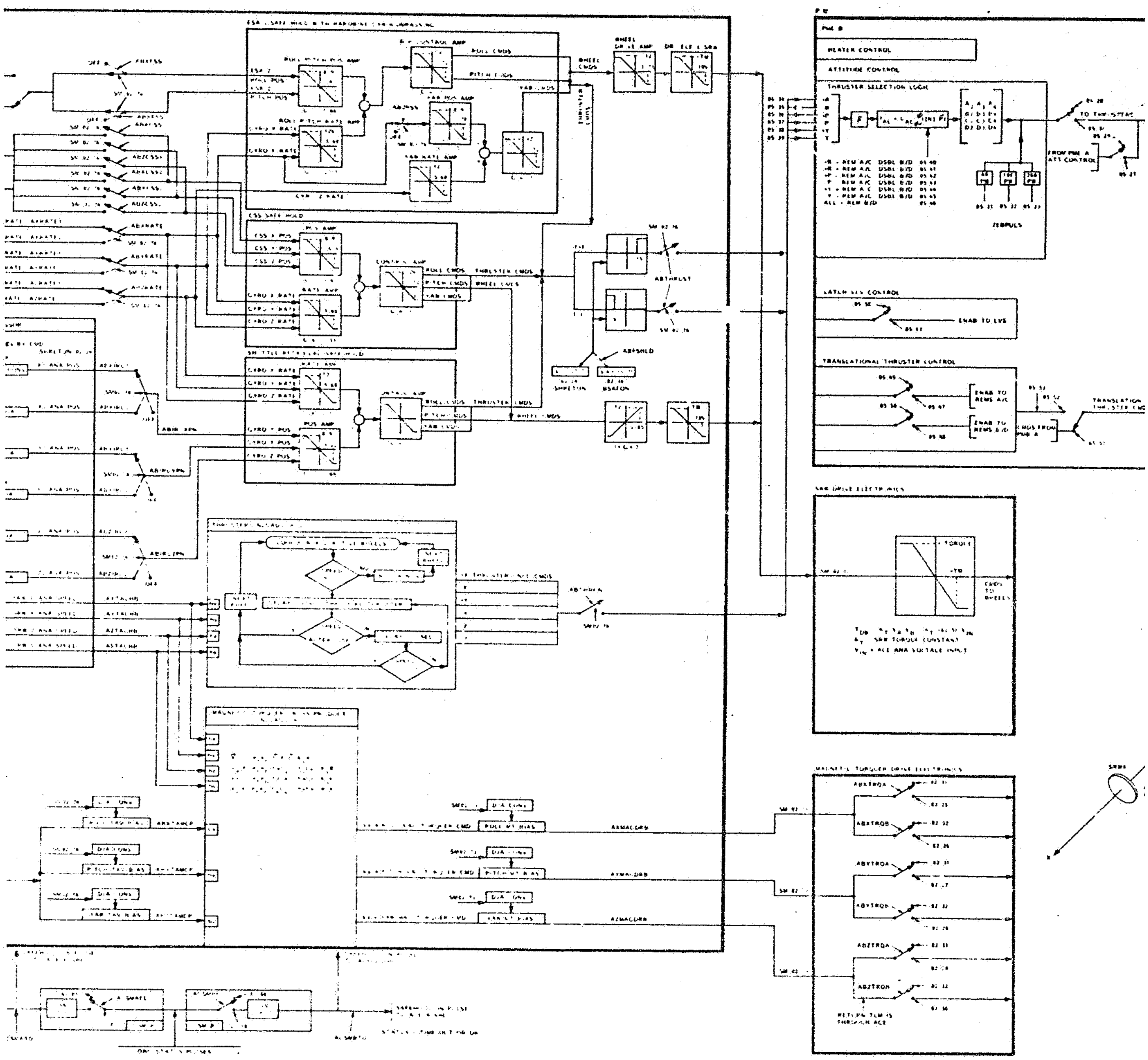

Fig

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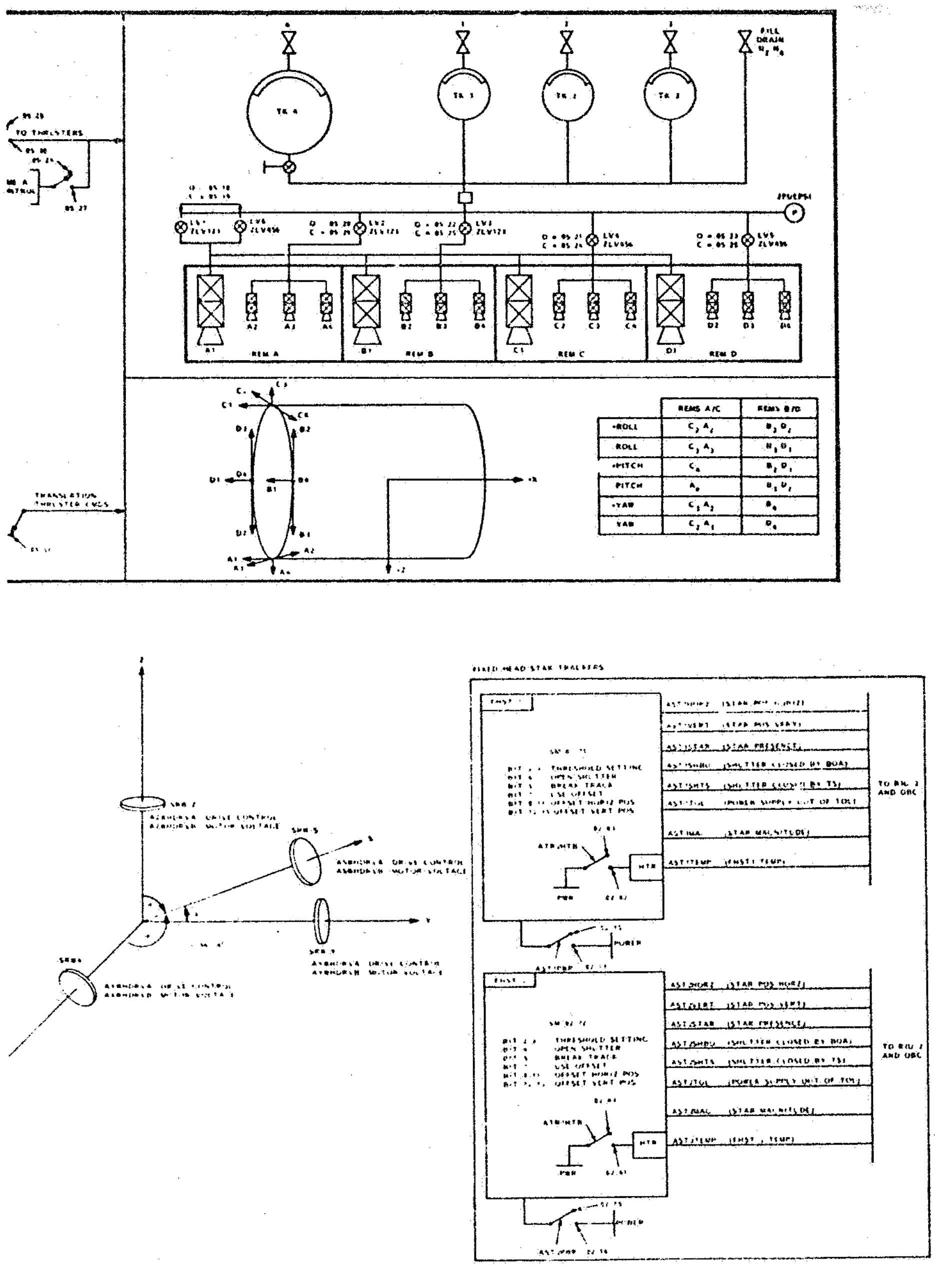

Figure 3-4. MACS Functional Block Diagram

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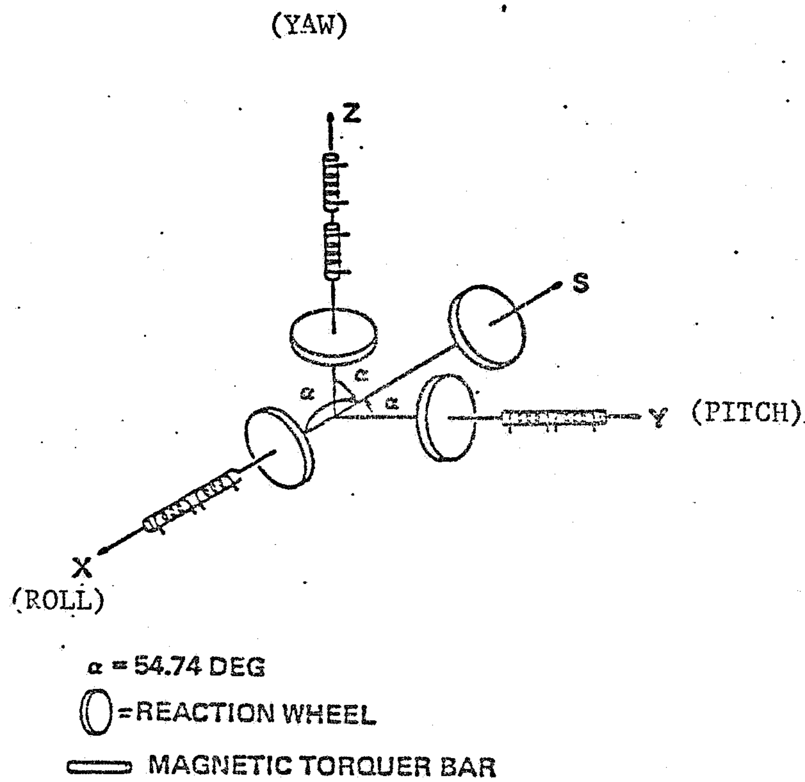

Figure 3-5. MACS Actuator Alignment

3.1 FUNCTIONAL DESCRIPTION

The MACS consists of sensors, actuators, associated electronics and a mounting structure. The MACS structure is mounted on the MMS with its rectangular coordinate axes aligned with the Flight Segment coordinate axes. The following sections give a general functional description of each component of the MACS module.

3.1.1 POWER SWITCHING UNIT (PSU)

The power switching unit receives fused power from the Modulator Power Subsystem and distributes power over separate fused paths to the individual MACS components. It contains power switching relays, pulse stretchers and fuses.

Unswitched fused power is routed to RIU2A and RIU2B through separate redundant wires and is applied to both RIUs when power is applied to the MACS.

3.1.2 REMOTE INTERFACE UNIT (RIU)

The MACS employs RIU 2A and RIU 2B for interface with the Communications and Data Handling Module. Either RIU can receive 64 discrete command and six Serial Magnitude Commands. Each RIU includes an Expander Unit (EU) and can supply telemetry data from 128 points.

3.1.3 INERTIAL REFERENCE UNIT (IRU)

The MACS includes the NASA standard IRU which supplies the inertial data required for attitude control. The IRU has three totally independent gyro channels and each channel supplies two axes information derived from a dedicated gyro with two degrees of freedom. The three channel inertial reference unit contains the following major elements:

1. Three two-degree of freedom dry tuned-gimbal gyros
2. Three independent sets of five each electronic modules
3. Three independent power supplies
4. One chassis and housing assembly
5. One optical alignment cube

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The three gyros are aligned with the MACS rectangular coordinate axes and supply inertial rate and position information relative to the MACS coordinate reference frame. The IRU channel assignment is as follows:

Channel	Axes	Rate and Position Signal
B	+X, -Y	Roll 1, Pitch 1
A	-Z, +X	Yaw 1, Roll 2
C	-Y, -Z	Pitch 2, Yaw 2

Figure 3.1-1 shows a functional block diagram of a single gyro channel. Table 3.1-1 lists the major components or modules used in each of the three channels as well as some of their functions.

Any 2 of the 3 channels are required to yield 3-axes information. Nominally Channels A and C will be used with the prime sensors being Roll 2, Pitch 2, and Yaw 2. Note that the configuration Roll 1, Pitch 1, and Yaw 1 also requires the use of Channel A.

The gyros are caged in an analog torque balance mode with restoring currents which are proportional to the spacecraft angular rate. The voltage developed by the current passing through precision scaling resistors is then voltage-to-frequency (V/F) converted by reset integrator V/F converters. Two sets of scaling resisters are used per gyro axis to provide for the externally commandable high and low rate ranging.

Each channel supplies $\pm\ \theta$ pulse trains with an associated reference clock which gives a pulse count proportional to the incremental rotation about each gyro axis. The pulse count scale factor is selected by the applicable discrete command: 0.05 arc sec./pulse for the low rate mode and 0.8 arc sec./pulse for the high rate mode. The gyro performance temperature coefficients are highly linear and stable, therefore self-contained analog temperature compensation is employed for operation over a $40^{o}C$ temperature range without the need for external software compensation. No heaters or temperature control is used which significantly reduces power consumption and enhances reliability. Each gyro contains three independent temperature sensors with one for each sensing axis used for internal compensation and the third for telemetry output.

At turn ON, each channel is initialized in the high rate. Bilevel telemetry from each IRU channel indicates the rate selected.

Analog telemetry supplied to the RIU gives the regulated DC voltages, the gyro spin motor current and the gyro temperature.

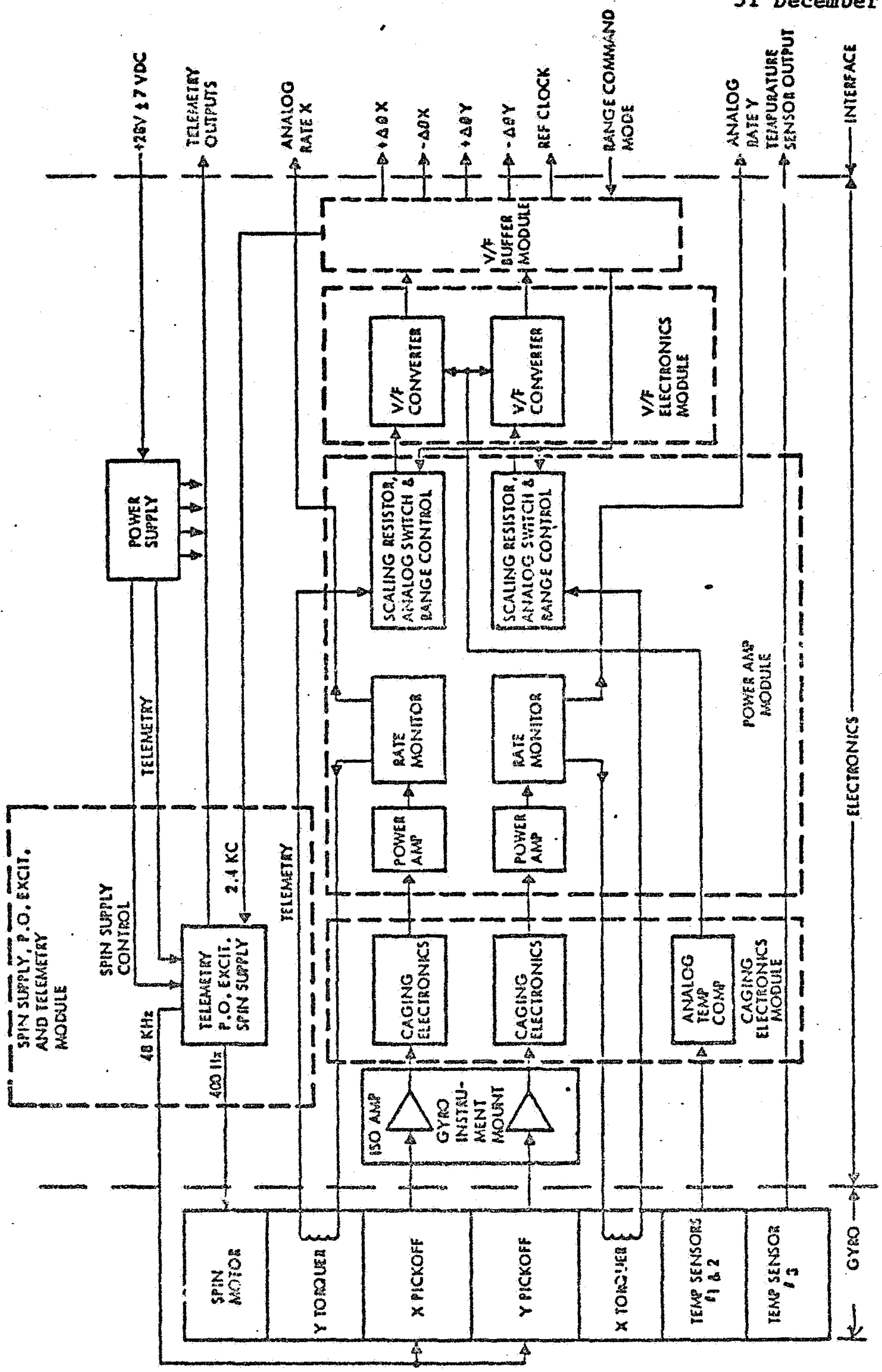

Figure 3.1-1. IRU Single Gyro Channel Functional Block Diagram

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Table 3.1-1. DRIRU II Hardware Components Per Channel

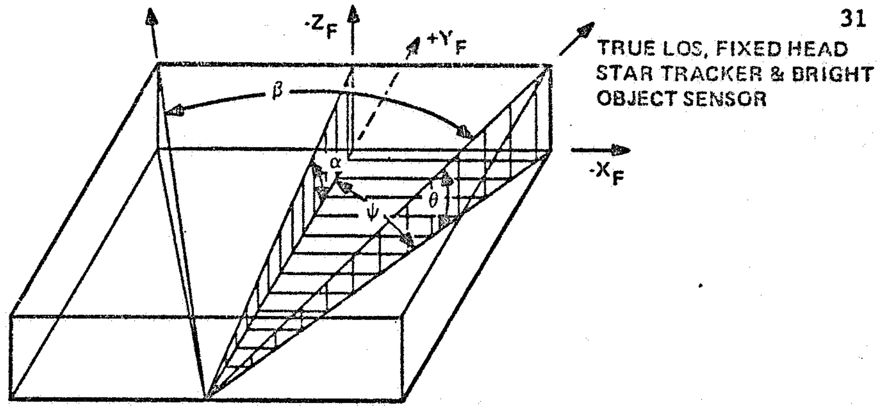
Quantity	Component/Module
1	SDG-5 Strapdown gyro plus interface module
1	V/F converter module
1	V/F buffer module BI-Polar output logic Countdown logic "High" mode start logic Range select
1	Caging and temperature compensation module Integral gain 2nd order filter Demodulator
1	Power amplifier and range control module Cross axis compensation (direct optional) Range control and status Scaling Resistors Analog output
1	SS poet module Spin supply, timing and switching logic Motor anti-hunt (optional) P.O. exicitation Telemetry (motor current and power supply voltage)
1	Power supply

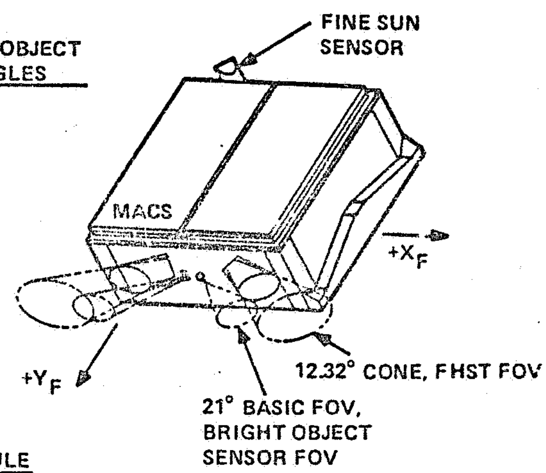
3.1.4 FIXED HEAD STAR TRACKER (FHST) AND BRIGHT OBJECT SENSOR (BOS)

The Landsat-D MACS contains two Fixed Head Star Trackers (FHST). The orientation is shown in Figure 3.1-2. In normal operations the star trackers will never view the sun or the earth. Each tracker, however, is equiped with a Shutter Housing Assembly (SHA) with its associated Bright Object Sensor (BOS #1 for FHST #1 and BOS #2 for FHST #2) and a Stray Light Shield. Figure 3.1-3 shows the FHST, BOS and Stray Light Shield integrated with the spacecraft housing.

The star tracker is designed to acquire and track stars whose magnitude is between 5.7 and 7, with angular size as large as 8 arc minutes. The FHST can maintain tracking throught its field-of-view, and provide two-axis position information at vehicle rates up to 0.3 degrees per second. The block diagram of the FHST is shown in Figure 3.1-4. The FHST consists of nine basic subsystems. These include the following:

1. Lens
2. Image Disection Tude (IDT)
3. Power Subsystem
4. Scan Generators
5. Deflection Circuits
6. Timing and Control Logic
7. Video Processor
8. Input Circuitry
9. Output Circuitry





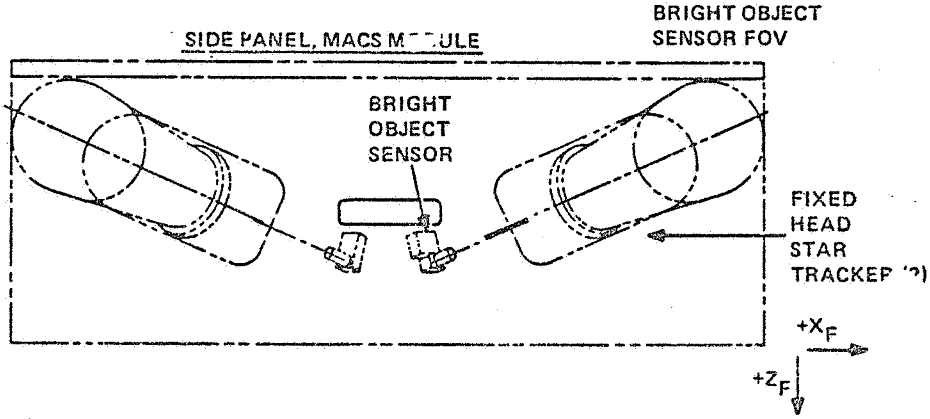


Figure 3.1-2. MACS Fixed Head Star Tracker Orientations

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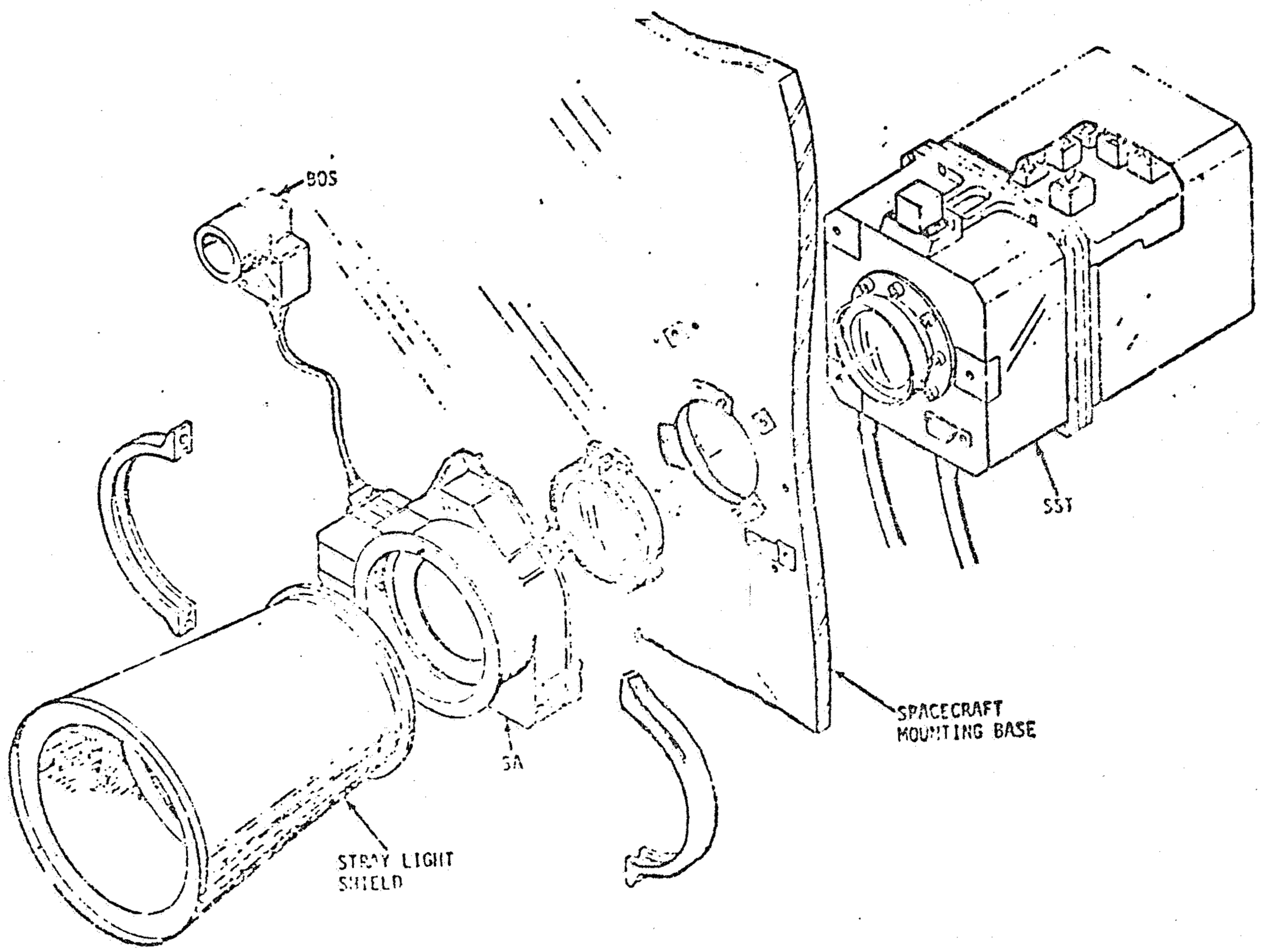

Figure 3.1-3. FHST With Bright Object Protection and Stray Light Shield

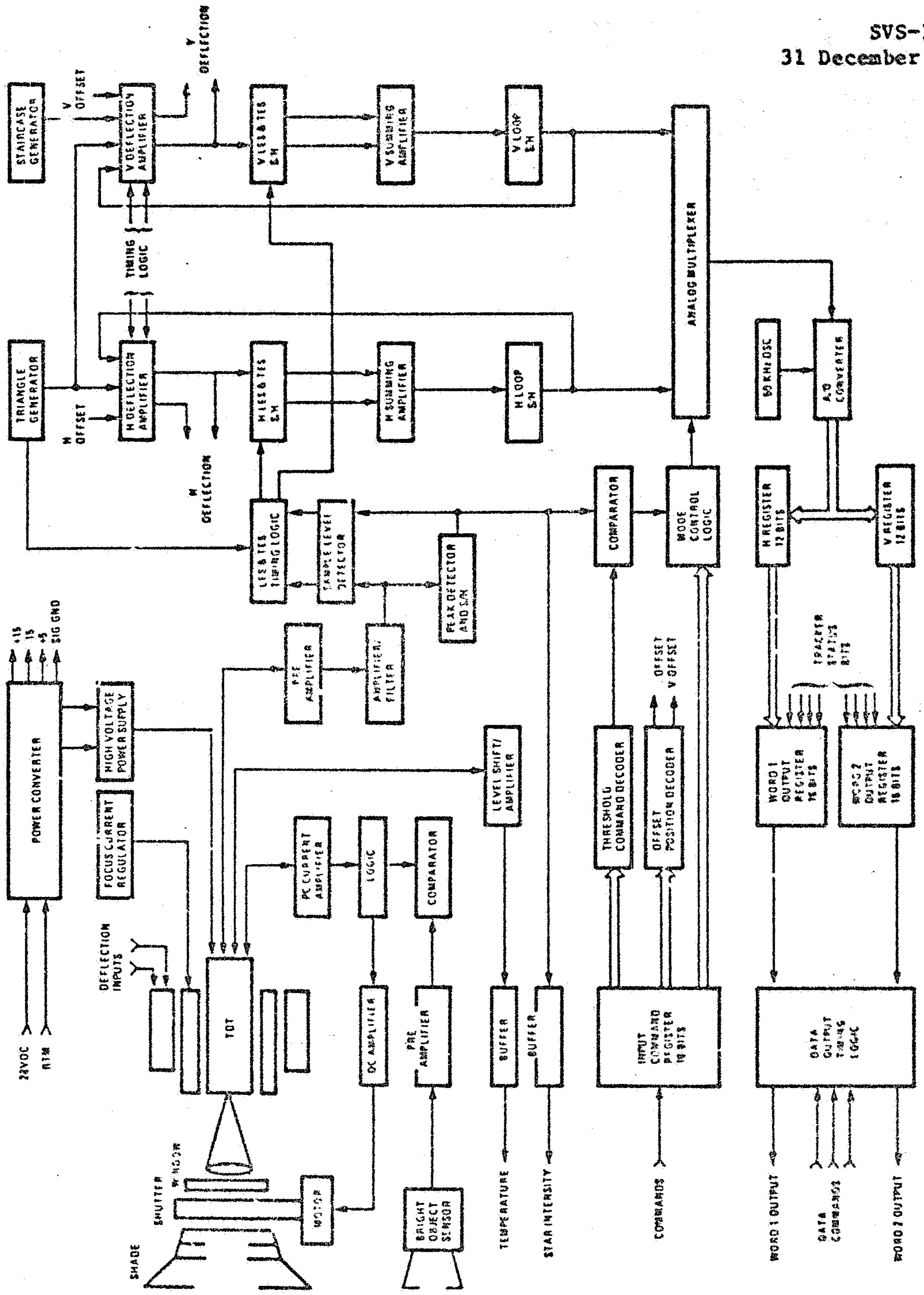

Figure 3.1-4. FHST Block Diagram

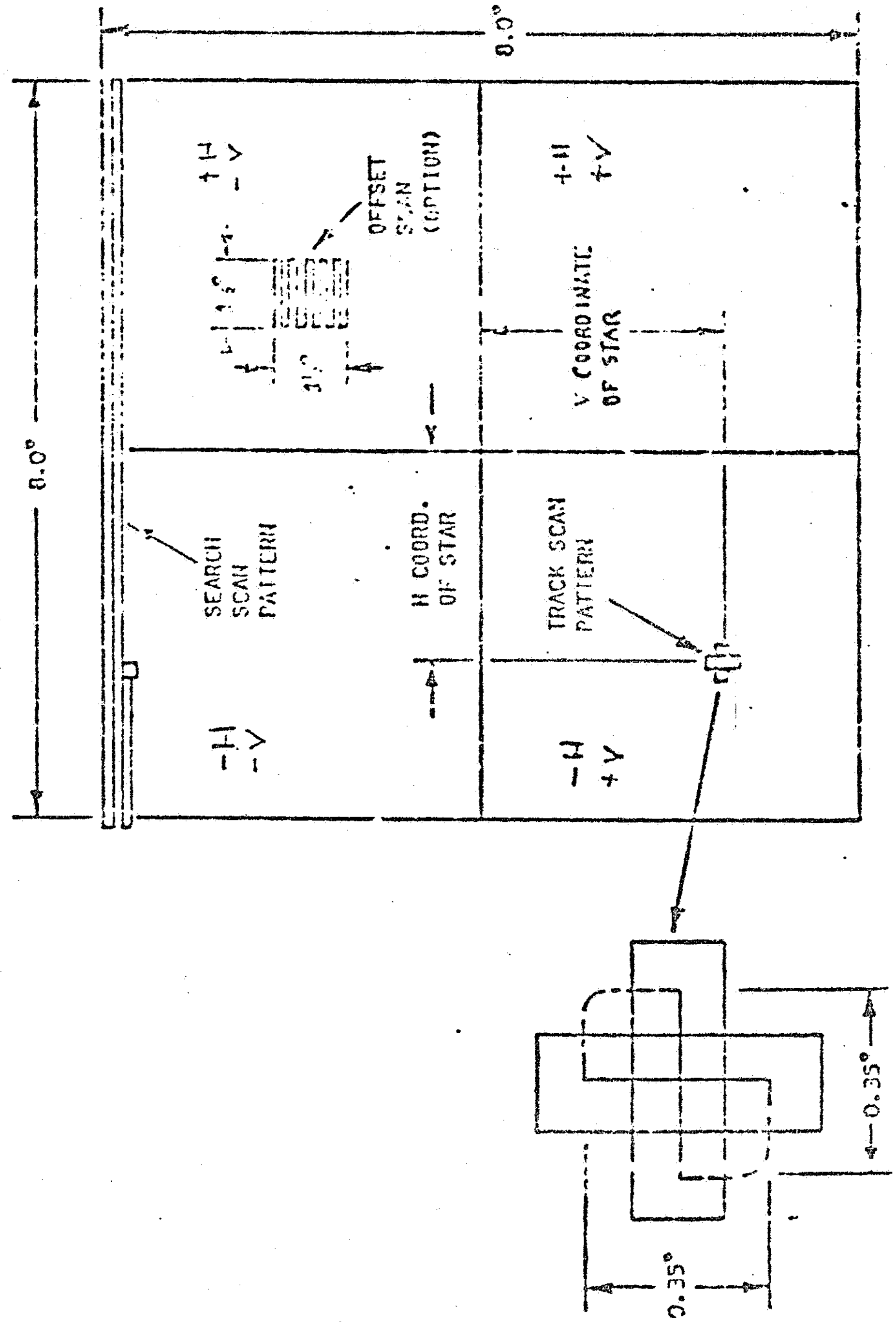

Figure 3.1-5. FHST Scan Geometry

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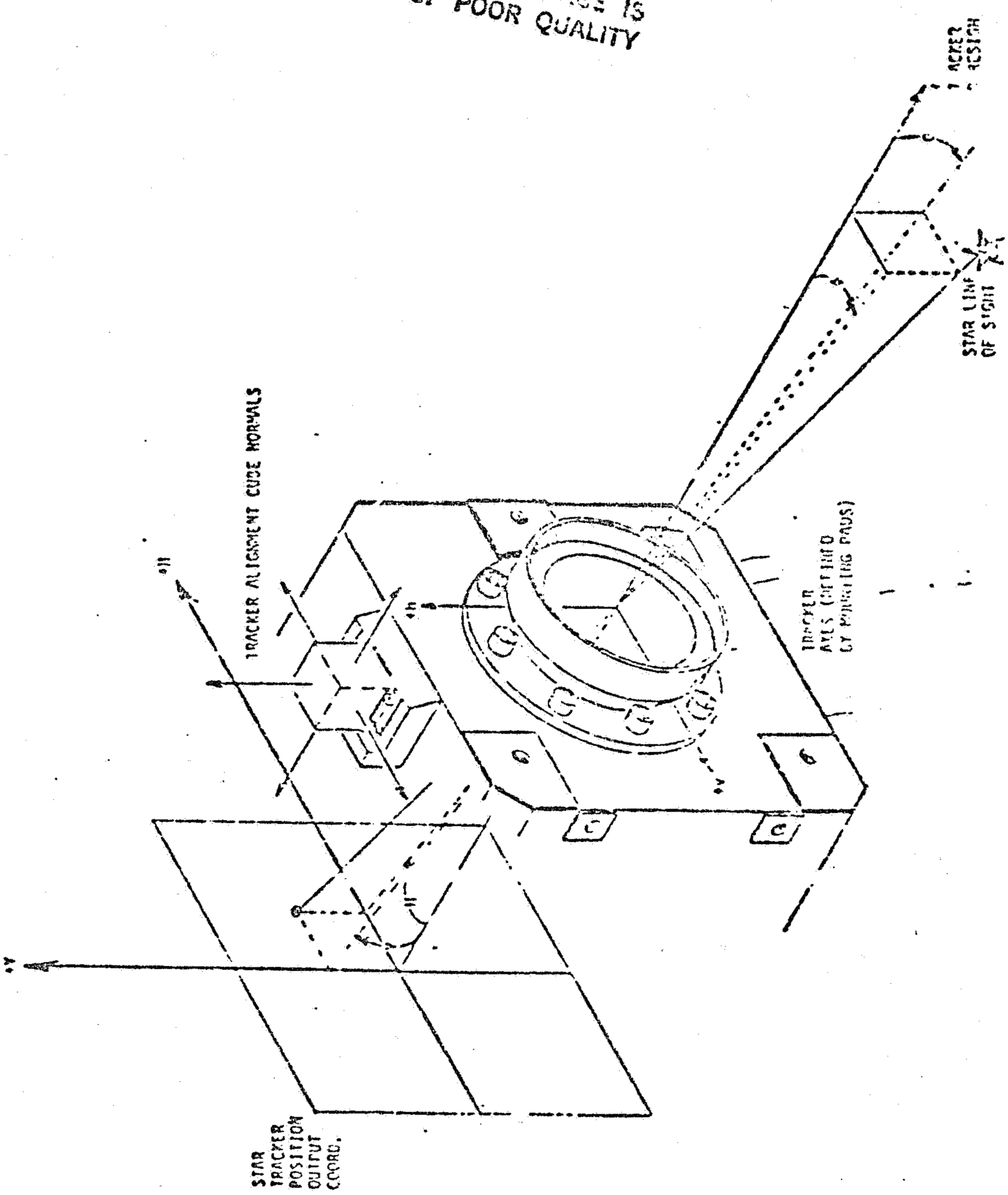

Figure 3.1-6. FHST Coordinate Definition

When power is applied to the system and no other mode is commanded, the FHST will automatically start out in the search mode. This mode causes the instrument to search the total field of view (TFOV) by scanning the pattern shown in Figure 3.1-5. This pattern is a left to right, then right to left horizontal direction sweep of approximately 70 position (shown in Figure 3.1-5) and takes ten seconds to complete the TFOV. During the search mode, the FHST delivers no information on targets in the FOV. Rather, its objective is to locate a proper target about which information can be obtained. Four commandable threshold levels are available to provide for setting of the minimum sensitivity from 5.7 to 3 visual magnitude. On Landsat-D the nominal threshold is set at 4.0. The search scan continues until the first star that exceeds the commanded threshold level is detected. When this occurs, the star is acquired and track scan begins.

When the FHST enters the track mode, the instrument forms a smaller cross pattern with a repetition rate of 100 times per second. This pattern is shown spatially in Figure 3.1-5. The track pattern centers on the star image and a STAR PRESENT bit is generated in the output word signifying that two-axis position and intensity data are available. The horizontal position information (ones-complement) is contained in the first 12 bits of FHST word 1 (MACS Serial Digital Data (SSD) word 8 for FHST 1, and MACS SSD word 10 for FHST 2). The vertical position information is contained in the first 12 bits of FHST word 2 (MACS SDD word 9 for FHST 1 and MACS SSD word 11 for FHST 2). As the star moves in the FOV due to vehicle attitude changes, the track pattern remains locked onto the star image and the position information is continuously updated. During this mode of operation the FHST sees only the acquired star. It is not influenced by and provides no information about, other targets in the FOV. Tracking of the same star continues until:

1. The star leaves the FOV.

2. A Break Track command is received.

3. The star intensity falls below the commanded level.

When any of the three above events occur, the search mode is resumed at a point approximately 0.7 degrees more positive in the V coordinate from where the star was last tracked. This assures that the same star will not be required for one complete TFOV scan. Figure 3.1-6 shows the FHST coordinate system.

The FHST electronics has an OFFSET Mode which selects a 1-1/4 by 1-1/4 degree Reduced Field of View (RFOV). The RFOV is selected by the appropriate SM command allowing the FHST to acquire any star within the selected RFOV. Once acquired, the star is tracked throughout the TFOV. Loss of acquisition causes the return of the FHST to the acquisiton scan of the RFOV at the selected coordinates (sector) within the TFOV.

The Bright Object Sensor (BOS) protects the IDT from exposure to the sun or earth limb. Should the sun come within 28 degrees or the earth limb within 17.5 degrees of the optical axis, the BOS sends the FHST a signal to close the shutter. The shutter remains closed until the receipt of the FHST Serial Magnitude Command $(110\ 000\ 000\ 000\ 0000)_2$, Shutter Open Enable/Threshold Set Enable.

Upon receipt of the appropriate SM command, the tracker will enter the OFFSET Mode and scan a Reduced Field of View (RFOV). The OFFSET Mode is used to search for a star known to be within the selected portion of the Total Field of View (TFOV).

In response to either a Bright Object Alert (BOA) signal from the BOS, or Target Suppress (TS) signal, the FHST will close its shutter. The target suppress signal is sent any time the tracker detects excessive image disector current. The FHST shutter is closed to protect the IDT, and the shutter remains closed until commanded open by either:

1. A Shutter Open SM command.

2. Or a Break Track SM command.

The Break Track SM command unlatches the FHST shutter closed by either a BOA or Target Suppress signal and also returns the tracker to the normal Search Mode of operation.

Each FHST has a sun shade which is a conical component assembled to the FHST shutter housing assembly boresighted to the optical axes. The sun shade allows the acquisition and tracking of stars that have sun angles of 85 degrees or more from the +Y MACS axis.

3.1.5 THREE AXIS MAGNETOMETER (TAM)

A MACS includes redundant Magnetometers with the X, Y and Z axes coincident (1 deg. mounting accuracy) with the MACS rectangular coordinate reference frame. The polarity convention specifies the earth's magnetic field vector as positive in the northerly direction and positive into the earth at higher northern latitudes.

A TAM is a triaxial flux-gate magnetometer that outputs analog signals that are proportional to the three axis components of the magnetic field vector.

The TAM is operational any time it is powered ON, and both TAM1 and TAM2 can be powered simultaneously. TAM outputs are connected to both RIUs and to the ACE. Each TAM provides a linear 0 to 5 VDC output for sensed magnetic field intensity within the range of -1000 milligauss to +1000 milligauss on each axis outputs to the analog telemetry data inputs of both RIU's. The RIU digitizes the 0 to 5VDC TAM telemetry outputs. An eight bit word provides the OBC with a 20 millivolt or 8 milligauss resolution. TAM1 or TAM2 supplies 10 millivolt/milligauss X, Y and Z analog signals to the ACE. The ACE selects the appropriate signals for use in the Safehold Mode.

The X, Y and Z axes signals from both TAM1 and TAM2 are supplied to their respective telemetry data inputs to the "ON" RIU.

3.1.6 STANDARD REACTION WHEEL (SRW)

The NASA Standard Reaction Wheel includes a two-phase 20-pole induction motor and a flywheel mounted within a sealed enclosure. The SRW can store 21.9 N-M-sec (nominal) of angular momentum at a synchronous speed of 2400 RPM. The SRW creates a 0.16 N-M torque for wheel speeds between stall and 50% of sync speed when a 24 V zero to peak 400 Hz square wave is applied.

The MACS employs four SRWs. The roll SRW is mounted to the interior +X MACS module face with its negative momentum vector aligned in the +X MACS direction. The Pitch SRW is mounted to the interior -Y MACS module face with its positive momentum vector aligned in the +Y MACS direction. The Yaw SRW is mounted to the -Z MACS module face with its positive momentum vector aligned in the +Z MACS direction. The Skew SRW is mounted to the interior -X MACS module face by means of a skew bracket which aligns the wheel positive momentum vector equiangular to the MACS reference frame.

Each SRW has redundant TACHS with channel 1 dedicated to ACE A and IRU POSN/Tach Signal Processor (ITP) A and channel 2 dedicated to ACE B and ITP B.

The SRWs provide the spacecraft torque required for orbital fine pointing with the wheels normally unloaded to maintain wheel speed below 1000 RPM.

3.1.7 MAGNETIC TORQUERS

The Magnetic Torquers are electromagnets that are placed along the MACS control axes. The X and Y Magnetic Torquers are identical, with each consisting of two windings on one 29.2" ferromagnetic rod. The Z-axis has two identical electromagnets, each wound on a 15.75" ferromagnetic rod. The Magnetic Torquers provide redundant operation. In normal operation, all six windings are powered. Each winding can produce a nominal dipole moment of 63,000 pole-cm.

The Magnetic Torquers produce a magnetic dipole moment which reacts against the earth's magnetic field and produces a torque on the spacecraft. The reaction wheels (SRWs), during orbital fine pointing, are used to supply the torques to control the spacecraft's attitude. The Magnetic Torquers are used to produce a spacecraft disturbance torque which, when corrected by the normal operation of the ACS, will reduce the wheel (SRW) speed.

A control signal request for a specified axis dipole moment is processed by the Magnetic Torquer A and B Drive Electronics which results in equal drive currents in the A and B windings. In the event of a winding or electronics failure, the redundant channel gain is changed to compensate for the failure, producing the disturbance torques per control signal requests.

3.1.8 COMPUTER STATUS MONITOR (CSM)

Identical CSMs provide a redundant capability to sense an OBC anomaly. Figure 3.1-7 shows the functional block diagram. The OBC continuously sends a series of pulses at 1 second intervals is received by the CSM. Interruption of three consecutive discrete command pulse trains will cause the CSM interval timer to "time out". And as a result of this "time out" the CSM generates an internal Safehold bilevel logic signal. This logic signal generates a Safehold "ON" logic signal if a CSM Inhibit discrete command has not been received by the corresponding CSM. A Safehold ON logic signal will be generated by either CSM if the following sequence of events has transpired:

1. A corresponding ACS Enable has been received.

2. A corresponding CSM Inhibit C discrete command has not been received (A CSM Enable discrete command will reset the CSM).

3. The corresponding OBC pulse train has been interrupted for three consecutive commands.

When a safehold "ON" logic signal is generated, power is switched to the dedicated Safehold Electronics (SHE) of the powered ACE and the MACS is transferred from the Computer Mode to the Safehold Mode.

The CSM Timer is reset upon the receipt of a CSM Inhibit discrete command. If valid CSM pulse trains are present (no CSM time outs), the Safehold OFF discrete command can be issued and the MACS will return to the Computer Mode.

The ACE turns on in the Computer Mode whether from the initial application of MPS power or when switching between ACE blocks. The CSM logic is volatile and the effects of any previous commands will be ignored.

3.1.9 ATTITUDE CONTROL ELECTRONICS (ACE)

The ACS contains the electronics required to drive the Reaction Wheel and/or the Magnetic Torquer. The ACE also includes the safehold electronics which can, without the use of the On-Board Computer, perform the analog functions required to maintain the spacecraft on a safe orbit. See Paragraph 3.3.2 for a description of the safehold mode. As shown in Figure 3.1-8, the ACE includes the following functional blocks:

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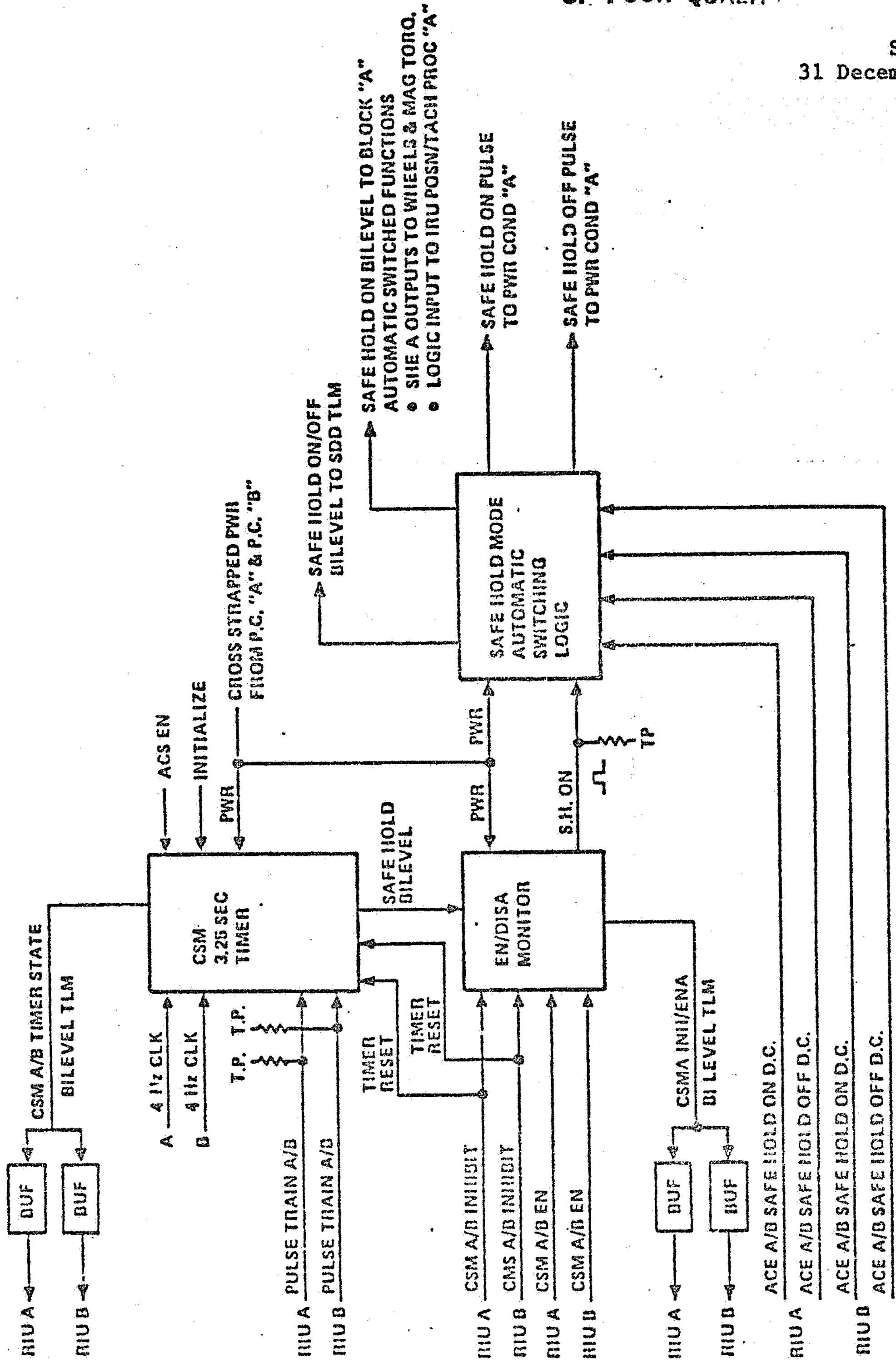

Figure 3.1-7. Computer Status Monitor "A"/"B" Functional Block Diagram

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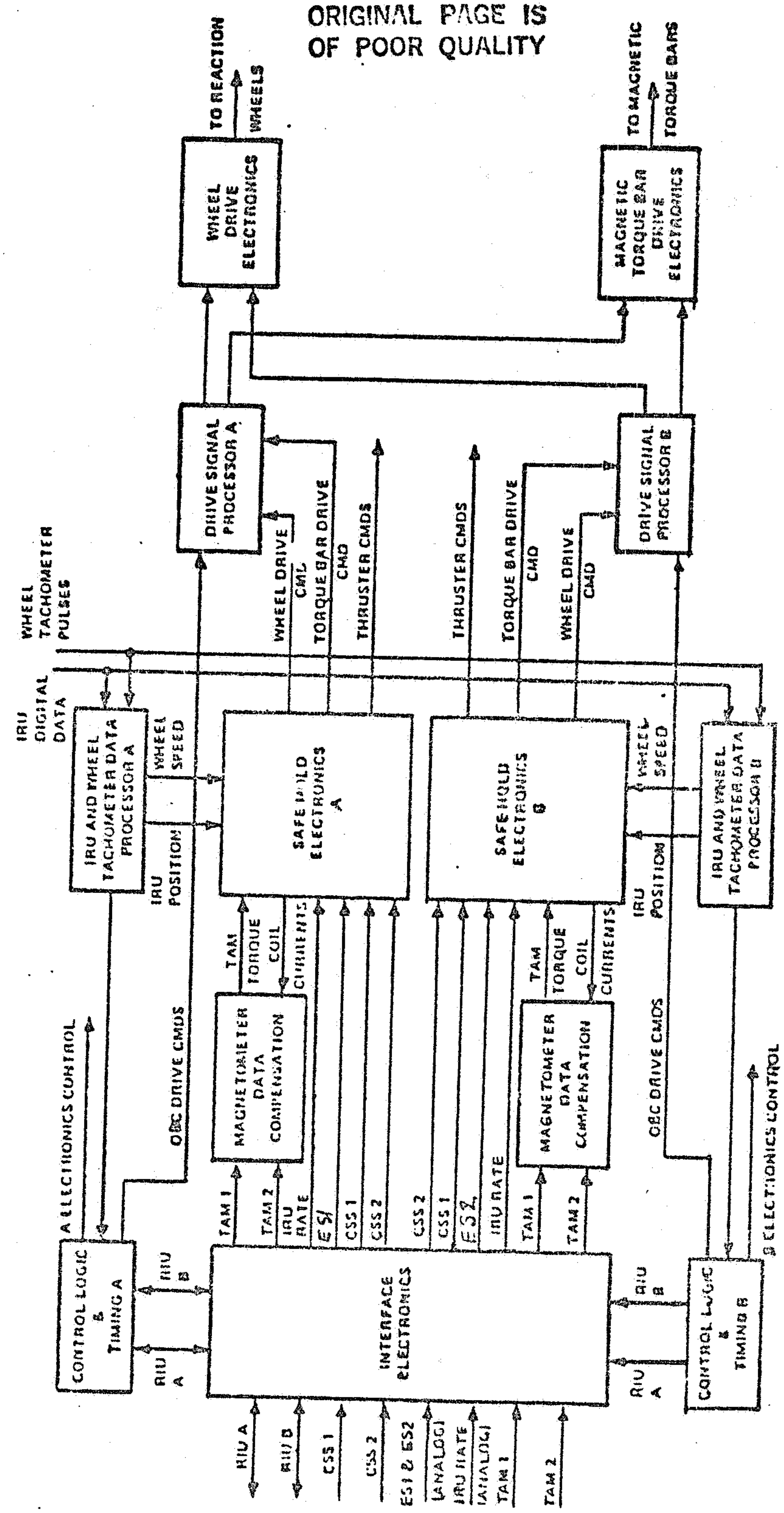

Figure 3.1-8. Attitude Control Electronics Fundamental Block Diagram

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1. Interface electronics provide interface with the MACS sensors and the C&DH module (RIU 2A and 2B).

2. Control Logic and Timing in the RIU interface.

3. IRU and Wheel Tachometer Data Processor processes the wheel tach pulses and supplies wheel speed data to the RIU (OBC) and to the safehold electronics.

4. Safehold Electronics inputs analog sensor signals, computes analog error signals and generates logic commands to control the three axis of the spacecraft. The SHE also includes the control logic that unloads the momentum of the four SRWs.

5. Drive Signal Processor decodes the OBC drive cmds, the SHF wheel cmds and the torquer bar drive cmds. It also provides the drive signals for the SRW and/or the Magnetic Torquers.

6. Wheel Drive Electronics contains the drive for each of the four SRWs.

7. Magnetic Torquer Bar Drive Electronics contains the drive for the magnetic torquers. The torquers on the x and y-axis have two independent windings and the z-axis has two independent torquer bars. The torquer bar drive electronics contains an independent drive for each of the independent windings. See Figure 3-5.

8. Magnetometer Data Compensation block corrects the TAM signals for the magnetic fields produced by the magnetic torquer drive currents.

3.1.10 IRU POSITION - TACHOMETER PROCESSOR (ITP)

The ITP consists of six 24-bit registers for gyro data, six 8-bit gyro bias registers, four 16-bit registers for wheel speed data and associated D/A converters to transfer the digital data to analog for input to the SHE.

The six gyro registers are 24 bit up-down counters. There is one per gyro channel. The registers then contain the integrated position derived from IRU $\Delta\theta$ data obtained once every 64 milliseconds. The shuttle retrieval on command will reset these registers to all zeros. The six 8-bit bias registers are used to compensate the position data for use in the SHF analog circuit only. This bias is not subtracted from the OBC data outputed from the ITP. These 6-bias registers are set by ground command. It should be noted that the ITP gyro registers will always be in the high rate scale (.6 sec per count) when used in conjunction with SHE.

Each SRW has 2 tachs. Tach A is dedicated to ACE A and Tack B to ACE B. The tachs provide a series of type 01 and type 02 pulses to the ITP. The order, or phasing of the 01 and 02 pulses determines the wheel speed polarity. The number of pulse pairs per cycle yields the wheel speed. The tach pulse pairs are accumulated algebraically over a time interval providing a wheel speed and polarity for that interval. When the pulses are read the ITP registers are zeroed and a new number is accumulated each cycle.

3.1.11 FINE SUN SENSOR (FSS)

The FSS yields 2-axis analog and digital position data from a ± 32 degree square field of view. The error signals are measured with respect to the FSS axes and transformed to the spacecraft axes in the ACE. The telemetry and OBC inputs are errors with respect to the FSS axes. The FSS is a non-redundant digital sensor with course and fine outputs. A functional block diagram is provided in Figure 3.1-9. FSS operation is primarily for the Computer mode. The output of the FSS is random until a sun presence is indicated. FSS analog outputs are provided to the ACE whenever the FSS is powered. The analog outputs,which can serve as a backup to a failed CSS for Safehold mode operation. However, since these outputs are random with no sun in the FOV of the sensor, they must not be employed unless Sun Presence in indicated.

3.1.12 EARTH SENSOR ASSEMBLY MODULE (ESAM)

The Earth Sensor Assembly Module is mounted on the Instrument Module (IM). Although both earth sensors are identical, one earth sensor (designated ESA 1) is mounted to the spacecraft with its scanner boresight axis in the X-Z plane, tilted down 24 degrees from the -X axis. The second earth sensor (designated ESA 2) is mounted with its scanner boresight in the spacecraft Y-Z plane, titled down 24 degrees from the +Y axis. Knowledge of the alignment is ± 0.1 degree. The signal interface between the ESAM and the MACS is through the ACE interface electronics to the Safehold electronics. The ESA provides an E and H channel error for each earth sensor. These errors are then processed either in the OBC or safehold electronics to obtain roll and pitch errors. The mounting orientation for ESA 1 is:

+Pitch	-E
+Roll	-H

and for ESA 2:

+Pitch	+H
+Roll	-E

The MACS also uses the roll error signal to determine the roll rate which is then used to determine the yaw position error. The ESAM outputs are used by the M/CS in both the safehold mode and the computer mode. Earth Sensor (ES)1 outputs are dedicated to ACE A and ES2 outputs to ACE B. An ESA/ACS signal interface diagram is provided in Figure 3.1-10.

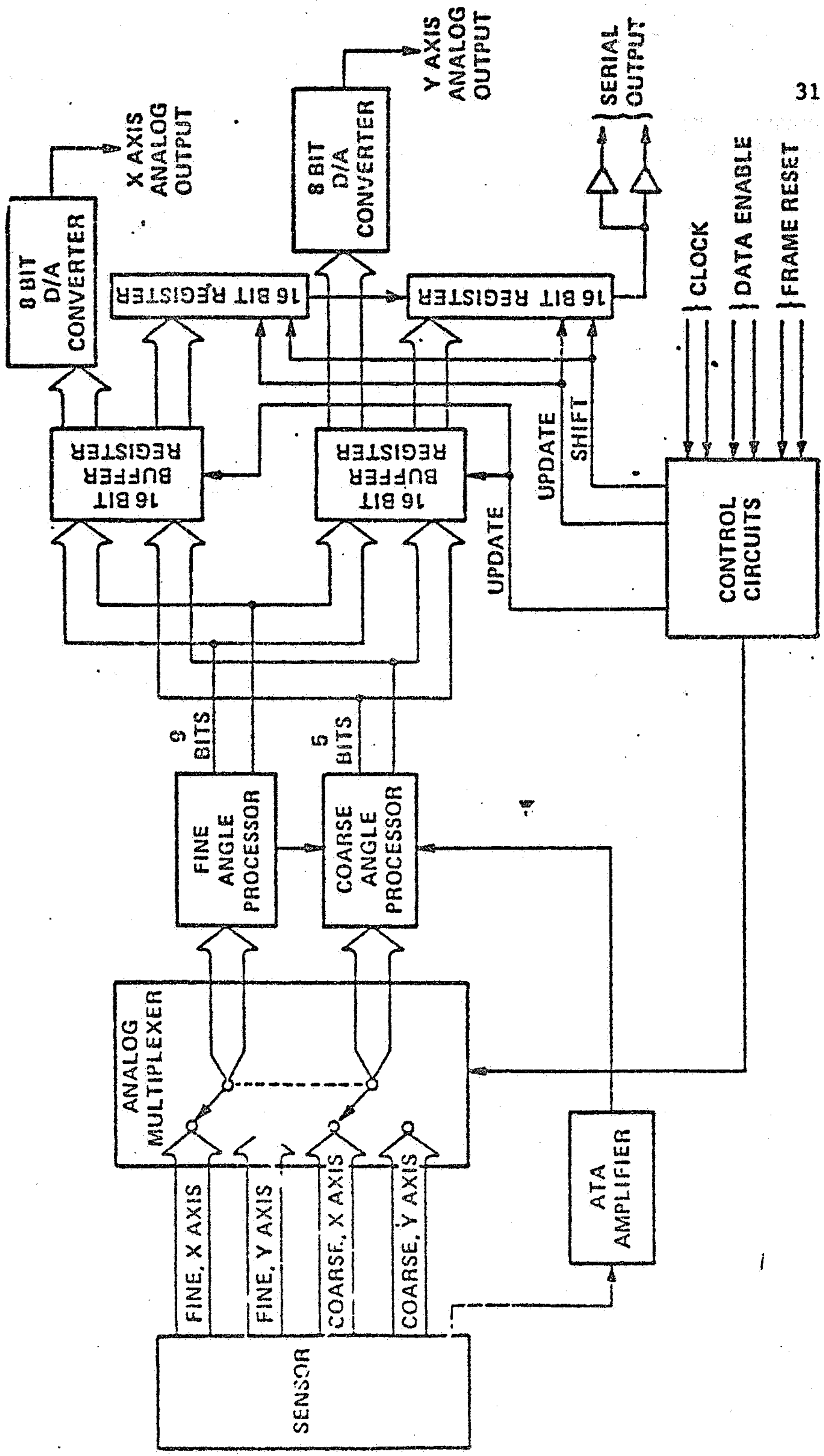
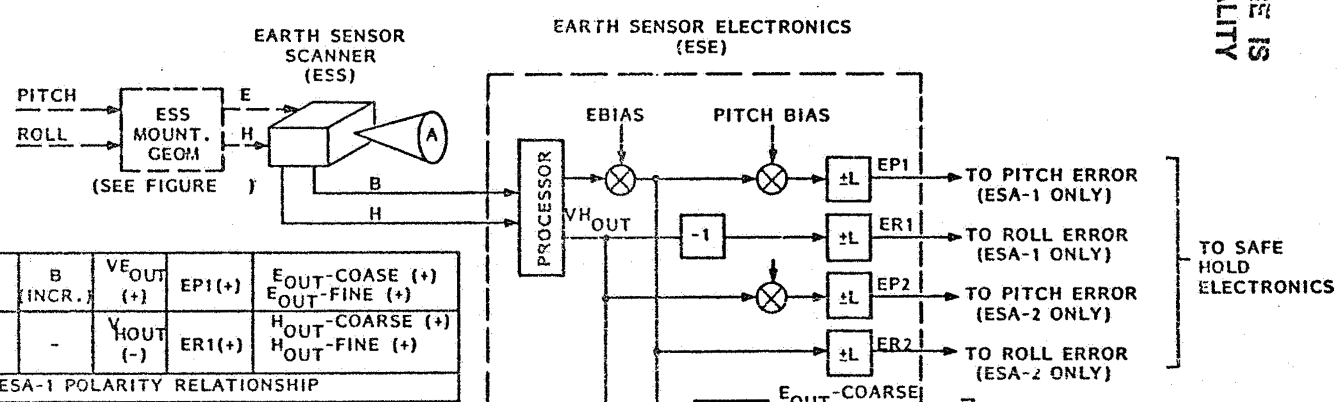


Figure 3.1-9. FSS Functional Block Diagram



PITCH (+)	E* (-)	B (INCR.)	VE_{OUT} (+)	EP1(+)	E_{OUT}-COASE (+) E_{OUT}-FINE (+)
ROLL (+)	H* (-)	-	V_{HOUT} (-)	ER1(+)	H_{OUT}-COARSE (+) H_{OUT}-FINE (+)
ESA-1 POLARITY RELATIONSHIP					

PITCH (+)	H* (+)	-	V_{HOUT} (+)	ER2(+)	H_{OUT}-COARSE (-) H_{OUT}-FINE (-)
ROLL (+)	E* (-)	B (INCR.)	V_{EOUT} (-)	ER2(+)	E_{OUT}-COARSE (+) E_{OUT}-FINE (+)
ESA-2 POLARITY RELATIONSHIP					

*SEE ESS REF FRAME & POLARITY DEFINITIONS (FIGURE)

Figure 3.1-10. Earth Sensor Assembly/ACS Signal Interface and Polarity

Also outputed is an invalid earth signal and a sun presence signal. A valid earth signal must meet the following two conditions:

1. Both the leading and trailing edges are within the unblanked region.

2. The leading edge (cold to hot transition) must preceed the trailing edge (hot to cold transition).

If either condition fails, the earth sensor output is clamped to 2.5 volts (2.5 volts —> zero error). One scan with an invalid earth is sufficient to set the errors to zero. Two successive scans with a valid earth are required before normal operation continues. Sun presence is detected by:

1. More than one hot to cold then cold to hot transition in 1 cycle.

2. The time between temperature transitions is larger than the allowable tolerance.

If a sun presence is detected, the earth sensor will clamp the last "good" state until no sun presence is indicated.

The ESAM is made up of the following functional blocks:

1. Heater Cortrol

2. Power Supply/Motor Driver Assembly

3. Earth Sensor Scanner

4. Signal Processor

5. H Processing

6. E Processing

3.2 PERFORMANCE CAPABILITIES

The MACS can operate in either the Computer Mode or the Safehold Mode. The Computer Mode is the mode used for on-orbit fine pointing, orbit adjust and orbit transfer. The OBC reads sensor data, computes error data (closed loop) and issues commands to control the actuators. The sensors include the Earth Sensor located on the Instrument Module (IM), Fine Sun Sensor (FSS), the Inertial Reference Unit and the Fixed Head Star Trackers. Table 3.2-1 shows the expected pointing accuracy for three spacecraft missions. (Earth pointing accuracy of ± 0.3 degrees with the earth sensors.)

Table 3.2-1. MACS Performance Requirements (Computer Mode)

	Initial Conditions	Point Accuracy W/O Payload Sensor	Point Accuracy W Payload* Sensor	Average Rate W/O Payload Sensor	Average Rate W Payload* Sensor	Jitter W/O Payload Sensor	Jitter W Payload* Sensor	Settling Time
Stellar Mission	1. Inertial hold mode at nominal desired Attitude. 2. Wheel speeds less than 25%. No load speed.	0.01 deg	10^{-4} deg. (error sig. via computer) 10^{-5} deg (analog error signal)	10^{-6} deg/sec (1)	– – –	0.0008 deg (2)	10^{-5} deg (error signal via computer) 10^{-6} deg (analog error signal) (3)	< 3 Min
Solar Mission	1. Inertial hold mode at nominal desired attitude. 2. Wheel speeds less than 25%. No load speed.	0.01 deg	10^{-4} deg. (error signal) via computer 10^{-5} deg (analog error signal)	10^{-6} deg/sec (1)	– – –	0.0008 deg (2)	10^{-5} deg (error signal via computer 10^{-6} deg (analog error signal) (3)	< 3 Min
Earth Pointing Mission	1. Inertial hold mode at nominal desired attitude. 2. Wheel speeds less than 25%. No load speed.	0.01 deg	– – –	10^{-6} deg/sec (1)	– – –	0.0008 deg (2)	– – –	< 8 hr for orbit altitude less than 800 nmi < 36 hr for geosynchronous orbit

*Assumes ideal attitude sensor and applies to axes responding to the payload sensor.
(1) Based on best straight line fit for interval of 30 min. with 2 min. sampling rate of the attitude data.
(2) Relative to best fit baseline for periods of up to 20 min. Based on sampling interval of 200 msec.
(3) Relative to best fit baseline on a continuous basis. Based on sampling interval of 200 msec.

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Upon transition to the Safehold Mode, the Safehold Electronics shall form closed control loops about each of the three MACS coordinate reference axis. The yaw axes, controlled by the IRU i ll axis rate gyro, shall be stabilized to within ±0.1 degree/second. The Earth Sensor provides sensor data about the pitch and roll axes with the spacecraft stabilized to within ±10 degrees.

3.3 MODES OF OPERATION

The MACS can operate in any one of the following modes:

1. COMPUTER MODE: The computer mode is the mode used for on orbit fine pointing and for orbit adjust. In this mode, the On-Board Computer software controls the sensor and actuators, as required, to maintain the attitude and/or orbit of the spacecraft. The OBC information from the appropriate sensors computes the error in attitude and issues commands to the actuators. The actuators create the torques and/or thrusts that control the spacecraft.

2. SAFEHOLD MODE: The safehold mode is entered to maintain the spacecraft on orbit in a safe attitude. This mode does not require the use of the On-Board Computer.

3.3.1 COMPUTER MODE

The Remote Interface Unit (RIU) transfers information between the OBC and the MACS components. The OBC software, via the RIU, requests information from appropriate sensors, performs specified computations and issues, via the RIU, commands to the specified MMS subsystem. The functions performed while in the computer mode are controlled by the OBC software. Table 3.3-1 shows the available MACS Operational Function that can be performed while in the Computer Mode.

Table 3.3-1. MACS Operational Modes (Functions)

Mode	Sensors	Actuators	Description
Local Vertical(LV) Acquisition	IRU, ESA, TAM	Reaction Wheels,Torquers	Upon separation; will acquire local vertical. Reduces position and rate errors in roll and pitch (Mode=1)
Yaw Acquisition	IRU,ESA, TAM	Reaction Wheels, Torquers	Follows LV acquisition; reduces position and rate errors in yaw. (Mode=2)
Stellar Acquisition	IRU, Star Tracker, FSS,ESA	Reaction Wheels, Torquers	Follows Yaw Acquisition. For low orbit altitude missions uses FSS and magnetometer data to compute initial inertial attitude. Uses IRU and star tracker data to refine inertial attitude determination. (Mode=3)
Orbit Adjust	IRU	Thrusters	Uses IRU data and thrusters to hold LV pointing during orbit adjust burn. Low level thrusters used for roll control, high level thrusters modulated on/off for pitch and yaw control. (Mode=7)
Earth Pointing	IRU,Star Tracker, FSS,TAM	Reaction Wheels, Torquers	Uses IRU and star tracker data for precision earth pointing. Requires high accuracy spacecraft ephemeris data to achieve desired pointing accuracy. (Mode=4)

3.3.2 SAFEHOLD MODE

Attitude control using the Safehold Mode does not use the On-Board Computer. Safehold is used to hold the spacecraft in a safe attitude (+Z axis to within 5° of local vertical) during the time that the OBC is not available, when it is not logical to use the OBC or the OBC onboard failure detection logic has issued an automatic Safehold condition.

For the ground commanded Safehold configuration, serial magnitude commands from the ground select the sensors and the actuators to be used while in the Safehold Mode. Operation in this mode requires the IRU and the Three Axis Magnetometer (TAM) bias values to have been uploaded to compensate for IRU drift and for the residual magnetic fields created by the spacecraft. Paragraph 3.6 describes the commands and the format for uploading the needed values.

In the transition to the Safehold Mode, the control of the actuators is transferred from the OBC to the Safehold Electronics (SHE). The SHE forms closed control loops about the three MACS axes. The control loops input analog signals from the selected sensors (ES and IRU roll axis rate gyro), computes the error signals and generates the logic to drive the actuator to correct the attitude errors. The "IRU and Wheel Tachometer Data Processor" determines the SRW wheel speeds and when required, the SHE generates the logic to drive the actuators (Magnetic Torquers and/or Thrusters) to unload the SRWs. Thruster unloading is an option to be exercised if and only if a magnetic torquer fails. If a pitch torquer fails, thruster unloading in that axis will be required. If the roll, pitch, and yaw SRW's are powered the Safehold Electronics (SHE) will not drive the skew wheel even if it is powered. If, however, either of the roll, pitch, or yaw SRW's is powered off the SHE will substitute the skew wheel for the off powered wheel providing the skew wheel is powered. When the skew wheel replaces one of the primary wheels the SHE will compensate the Drive Electronics of the remaining channels for the effect of the skew wheel.

The MACS switches to the Safehold Mode upon receipt of the appropriate Discrete Command or when the Computer Status Module (CSM) detects an OBC anomaly and issues a command to transfer to the Safehold Mode.

Upon transition to Safehold, the selected ACE/SHE is automatically powered and control of the selected actuators switched to the SHE.

The three axes control loops are activated to stabilize the spacecraft about the three control axes. The Earth Sensor provides the sensors for the pitch and roll axes and stabilizes the spacecraft to within ±10 degrees. The IRU roll axis rate gyro supplies the sensor signal for the yaw axis position control loop which stabilize the spacecraft to within 0.1 degree/second about the yaw axis. The sensors used for roll, pitch, and yaw rate information are IRU R2, P2 and Y2.

The Safehold configuration is controlled by uploading the appropriate Serial Magnitude Commands which select the sensors and actuators and also upload the IRU and TAM bias values needed to correct for gyro drift and for magnetic fields created by the spacecraft. Discrete Commands control the power to some MACS components and these commands must be consistent with the sensor and/or actuators selected by SM commands. The required commands must be uploaded before the MACS can be placed in Safehold.

Upon entry into Safehold, the MACS sends logic signals to the Solar Array Drive and to the Propulsion Subsystems. Control logic signals to the Propulsion Subsystem low level thrusters to provide spacecraft control torques are available upon command or immediately if commanded on prior to transfer to Safehold. The Solar Array Drive indexes at one revolution per orbit. The Solar Array maintains the initial sun line angle. The Reaction Wheels are the desired (selected by SM Command) actuators. The ACE which includes an IRU and Wheel Tachometer Data Processor reads the Wheel TACH pulses and then the SHE may issue actuator commands which induce disturbance torques created by the magnetic torquers which when corrected by the SRWs, will unload the wheels. Either (or both) the Magnetic Torquers or the thrusters can be selectd to unload the wheels. When the Magnetic Torquers are selected, the SHE reads the Three Axis Magnetometer data and determines the Torquer Drive currents needed to unload the wheels.

In the case where the onboard Failure Detection and Correction (FDC) logic initiates the Safehold mode, the OBC will provide current serial magnitude data to the SHE registers for Safehold execution. These data will be transmitted to the SHE as part of two possible onboard command tables, selected by the OBC as due to a fault detection and the resultant configuration determined by software logic. The FDC logic will cause entry to either an earth-pointing Safehold mode using earth sensors and gyro compassing or an inertial hold mode using IRU´s. The activators are the SRW´s. One table defines a sequence of commands to go to Safehold using ACE A, and the other using ACE B. Twelve possible hardware configurations can be defined by the onboard logic and are shown in Figure 3.3-1. In order to provide positive control over the fault detection logic, the software must be re-initiated via ground command after execution, thereby allowing only one shot correction to an anomoly.

TABLE 1 (ON-BOARD LOGIC) CONFIGURATION & OPTIONS

EQUIPMENT STATUS

ON	OFF
ACE A/ES 1	ACE B/ES 2
RIU 2B	RIU 2A
TAM 1	TAM 2
ACE A&B SEP SIG OVRD	THRUSTERS & PME
ROLL, PITCH & YAW TORQUER A	
ROLL, PITCH & YAW TORQUER B	
SAFE HOLD ACE A	
IRU CH A/B/C HIGH RATE	

OPTIONS	SRW ENABLE & POWER				IRU GYRO RATE SENSOR			ITP 1 POSITION DATA		
	ROLL	PITCH	YAW	SKEW	ROLL	PITCH	YAW	ROLL	PITCH	YAW
1-0	On	On	On	-	1	1	2	-	-	-
1-1	-	On	On	On	1	1	1	-	-	-
1-2	On	-	On	On	1	1	1	-	-	-
1-3	On	On	-	On	1	1	1	-	-	-
1-4	On	On	On	-	1	1	2	On	On	On
1-5	-	On	On	On	1	1	1	On	On	On
1-6	On	-	On	On	1	1	1	On	On	On
1-7	On	On	-	On	1	1	1	On	On	On

TABLE 2 (ON-BOARD LOGIC) CONFIGURATION & OPTIONS

EQUIPMENT STATUS

ON	OFF
ACE B/ES2	ACE A/ES1
RIU 2A	RIU 2B
TAM 1	TAM 2
ACE A&B SEP SIG OVRD	THRUSTERS & PME
ROLL, PITCH & YAW TORQUER A	
ROLL, PITCH & YAW TORQUER B	
SAFE HOLD ACE B	
IRU CH A/B/C HIGH RATE	

OPTIONS	SRW ENABLE & POWER				IRU GYRO RATE SENSOR			ITP 1 POSITION DATA		
	ROLL	PITCH	YAW	SKEW	ROLL	PITCH	YAW	ROLL	PITCH	YAW
2-1	-	On	On	On	1	1	1	-	-	-
2-2	On	-	On	On	1	1	1	-	-	-
2-3	On	On	-	On	1	1	1	-	-	-
2-4	On	On	On	-	1	1	2	-	-	-

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Figure 3.3-1. MAC's Safehold Configuration (Software Control)

3.4 MODULAR ATTITUDE CONTROL SUBSYSTEM (MACS) CONSTRAINTS

3.4.1 MACS INITIALIZATION CONSTRAINTS

1. If the OBC pulse train is not initiated immediately after MPS power turn-on to the MACS, causing one or both ACE CSM timers to "time out", the following commands should be performed to reset the ACE CSM timer after the OBC pulse train is established:

   SEND 0205 CSM INHIBIT TO ACE A
   SEND 0206 CSM INHIBIT TO ACE B

   and when the ACE CSM Timer does not time out $\simeq$ 3 seconds):

   SEND 0208 CSM ENABLE TO ACE A
   SEND 0210 CSM ENABLE TO ACE B

2. The selected ACE block comes on line in the Computer Mode at power turn ON, with its SM command registers initialized to all 1's or maximum signal. For this reason Wheel Drive and Magnetic Torquer Driver SM commands of zero or other desired values must be issued before the Wheel and Magnetic Torquer drives are enabled. Both wheels and magnetic torquers are disabled by Launch Mode and by their respective power OFF commands.

3. The ACE TAM Bias, Magnetic Torquer Bias and IRU Rate Bias SM command registers must be initialized prior to their use by the MACS in the Safehold Mode. Therefore, it is recommended that SM commands of zero or the desired value be entered into their respective ACE block storage registers as soon as possible after power turn ON to that ACE block.

4. Inhibit the MACS CSM to prevent switching to the Safehold mode when commanding the MACS out of the launch mode if the OBC is not running.

   NOTE: If computer is on and functioning, the system will not go to Safehold.

3.4.2 MACS TELEMETRY CONSTRAINTS

1. The following MACS telemetry is unavailable as a function of Computer/Safehold Modes:

   a. Computer Mode

      (1) TACH and IRU Position Analog Telemetry not available

      (2) TAM Compensated Signal Analog Telemetry not available

      (3) FSS POSN SDD is not valid until the FSS is powered and Sun Acquired as indicated by a logic 1 in the Sun Presence bit

      (4) IRU POSN SDD only available from the OBC via the C&DH RIU

      (5) TACH POSN SDD only available from the OBC via the C&DH RIU

      (6) The FHST POSN SDD and Star Intensity Analog Telemetry is not valid until the FHST is powered and star acquired, as indicated by a logic "1" in the STAR PRESENT bit

   b. Safehold Mode/OBC Not Operational

      (1) TACH SDD not available

      (2) IRU POSN SDD not available

      (3) FSS POSN SDD is not valid until the FSS is powered and sun acquired as indicated by a logic "1" in the Sun Presence bit

   c. Safehold Mode/OBC Operational

      (1) TACH SDD not available

      (2) IRU POSN SDD only available from the OBC via the C&DH RIU

      (3) FSS POSN SDD is not valid until the FSS is powered and the sun acquired as indicated by logic "1" in the Sun Presence bit.

2. When an RIU/EU is powered in the STDBY 2 mode, temperature telemetry is available from the PSU, ACE, IRU, SRWs, FSS and the optical bench regardless of the power status of these components.

3. Valid IRU Motor Current, and Regulated Voltage analog telemetry is available only when the designated IRU channel is powered.

4. Valid ACE serial digital data is available only from the powered ACE block.

5. Valid ACE standard reaction wheel tach, inertial reference unit position and three axis magnetometer compensated analog telemetry is available only from the powered ACE safehold electronics block.

6. The 4 Hz Presence SDD telemetry provides an indirect measure of the status of the RIU 1.024 MHz clock. Since the telemetry bit is derived by ACE logic from the computer pulse train (CPT) and the ACE 4 Hz clock, that is, counted down from the 1.024 MHz clock it receives from the RIU, its performance and certain limitations must be understood for its effective use. These are best defined by the following signal combinations:

LAUNCH MODE(LM) STATUS	4 Hz SIGNAL STATUS	CPT SIGNAL STATUS	4 Hz PRESENCE SDD TLM
$\overline{LM}$	4 Hz	X	1
$\overline{LM}$	$\overline{4\ Hz}$	CPT	0
$\overline{LM}$	$\overline{4\ Hz}$	$\overline{CPT}$	?
LM	X	CPT	0
LM	X	$\overline{CPT}$	?

where X Denotes Do Not Care and ? denotes indeterminate

Once out of launch mode (LM)89, a valid 1.024 MHz clock signal produces a logic "1" 4 Hz Presence SDD telemetry bit. A failure of the 1.024 MHz clock produces a logic "0" 4 Hz Presence SDD telemetry bit, provided the CPT is present. When the MACS is out of the launch mode and should both the 1.024 MHz clock and CPT fail at the same time, the 4 Hz SDD output would be indeterminate. However, in this event, the MACS will switch to the Safehold Mode and anomalous performance indications from other telemetry will indicate the health of the 1.024 MHz clock. Verification of the 1.024 MHz RIU A and RIU B clock signals in launch mode requires the use of the Separation Signal Override ON and Separation Signal Override OFF Commands.

3.4.3 MACS COMMAND CONSTRAINTS

1. The "separation signal override OFF discrete command to ACE A" can only be issued via RIU A and the "separation signal override discrete command to ACE B" can only be issued via RIU B.

2. There is no shuttle retrieved OFF discrete command. This function is accomplished by the corresponding SAFEHOLD OFF discrete command.

3. Magnetic Torquer Bias Commands and TAM Bias Commands may be entered into the appropriate storage registers during operation in either the computer or Safehold modes but they are effective only during safehold.

4. Switching from ACE A to ACE B and then back to ACE A in 1 minute is prohibited because of potential power converter damage (also from ACE B to ACE A).

5. Commanding Low Rate mode for any IRU channel in less than 45 seconds after power turn on (of that channel) may cause it not to respond.

6. The reaction wheel enable telemetry reflects the combined status of the wheel ON command and the separation switch.

3.4.4 MACS TEMPERATURE CONSTRAINTS

1. If mission analysis predicts indicate low optical bench and FHST bracket temperatures prior to FHST Power Turn ON, send the following commands:

   SEND 0241 FHST 2 HEATER PWR ON
   SEND 0242 FHST 1 HEATER PWR ON

2. The MACS Group 1, Group 2 and Group 3 Heater power must be commanded ON to allow the thermal control thermostats to control current to their corresponding heaters at low environmental temperatures.

3. The MACS component operating temperature limits as provided by internal temperature sensors and readout on analog telemetry are as follows:

Standard Reaction Wheels (SRW)	-10°C to 65°C
Power Switching Unit (PSU)	-10°C to 55°C
Fine Sun Sensor (FSS)	-10°C to 55°C
Remote Interface Unit (RIU)	-10°C to 60°C
IRU CH A, B, C	0°C to 65°C
Fixed Head Star Tracker (FHST)	- 5°C to 60°C

Attitude Control Elec (ACE)	$-10^{o}C$ to $60^{o}C$
Optical Bench	$0^{o}C$ to $45^{o}C$

4. During mission normal operating modes, the fixed head star tracker (FHST) heater power must be commanded OFF when FHST power is commanded ON to avoid FHST over temperature condition. When the FHST power is OFF, the FHST heater power must be commanded ON to provide FHST heater control.

5. FHST Heater circuits are thermostatically controlled to turn OFF at $45^{o}C$, however, during periods when a FHST Heater is ON, the corresponding tracker must be commanded ON periodically for brief periods (less than a minute) to monitor the FHST temperature, since the FHST analog telemetry is derived from active circuits within the tracker.

3.4.5 MACS PRESSURE CONSTRAINTS

Not Applicable

3.4.6 MACS VIEWING CONSTRAINTS

1. Maximum linear range of the FSS is ± 32 degrees relative to its reference frame.

2. FHST maximum FOV is 8 degrees TFOV or 1.25 degrees square for RFOV (reduced FOV).

3. FHST FOV is blocked by a shutter whenever the sun or earth limb comes within 28 degrees or 17.5 degrees respectively of its optical axis.

4. CSS linear FOV is ± 25 degrees and saturates at ± 25.6 degrees. In a saturated condition, 0 VDC (0 counts) indicates a negative spacecraft rotation from CSS null and 5.12 VDC (255 count) for positive rotation from CSS null. CSS TFOV is -180 to +180 degrees.

3.4.7 MACS OPERATING MODE CONSTRAINTS

1. If thrusters are employed for sun acquisition, the wheel power ON Commands may be delayed until after sun acquisition, but the following Safehold thruster control enable signal must be sent as a contingency:

   SEND 0274 (010263 OCTAL) THRUSTER CONTROL ACE A SDD BIT 17

2. If thrusters are employed for sun acquisition, the magnetic torquer power ON Commands may be delayed until the wheel power ON commands are issued.

3. During launch spacecraft rates are limited by the IRU survival rate limit of 600 degrees per second for a duration of 20 minutes maximum. Spacecraft rates for MACS attitude control must be limited to 2 degrees per second, to provide a useful output for initial acquisition or reacquisition of spacecraft reference, due to the limited operational range of the IRU High Rate Range.

4. During normal operating modes, with the MACS operating in Computer Mode and the DRIRU in the Low Rate Range, spacecraft rates must be limited to 0.11 degrees per second to stay within the linear range of the IRU POSN output.

5. Before switching RIUs and still remain in the computer mode, insure that the pulse train is being sent to the RIU to be turned on prior to turning it on, as well as sending it to the RIU presently in use.

6. MPS power is provided to only one ACE block at a time. When out of the launch mode and ACE needs to be switched, power to the SRWs and Magnetic Torquers must be turned OFF just prior to switching ACEs and the initialization command executed immediately following switching to the redundant ACE block. Power to the SRWs and Magnetic Torquers are then switched back ON.

7. Following flight segment separation from the launch vehicle, the maximum tip off rates should not exceed .25 degrees per second to maintain nominal attitude.

8. Orbit Adjust Mode Restraints:

   a. OBC cycle time must be set to 256 ms., required by ACS servo with thrusters in use. (280 ms. max. ACS thruster pulse time in PM-1.)

   b. PM-1 ACS pulse length of 280 ms. must be selected.

   c. The solar array must be within $\pm 10^\circ$ of the equatorial position due to flexible body effects on ACS stability.

   d. The maximum burn duration is 10 minutes due to ACS long term instability.

   e. Thruster valves shall not be opened downstream of a closed latch valve such as to drain the lines between the latch valves and the thrusters because of potential problems when the lines are refilled. Also potential problems with the latch valves could result. If thrusters are preselected for safehold then latch valves should be opened.

f. The ACS mode to be entered upon completion of the orbit adjust mode must be entered (commanded) as part of the orbit adjust data. Appropriate flags must be set in the CBC.

g. PM-1 must be configured for orbit adjusts. PME enabled, latch valve positions, etc.

3.4.8 MACS SAFEHOLD RESTRAINTS

1. MPS power shutdown to the MACS module must always be preceded by commanding OFF all MACS equipment except one RIU/EU and one ACE. MACS turn-off commands are as follows:

   SWR Power OFF (R, P, Y & S)
   Magnetic Torquers OFF (A & B)
   FSS OFF
   FHST OFF (1 & 2)
   TAM OFF (1 & 2)
   IRU OFF (A, B, C)
   MACS HTR GRP OFF (1, 2 & 3)
   FHST HTR OFF (1 & 2)
   1 ACE OFF (A OR B)
   1 RIU OFF (A OR B)

2. When ACE A is powered, TAM 1 is automatically enabled and it is recommended that TAM 1 be powered and the TAM 1 bias commands be entered into the TAM bias storage registers. The same is true of ACE B and TAM 2. Should the TAMs be switched, the TAM bias commands must be updated.

3. When the MACS switches to the SAFEHOLD mode, the CSM Timer must be reset by the CSM inhibit command and the presence of the proper CSM pulse train verified prior to switching back to the computer mode.

4. The MACS serial magnitude command #4 must be sent to preselect (enable) the earth sensor and gyro compass inputs for safehold operation.

5. Gyro drift during safehold for Rate Damping mode of the Flight Segment is $\leq 7.2^{\circ}$/hr.

3.5 REDUNDANCY

The MACS provides redundancy for all essential components. The redundancy can be classified as one of three types as follows:

1. DEDICATED is where one redundant component is hardwired in a channel and becomes a fixed part of a redundant channel.

2. PASSIVE is where either of two redundant components can be selected by command for use in a specified channel.

3. ACTIVE is where two redundant units are cross-strapped and either only a selected unit is powered or both units are powered and active.

The MACS has two modes of operation and each mode uses a combination of components plus components common to both modes. The MACS redundancy depends upon the mode of operation.

In the Computer Mode, the On-board Computer determines the MACS configuration and performs the computations needed to control the spacecraft. The OBC, under software control, selects the sensors to be used, and the OBC can request data from any sensor that is powered ON which is the equivalent of ACTIVE redundancy.

The Attitude Control Electronics (ACE) has dual channels (ACE A/ACE B) and each channel has a dedicated Drive Signal Processor that decodes the C&DH commands for the Standard Reaction Wheels or for the Magnetic Torquer Bars. The ACE supplies the drive signals for the SRWs and for the Magnetic Toruqer Bars.

3.5.1 ATTITUDE CONTROL ELECTRONICS (ACE) REDUNDANCY

The MACS Attitude Control Electronics component has redundant channels: ACE A and ACE B. And only one channel can be powered at any one time. Discrete Commands apply power to the selected ACE as follows:

DC 7 ACE A PWR ON/ACE B PWR OFF
DC 61 ACE B PWR ON/ACE A PWR OFF

In the Computer Mode, the OBC commands are processed by the powered ACE. Figure 3.5-4 shows the ACE redundancy diagram.

The ACE includes redundant Safehold channels and each Safehold channel includes redundnat sensors. Serial Magnitude Commands determine the sensors to be used in the ACE A or ACE B Safehold Mode. Figure 3.5-2 shows the redundancy for the ACE A Safehold channel. And Figure 3.5-3 shows the redundancy diagram for the ACE B Safehold channel.

The Safehold Mode is controlled by Discrete Commands which must be consistent with the ACE currently powered. The Safehold Commands are as follows:

DC 16 ACE A SAFEHOLD ON
DC 20 ACE A SAFEHOLD OFF
DC 34 ACE B SAFEHOLD ON
DC 36 ACE B SAFEHOLD OFF

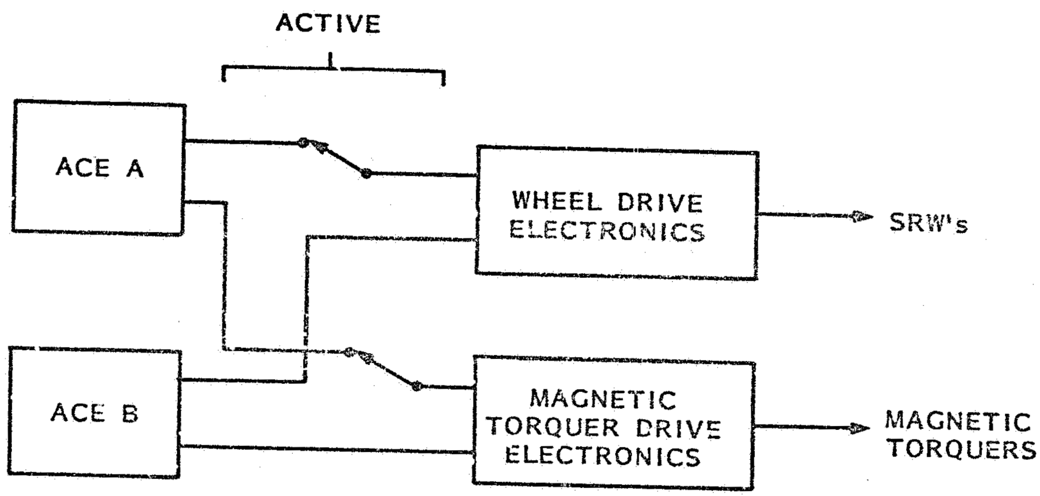

Figure 3.5-1. ACE Computer Mode Redundancy

C-2

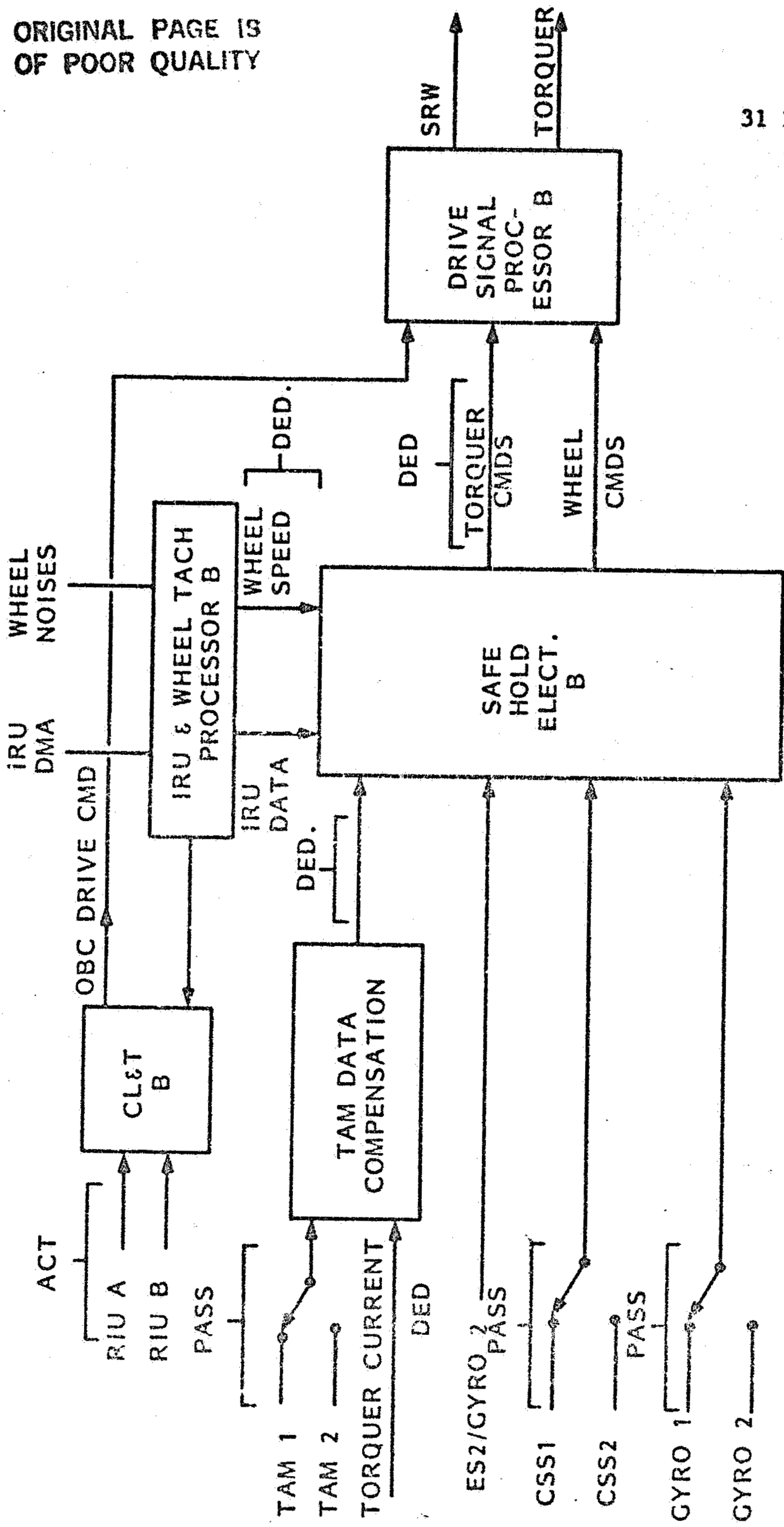

Figure 3.5-2. ACE A Redundancy Diagram

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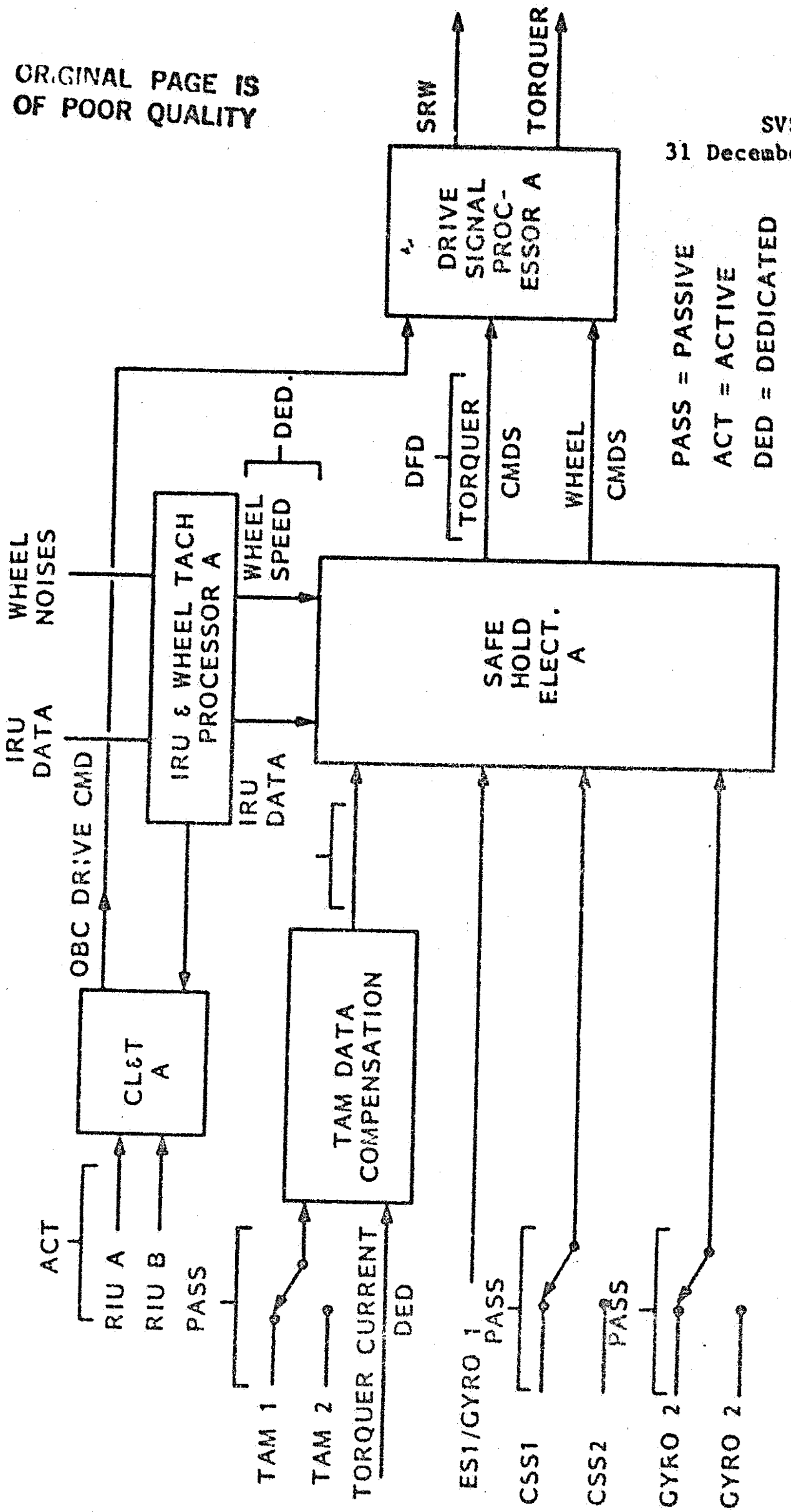

Figure 3.5-3. ACE B Redundancy Diagram

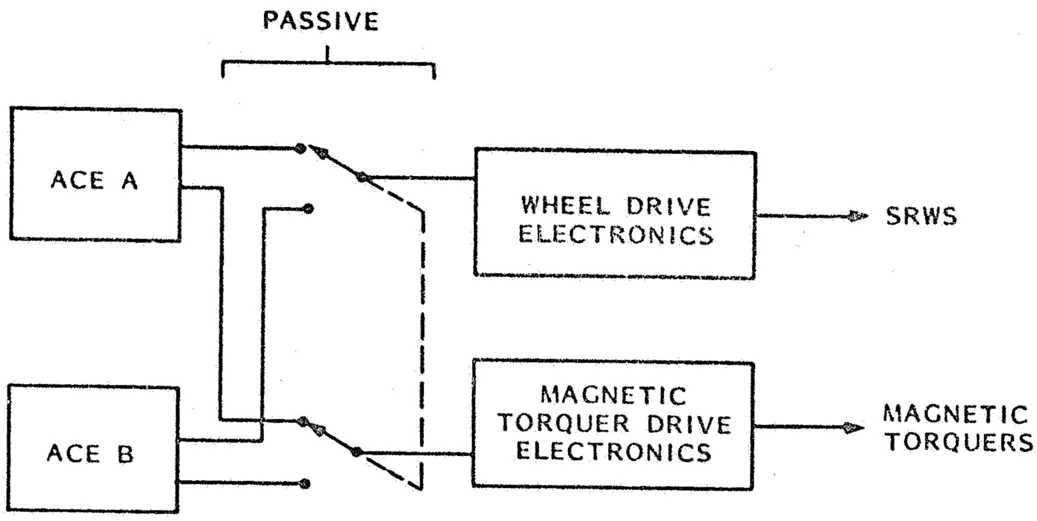

Figure 3.5-4. Safehold ACE Redundancy Diagram

The Safehold channel is selected by the appropriate Discrete Command which constitutes PASSIVE redundancy. Figure 3-12 shows the redundancy diagram for the ACE in the Safehold Mode.

3.5.2 INERTIAL REFERENCE UNIT REDUNDANCY

The IRU contains three gyros which are aligned to define three mutually orthogonal axis. The gyros supply angular inertial rate sensing about the three orthognal axes with redundancy for all three axes.

3.5.3 SRW REDUNDANCY

The MAC contains one SRW mounted along each of the three rectangular coordinate axis and one skew SRW mounted at equal angles from the other three SRWs. Each SRW has a dedicated drive electronics and the skew wheel can be activated to replace any single SRW. The SRWs must be powered ON by Discrete Command. A Serial Magnitude Command selects the three SRWs to be used by either Safehold channel. If the skew wheel is selected instead of one of the coordinate SRWs, the Safehold Electronics corrects for the torques generated by the skew wheel about the active SRW coordinate axes.

The skew wheel provides ACTIVE Redundancy for a failure of one out of three coordinate SRWs.

3.5.4 MAGNETIC TORQUER BAR REDUNDANCY

The X and Y-axis magnetic torquer bars each have two separate and independent windings and each winding has a dedicated Magnetic Torquer Drive Electronics channel. The z-axis has two independent Torquer Bars with dedicated Magnetic Torquer Drive Electronic channels. In normal operation all six channels are active.

In the event one of the dual channels (on the same axis) fails, the Magnetic Torquer Drive changes the gain in the remaining channel and the Magnetic Torquers continue to function with no degradation in performance. This provides passive redundancy for each of the three axis.

3.5.5 COMPUTER STATUS MONITOR (CSM) REDUNDANCY

CSM A and CSM B employ cross strapped power and provide a redundant capability to sense an OBC anomaly. The OBC sends pulse trains to both CSM A and CSM B. If either or both CSM A or CSM B fail to receive three consecutive discrete command OBC pulse train inputs, the CSM interval timer will "time out". A CSM "Time Out" Safehold bilevel signal will generate a Safehold ON logic signal provided a CSM Inhibit discrete command has not been received by the corresponding CSM.

The CSMs are ACTIVE redundant.

3.6 MACS/ESAM COMMANDS

Operation of the MACS is controlled utilizing a total of 70 commands, of these, 64 are discrete commands and 6 are serial message command words. Operation of the ESAM is controlled utilizing a total of 10 discrete commands. No serial message commands are used by the ESAM.

The commands are listed in Table 3.6-1 through 3.6-3 for the MACS and ESAM commands, and are described in Paragraph 3.6.1. Command sequences and restraints are provided in Paragraph 3.6.2 and 3.6.3. Functional schematics of command operation appear in Paragraph 3.6.4.

3.6.1 COMMAND DESCRIPTIONS

3.6.1.1 RIU Selection Commands

RIU 2 SELF STANDBY 1
RIU 2 SELF STANDBY 2

The selection of RIU 2A or 2B is controlled by these two discrete commands. The functional schematic for these commands is illustrated in Figure 3.6-1. The operation of these commands is identical for RIU A and B.

RIU 2 SELF STANDBY 1 to RIU A enables a pulse to one side of a latching relay, closing it, connecting RIU internal signal grounds to external signal grounds. In this configuration the RIU is in STANDBY 1 mode as evidenced by MACS bilevel telemetry, ARIUMATE = 1. RIU 2 SELF STANDBY 2 to RIU A elevates RIU A to the STANDBY 2 mode, enabling its use for command and telemetry. In addition, this command enables a pulse to RIU B, turning it off. This prevents both RIU's from being on simultaneously. The telemetry verification that RIU A is in the STANDBY 2 mode is indicated by MACS bilevel ARIUID = 0.

The complement to this series of commands is to send the same commands to RIU B, resulting in RIU B being on in the STANDBY 2 mode and RIU A off. The telemetry verification that RIU B is in the STANDBY 2 mode is indicated by MACS bilevel ARIUID = 1.

Table 3.6-1. MACS Discrete Command List

Command	Acronym	RIU Channel	Complement CMD Acronym	Verification TLM Acronym	Reference Paragraph
RIU 2 SELF STANDBY 1	RIU2EN	02-00	RIU2EN	ARIUMATE	3.6.1.1
RIU 2 SELF STANDBY 2	RIU2STD2	02-63	RIU2STD2	ARIUID	3.6.1.1
SEPARATION SIGNAL OVERRIDE ON TO ACE A	ASSOVON	02-01	ABSSOVOF	N/A	3.6.1.2
SEPARATION SIGNAL OVERRIDE ON TO ACE B	BSSOVON	02-02	ABSSOVOF	N/A	3.6.1.2
SEPARATION SIGNAL OVERRIDE OFF	ABSSOVOF	02-12	ASSOVON,BSSOVON	N/A	3.6.1.2
CSM PULSE TRAIN TO ACE A	ACSMPLSE	02-03	N/A	N/A	3.6.1.3
CSM PULSE TRAIN TO ACE B	BCSMPLSE	02-04	N/A	N/A	3.6.1.3
CSM INHIBIT TO ACE A	ACSMIN	02-05	ACSMEN	ACSMAED	3.6.1.4
CSM INHIBIT TO ACE B	BCSMIN	02-06	BCSMEN	ACSMBED	3.6.1.4
CSM ENABLE TO ACE A	ACSMEN	02-08	ACSMIN	ACSMAED	3.6.1.4
CSM ENABLE TO ACE B	BCSMEN	02-10	BCSMIN	ACSMBED	3.6.1.4
ACE A PWR ON/ACE B PWR OFF	AONBOFF	02-07	BONAOFF	AAONBOFF	3.6.1.5
ACE B PWR ON/ACE A PWR OFF	BONAOFF	02-61	AONBOFF	AAONBOFF	3.6.1.5
ACE A SAFEHOLD ON	ASAFON	02-16	ASAFOFF	AASFHLD	3.6.1.6
ACE A SAFEHOLD OFF	ASAFOFF	02-20	ASAFON	AASFHLD	3.6.1.6
ACE B SAFEHOLD ON	BSAFON	02-34	BSAFOFF	ABSFHLD	3.6.1.6
ACE B SAFEHOLD OFF	BSAFOFF	02-36	BSAFON	ABSFHLD	3.6.1.6
ACE A SHUTTLE RETRIEVAL ON	ASHRETON	02-38	ASAFOFF	AASHLRT	3.6.1.7
ACE B SHUTTLE RETRIEVAL ON	BSHRETON	02-24	BSAFOFF	ABSHLRT	3.6.1.7
FSS POWER ON	FSSON	02-09	FSSOFF	AFSSPWR	3.6.1.8
FSS POWER OFF	FSSOFF	02-11	FSSON	AFSSPWR	3.6.1.8
FHST 1 POWER ON	ST1ON	02-13	ST12OFF	AST1PWR	3.6.1.9
FHST 2 POWER ON	ST2ON	02-14	ST12OFF	AST2PWR	3.6.1.9
FHST 1 AND 2 POWER OFF	ST12OFF	02-15	ST1ON,ST2ON	AST1PWR,AST2PWR	3.6.1.9
TAM 1 POWER ON	TAM1ON	02-17	TAM12OFF	ATAM1PWR	3.6.1.10
TAM 2 POWER ON	TAM2ON	02-18	TAM12OFF	ATAM2PWR	3.6.1.10
TAM 1 AND 2 POWER OFF	TAM12OFF	02-19	TAM1ON,TAM2ON	ATAM1PWR,ATAM2PWR	3.6.1.10
IRU CH A POWER ON	IRUAON	02-21	IRUAOFF	AIRUAPWR	3.6.1.11
IRU CH B POWER ON	IRUBON	02-22	IRUBOFF	AIRUBPWR	3.6.1.11
IRU CH C POWER ON	IRUCON	02-59	IRUCOFF	AIRUCPWR	3.6.1.11
IRU CH A POWER OFF	IRUAOFF	02-23	IRUAON	AIRUAPWR	3.6.1.11
IRU CH B POWER OFF	IRUBOFF	02-40	IRUBON	AIRUBPWR	3.6.1.11
IRU CH C POWER OFF	IRUCOFF	02-57	IRUCON	AIRUCPWR	3.6.1.11
IRU CH A HIGH RATE	IRUAHI	02-46	IRUALO	AIRUARNG	3.6.1.12
IRU CH B HIGH RATE	IRUBHI	02-54	IRUBLO	AIRUBRNG	3.6.1.12
IRU CH C HIGH RATE	IRUCHI	02-62	IRUCLO	AIRUCRNG	3.6.1.12
IRU CH A LOW RATE	IRUALO	02-44	IRUAHI	AIRUARNG	3.6.1.12
IRU CH B LOW RATE	IRUBLO	02-52	IRUBHI	AIRUBRNG	3.6.1.12
IRU CH C LOW RATE	IRUCLO	02-60	IRUCHI	AIRUCRNG	3.6.1.12

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Table 3.6-1. MACS Discrete Command List

Command	Acronym	RIU Channel	Complement CMD Acronym	Verification TLM Acronym	Reference Paragraph
X MAG TORQUER A ON	AXTRQON	02-25	AXYZTQOF	AAXTRQA,ABXTRQA	3.6.1.13
X MAG TORQUER B ON	BXTRQON	02-26	BXYZTQOF	AAXTRQB,ABXTRQB	3.6.1.13
Y MAG TORQUER A ON	AYTRQON	02-27	AXYZTQOF	AAYTRQA,ABYTRQA	3.6.1.13
Y MAG TORQUER B ON	BYTRQON	02-28	BXYZTQOF	AAYTRQB,ABYTRQB	3.6.1.13
Z MAG TORQUER A ON	AYTRQON	02-29	AXYZTQOF	AAZTRQA,ABZTRQA	3.6.1.13
Z MAG TORQUER B ON	BYTRQON	02-30	BXYZTQOF	AAZTRQB,ABZTRQB	3.6.1.13
X,Y,Z MAG TORQUER A OFF	AXYZTQOF	02-31	AXTRQON AYTRQON AZTRQON	AAXTRQA,ABXTRQA AAYTRQA,ABYTRQA AAZTRQA,ABZTRQA	3.6.1.13
X,Y,Z MAG TORQUER B OFF	BXYZTQOF	02-32	BXTRQON BYTRQON BZTRQON	AAXTRQB,ABXTRQB AAYTRQB,ABYTRQB AAZTRQB,ABZTRQB	3.6.1.13
ROLL WHEEL POWER ON	XSRWON	02-45	XSRWOFF	AXWHED	3.6.1.14
PITCH WHEEL POWER ON	YSRWON	02-53	YSRWOFF	AYWHED	3.6.1.14
YAW WHEEL POWER ON	ZSRWON	02-56	ZSRWOFF	AZWHED	3.6.1.14
SKEW WHEEL POWER ON	SKSRWON	02-49	SKSRWOFF	ASWHED	3.6.1.14
ROLL WHEEL POWER OFF	XSRWOFF	02-47	XSRWON	AXWHED	3.6.1.14
PITCH WHEEL POWER OFF	YSRWOFF	02-55	YSRWON	AYWHED	3.6.1.14
YAW WHEEL POWER OFF	ZSRWOFF	02-58	ZSRWON	AZWHED	3.6.1.14
SKEW WHEEL POWER OFF	SKSRWOFF	02-51	SKSRWON	ASWHED	3.6.1.14
MACS HEATER GROUP 1 ON	HTG1ON	02-33	HTG1OFF	AHTRA1A,AHTRA1B AHTRB1A,AHTRB1B	3.6.1.15
MACS HEATER GROUP 2 ON	HTG2ON	02-37	HTG2OFF	AHTRA2A,AHTRA2B AHTRB2A,AHTRB2B	3.6.1.15
MACS HEATER GROUP 3 ON	HTG3ON	02-48	HTG3OFF	AHTRA3A,AHTRA3B AHTRB3A,AHTRB3B	3.6.1.15
MACS HEATER GROUP 1 OFF	HTG1OFF	02-35	HTG1ON	AHTRA1A,AHTRA1B AHTRB1A,AHTRB1B	3.6.1.15
MACS HEATER GROUP 2 OFF	HTG2OFF	02-39	HTG2ON	AHTRA2A,AHTRA2B AHTRB2A,AHTRB2B	3.6.1.15
MACS HEATER GROUP 3 OFF	HTG3OFF	02-50	HTG3ON	AHTRA3A,AHTRA3B AHTRB3A,AHTRB3B	3.6.1.15
FHST 1 HEATER ON	ST1HTRON	02-42	ST12HTOF	ATR1HTA,ATR1HTB	3.6.1.16
FHST 2 HEATER ON	ST2HTRON	02-41	ST12HTOF	ATR2HTA,ATR2HTB	3.6.1.16
FHST 1 AND 2 HEATERS OFF	ST12HTOF	02-43	ST1HTRON ST2HTRON	ATR1HTA,ATR1HTB ATR2HTA,ATR2HTB	3.6.1.16

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Table 3.6-2. MACS Serial Magnitude Command List

Command	Acronym	RIU Channel	Complement CMD Acronym	Verification TLM Acronym	Reference Paragraph
FHST 1 CONTROL	*	02-71	N/A	**	3.6.1.17
FHST 2 CONTRO'	*	02-72	N/A	**	3.6.1.17
ACE A COMMAND WORD 1	*	02-73	N/A	**	3.6.1.18
ACE A COMMAND WORD 2	*	02-74	N/A	**	3.6.1.19
ACE B COMMAND WORD 1	*	02-76	N/A	**	3.6.1.18
ACE B COMMAND WORD 2	8	02-77	N/A	**	3.6.1.19

*Acronyms assigned to specific command functions rather than general command
**Refer to the referenced paragraph for a complete list of TLM verifications for these multi-function commands

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Table 3.6-3. ESAM Command List

Command	Acronym	RIU Channel	Complement CMD Acronym	Verification TLM Acronym	Reference Paragraph
ESA1 POWER ON	ES1ON	04-18	ES1OFF	EES1SEN	3.6.1.20
ESA1 POWER OFF	ES1OFF	04-13	ES1ON	EES1SEN	3.6.1.20
ESA1 LOGIC ENABLE	ES1LOGEN	04-60	ES1HTDIS	EES1SIG	3.6.1.21
ESA1 HEATER ENABLE	ES1HTEN	04-40	ES1HTDIS	EES1SEN	3.6.1.21
ESA1 LOG/HTR DISABLE	ES1HTDIS	04-25	ES1LOGEN,ES1HTEN	EES1SIG,EES1SEN	3.6.1.21
ESA2 POWER ON	ES2ON	04-07	ES2OFF	EES2SEN	3.6.1.20
ESA2 POWER OFF	ES2OFF	04-34	ES2ON	EES2SEN	3.6.1.20
ESA2 LOGIC ENABLE	ES2LOGEN	04-39	ES2HTDIS	EES2SIG	3.6.1.21
ESA2 HEATER ENABLE	ES2HTEN	04-19	ES2HTDIS	EES2SEN	3.6.1.21
ESA2 LOG/HTR DISABLE	ES2HTDIS	04-54	ES2LOGEN,ES2HTEN	EES2SIG,EES2SEN	3.6.1.21

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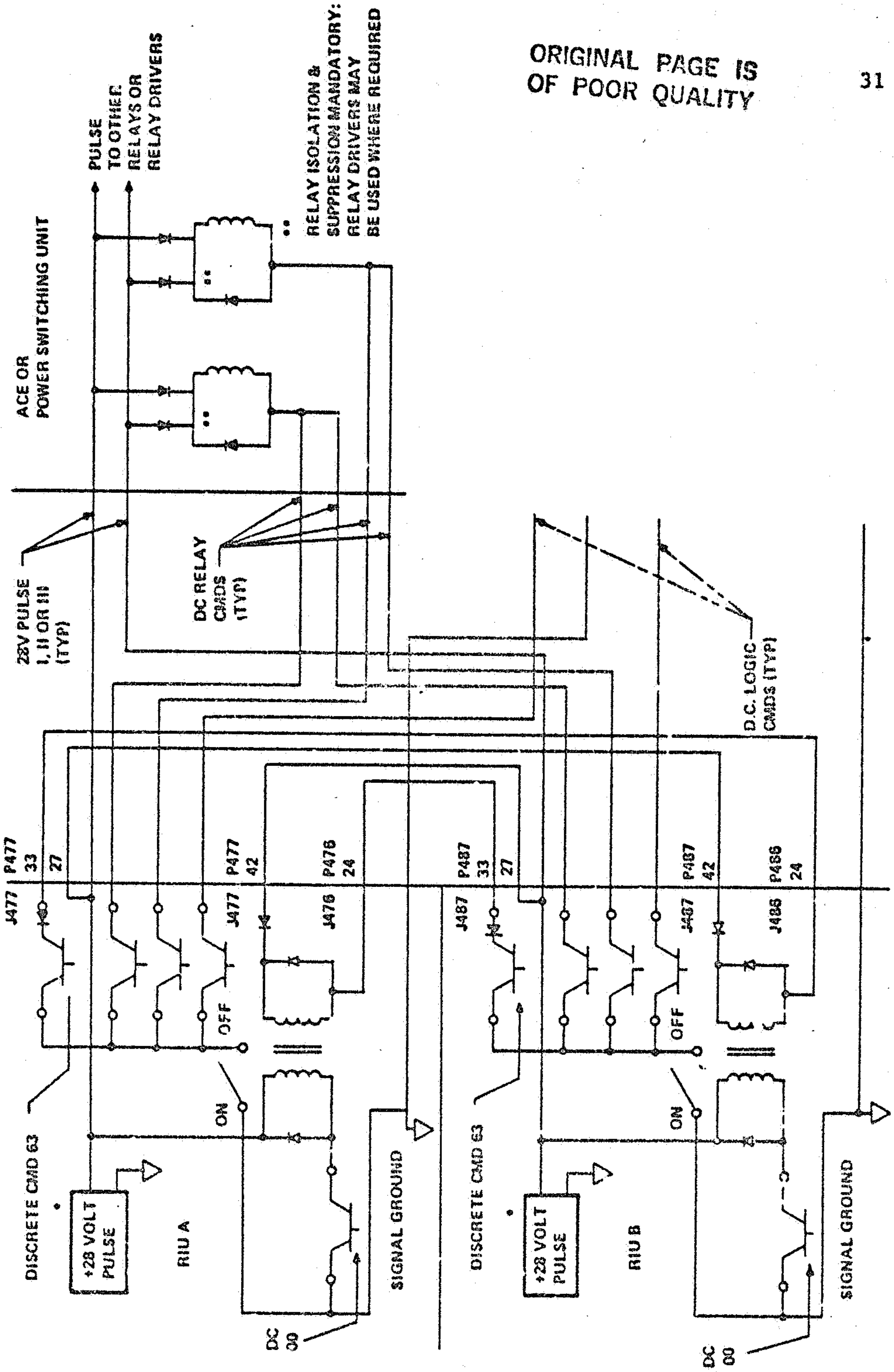

DISCRETE COMMAND (D.C.) CHARACTERISTICS ARE DEFINED IN S-700-54 PARA 2.2
*(3) 28 VDC PULSES ISOLATED FROM UNREGULATED 28VDC: I FOR ALL EVEN D.C. 2-62,
II FOR ALL ODD D.C. 1 TO 47, III FOR ALL ODD 49 TO 61.
D.C. DESIGNATIONS & REF 28V PULSE ARE DEFINED IN TABLE 5.2.1

Figure 3.6-1. Typical Relay Discrete Command Interface

3.6.1.2 Separation Signal Override Control

SEPARATION SIGNAL OVERRIDE ON TO ACE A
SEPARATION SIGNAL OVERRIDE ON TO ACE B
SEPARATION SIGNAL OVERRIDE OFF

The function of these three discrete commands is to control the separation signal override capability built into each ACE. The functional schematics for these commands is illustrated in Figure 3.6-2. The operation, functional schematic, and complement are identical for both ACE A and B commands.

Separation signal override on command, enables a logic function in the ACE which overrides separation switch closure. The complement to the override enable command is the off command which pulses a logic flip-flop to disable the override function. Note that the separation signal override off command to ACE A must be commanded thru RIU A. Likewise, the off command to ACE B must be thru RIU B.

Telemetry indication of override state is made via launch mode A and B telemetry points. A bilevel 1 indicates launch mode with the override function disabled. A bilevel zero indicates that the override function is enabled or that the separation switches are open.

3.6.1.3 CSM Pulse Train Commands

CSM PULSE TRAIN TO ACE A
CSM PULSE TRAIN TO ACE B

The function of these two discrete commands is to enable a logic level pulse to the CSM electronics thus simulating the presence of the actual pulse train from the OBC. The functional schematic for these commands is illustrated in Figure 3.6-2. The operation, functional schematic and complement are identical for both ACE A and B commands.

To simulate the OBC pulse train, these commands must be sent repeatedly. If not, and the CSM detection circuit is enabled, a CSM timeout will occur. There are no complements or telemetry points associated with these commands.

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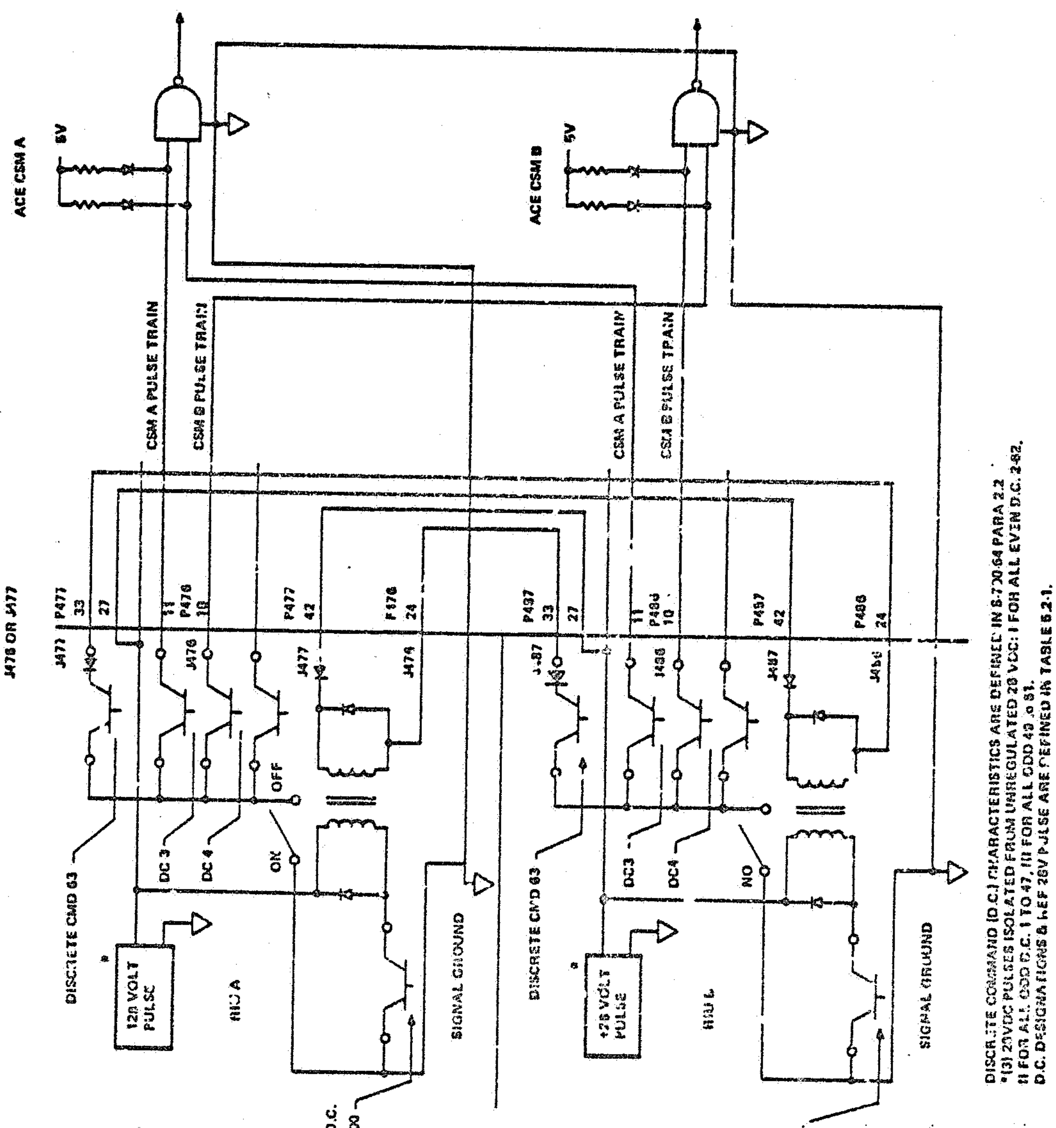

Figure 3.6-?. Typical Logic Discrete Command Interface

3.6.1.4 CSM Control

CSM ENABLE TO ACE A
CSM ENABLE TO ACE B
CSM INHIBIT TO ACE A
CSM INHIBIT TO ACE B

The function of these four discrete commands is to enable or inhibit the associated ACE A or B CSM detection circuits. The functional schematic for these commands is illustrated in Figure 3.6-2. The operation , functional schematic, telemetry verification and complement are identical for both A and B commands.

ESM ENABLE to ACE A, enables a pulse to one side of a logic flip-flop setting it to enable the CSM detection circuit. In this mode the CSM pulse train must be present to prevent a CSM timeout and automatic switch to safehold. The complement to the enable command is the CSM INHIBIT command. The INHIBIT command enables a pulse to the opposite side of the logic flip-flop, causing it to reset, disabling the CSM detection circuit.

Telemetry verification of CSM detection circuit enable/inhibit state is indicated by MACS telemetry points ACSMAED and ACSMBED for ACE A and B circuits respectively. A bilevel zero indicates that the circuit is enabled, a bilevel one indicates inhibited.

3.6.1.5 ACE Power Control

ACE A POWER ON/ACE B POWER OFF
ACE B POWER ON/ACE A POWER OFF

The function of these two discrete commands is to enable ACE power. The functional schematic for these commands is illustrated in Figure 3.6-5.

ACE A POWER ON enables a pulse to one coil of a latching relay causing it to switch the +28 VDC power to ACE A, while simultaneously removing power from ACE B. The complement is the ACE B POWER ON command. This command enables a pulse to the opposite coil of the latching relay, causing it to switch the +28 VDC power to ACE B, removing power from ACE A.

Telemetry indication of ACE power status is made via MACS bilevel telemetry point AAONBOFF. A bilevel one indicates ACE A power on. A bilevel zero indicates ACE B power on.

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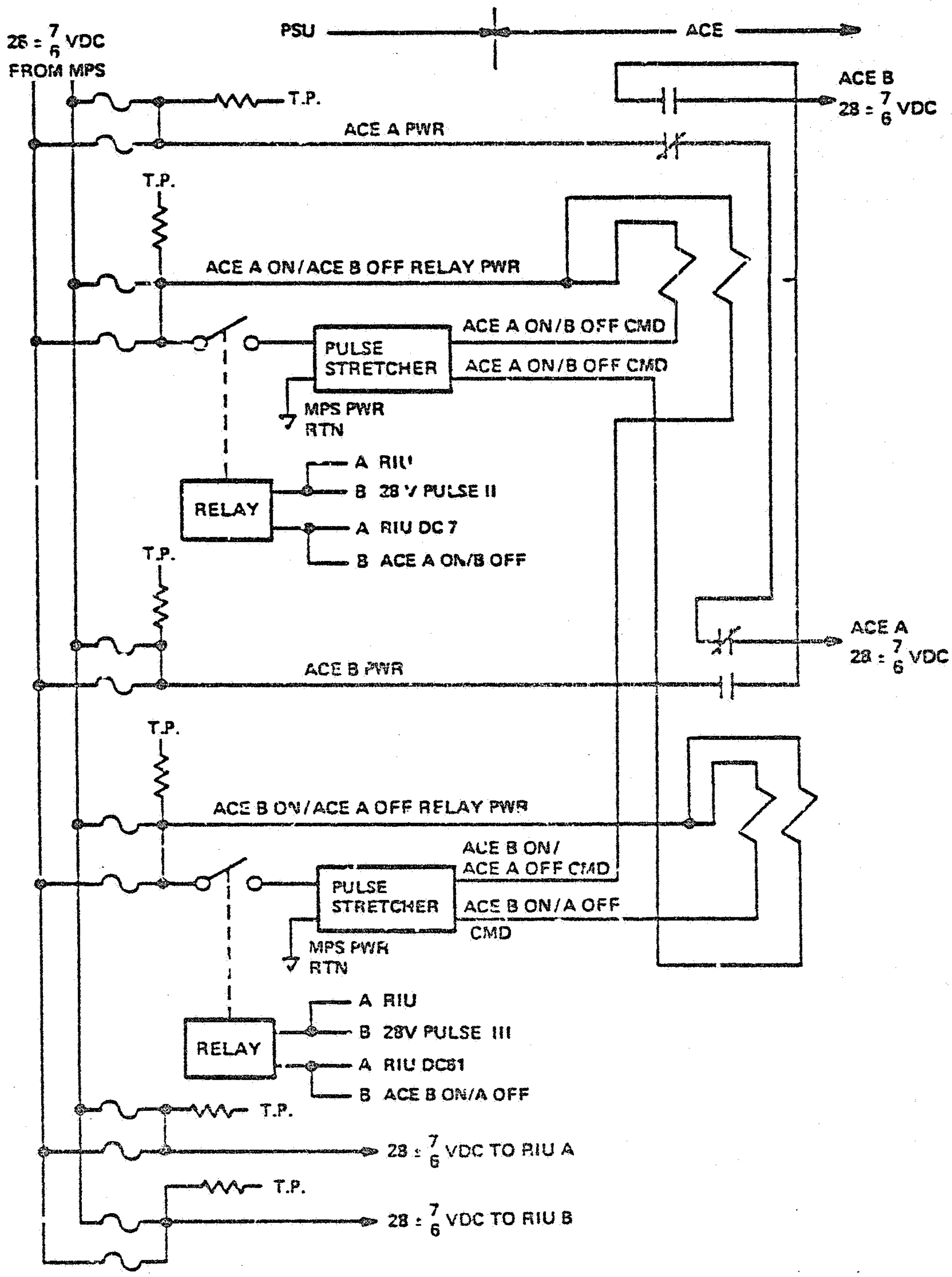

Figure 3.6-3. ACE Power Control Command Interface

3.6.1.6 Safehold Control

ACE A SAFEHOLD ON
ACE A SAFEHOLD OFF
ACE B SAFEHOLD ON
ACE B SAFEHOLD OFF

The function of these four discrete commands is to enable or disable the associated ACE A or B safehold circuits. The functional schematic for these commands is illustrated in Figure 3.6-2. The operation, functional schematic, telemetry verification and complement are identical for both ACE A and ACE B commands.

ACE A SAFEHOLD ON command enables a pulse to one side of a logic flip-flop, setting it to enable ACE A safehold electronics. The complement to the enable command is the ACE A SAFEHOLD OFF command. This command enables a pulse to the opposite side of the logic flip-flop, causing it to reset, disabling ACE A SAFEHOLD electronics. ACE B SAFEHOLD commands operate in a similar fashion.

Telemetry verification of safehold is indicated by ACE A and B SAFEHOLD electronics status monitors which are multi-bit serial telemetry monitors the bilevels AASFHLD and ABSFHLD indicate the state of ACE A and ACE B SAFEHOLD electronics respectively. A bilevel one indicates enabled, zero off.

3.6.1.7 Shuttle Retrieval Commands

ACE A SHUTTLE RETRIEVAL ON
ACE B SHUTTLE RETRIEVAL ON

The function of these two discrete commands is to enable ACE A and ACE B shuttle retrieval. The functional schematic for these commands is illustrated in Figure 3.6-2. The operation, functional schematic, telemetry verification and complement are identical for both ACE A and B commands.

ACE A SHUTTLE RETRIEVAL ON command enables a pulse to one side of a logic flip-flop setting it to enable the shuttle retrieval circuits. ACE B SHUTTLE RETRIEVAL ON commands operates in a similar fashion. The complement to the ON command is the SAFEHOLD OFF command. Safehold must first be enabled before switching to the shuttle retrieval mode.

Telemetry verification of shuttle retrieval is indicated by ACE A and B safehold electronics status monitors which are multi-bit serial telemetry words. AASHLT and ABSHLT are the bilevel telemetry points. A bilevel 1 indicates SHUTTLE RETRIEVAL is enabled, a zero indicates disabled.

3.6.1.8 FSS Power Control

FSS POWER ON
FSS POWER OFF

The function of these two discrete commands is to control power to the FSS. The functional schematic for these commands is illustrated in Figure 3.6-4.

FSS POWER ON command enables a pulse to one coil of a latching relay in the PSU, causing it to close, switching +28 VDC power to the FSS electronics. The complement to the POWER ON command is the POWER OFF. This command enables a pulse to the opposite coil of the latching relay, resulting in the removal of the +28 VDC power from the FSS.

Telemetry indication of FSS power status is made via the FSS two bit power status indicator AFSSPWR defined as follows:

Power Status	MSB	LSB
FSS OFF	1	1
FSS ON	1	0

3.6.1.9 FHST Power Control

FHST 1 POWER ON
FHST 2 POWER ON
FHST 1 AND 2 POWER OFF

The function of these three discrete commands is to control power to FHST 1 and 2. The functional schematic for these commands is illustrated in Figure 3.6-5. The operation of the POWER ON command is identical for both trackers.

FHST POWER ON command enables a pulse to one coil of a latching relay in the PSU, switching +28 VDC power to the associated FHST electronics. POWER ON to each tracker is controlled independently. The complement to the POWER ON commands is the POWER OFF command which acts on both trackers. The OFF command enables a pulse to the opposite coil of the latching relays to both FHST 1 and 2, causing them to open, removing the +28 VDC power from both trackers.

Telemetry verification of FHST power status is indicated via bilevel telemetry points AST1PWR and AST2PWR for FHST 1 and 2 respectively. A bilevel one indicates FHST POWER ON, zero OFF.

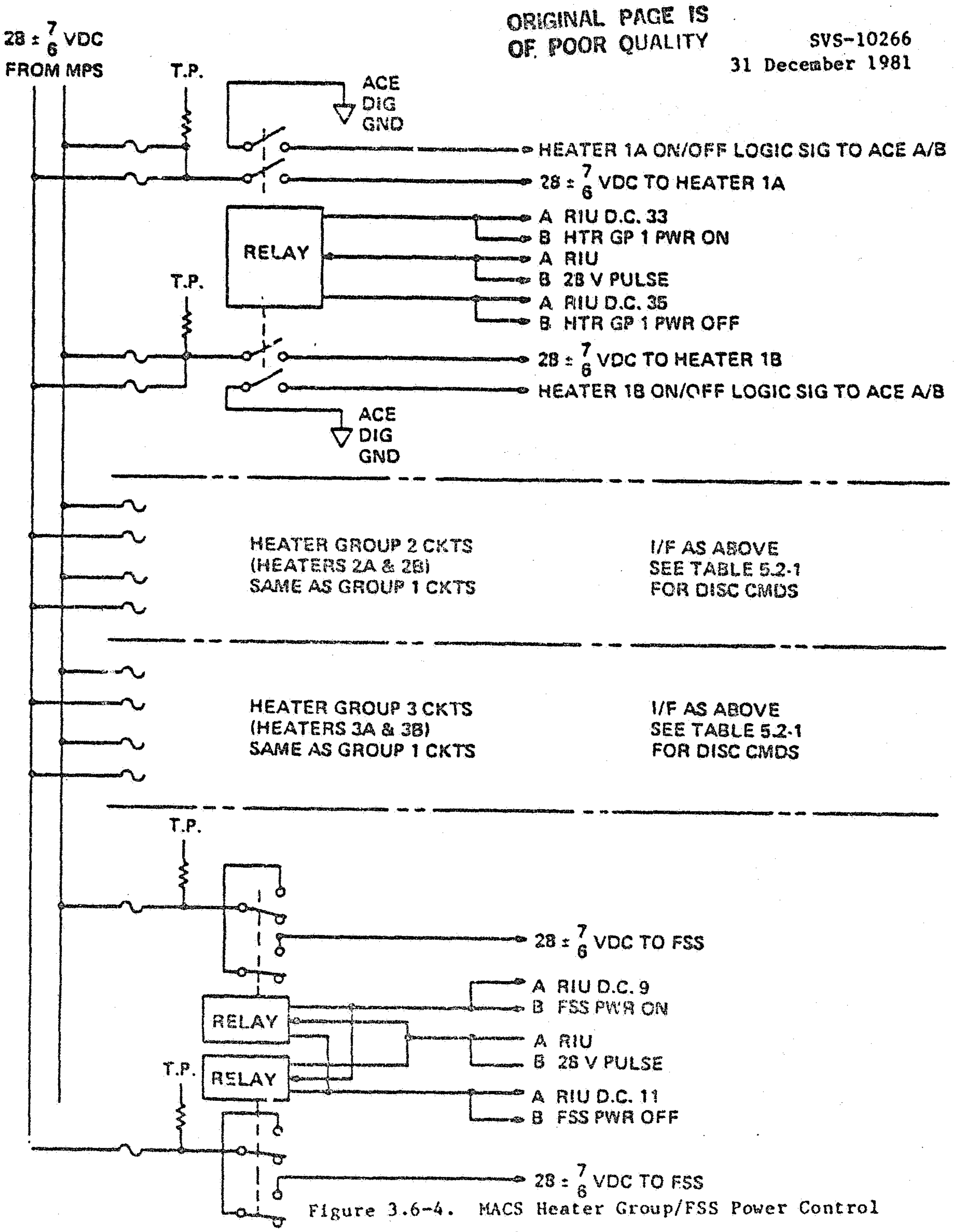

Figure 3.6-4. MACS Heater Group/FSS Power Control

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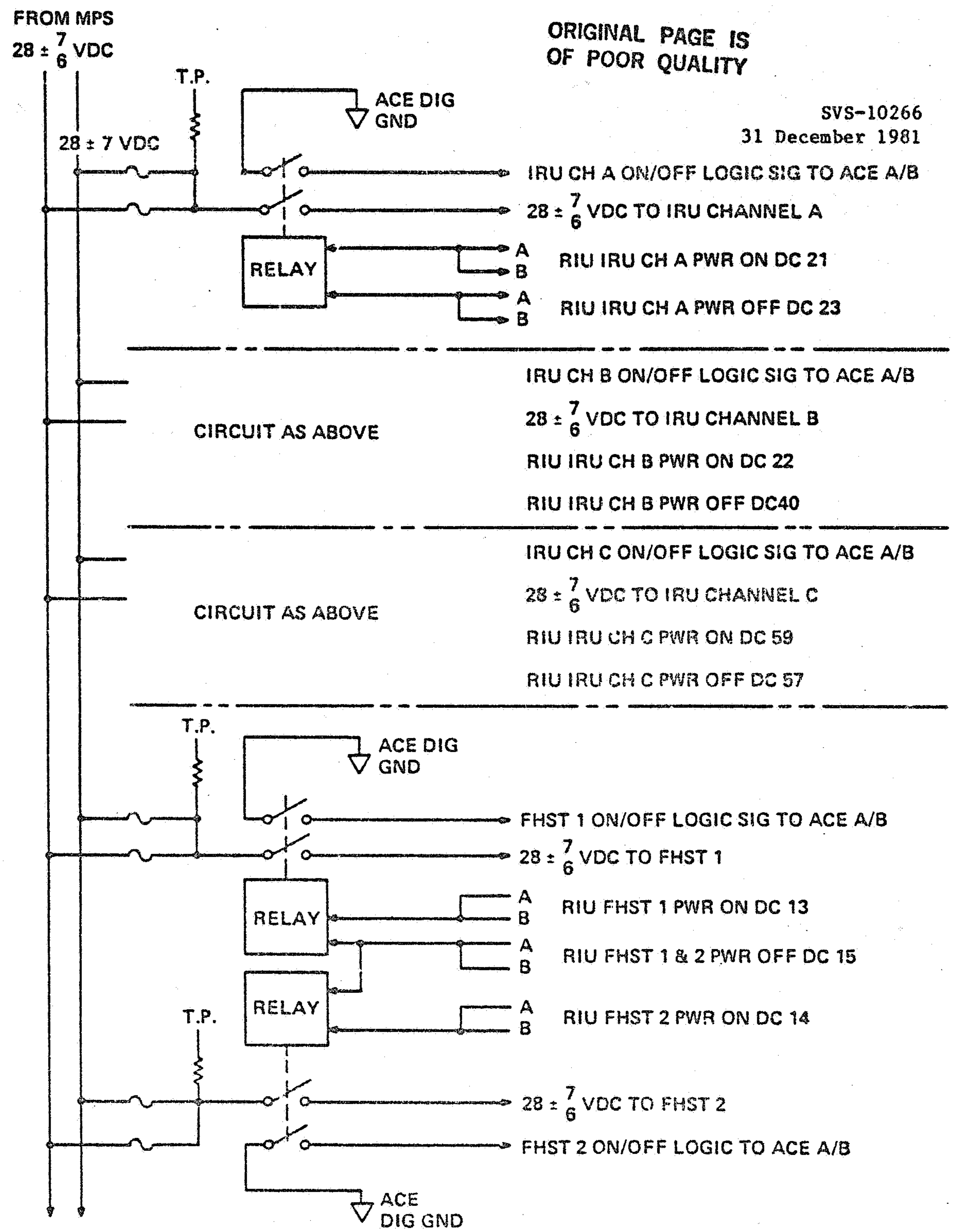

Figure 3.6-5. IRU/FHST Power Control Command Interface

3.6.1.10 TAM Power Control

TAM 1 POWER ON
TAM 2 POWER ON
TAM 1 AND 2 POWER OFF

The function of these three discrete commands is to control power to TAM 1 and 2. The functional schematic for these commands is illustrated in Figure 3.6-1. The operation of the POWER ON command is identical for each TAM.

TAM POWER ON command enables a pulse to one coil of a latching relay in the PSU, switching +28 VDC power to the associated TAM electronics. POWER ON to each TAM is controlled independently. The complement to the POWER ON commands is the POWER OFF command which acts on both magnetometers. The OFF command enables a pulse to the opposite coil of the latching relays to both magnetometers, causing them to open, removing the +28 VDC power.

Telemetry verification of TAM power status is indicated via bilevel telemetry points ATAM1PWR and ATAM2PWR for TAM 1 and 2 respectively. A bilevel one indicates TAM POWER ON, zero OFF.

3.6.1.11 IRU Power Control

IRU CH A POWER ON
IRU CH B POWER ON
IRU CH C POWER ON
IRU CH A POWER OFF
IRU CH B POWER OFF
IRU CH C POWER OFF

The function of these six discrete commands is to control power to each IRU channel. The functional schematic for these commands is illustrated in Figure 3.6-5. The operation, functional schematic, telemetry verification and complement are identical for each channel.

IRU CHANNEL POWER ON command enables a pulse to one coil of a latching relay in the PSU, switching +28 VDC power to the associated IRU channel. The complement to the POWER ON command is the POWER OFF command. This command enables a pulse to the opposite coil of the latching relay, causing it to open, removing the +28 VDC power.

Telemetry verification of IRU power status is indicated via bilevel telemetry points AIRUAPWR, AIRUBPWR and AIRUCPWR for IRU channels A, B and C respectively. A bilevel one indicates IRU POWER ON, zero OFF.

3.6.1.12 IRU Range Selection

IRU CH A HIGH RATE
IRU CH B HIGH RATE
IRU CH C HIGH RATE
IRU CH A LOW RATE
IRU CH B LOW RATE
IRU CH C LOW RATE

The function of these six discrete commands is to control the selection of IRU rate range. The functional schematic for these commands is illustrated in Figure 3.6-6. The operation, functional schematic, telemetry verification and schematic are identical for each channel.

IRU CHANNEL HIGH RATE command enables a pulse to one coil of a latching relay in the IRU, switching the high rate scaling resistor network into the gyro torquer coil current monitor circuit. The complement to the HIGH RATE command is the LOW RATE command. The LOW RATE command enables a pulse to the opposite coil of the latching relay, switching the low rate scaling resistor network into the gyro torquer coil current monitor circuit.

Telemetry verification of IRU rate range status is indicated via bilevel telemetry points AIRUARNG, AIRUBRNG and AIRUCRNG for IRU channels A, B and C respectively. A bilevel one indicates LOW RANGE operation, zero HIGH RANGE.

3.6.1.13 Magnetic Torquer Power Control

X MAG TORQUER A ON
X MAG TORQUER B ON
Y MAG TORQUER A ON
Y MAG TORQUER B ON
Z MAG TORQUER A ON
Z MAG TORQUER B ON

X,Y,Z MAG TORQUER A OFF
X,Y,Z MAG TORQUER B OFF

The function of these eight discrete commands is to enable magnetic torquer drives. The functional schematic for these commands is illustrated in Figure 3.6-1. The operation of the POWER ON command is identical for each torquer circuit.

The MAGNETIC TORQUER ON command enables a pulse to one coil of a latching relay in the ACE, switching the drives to the torquers. Each torquer is enabled independently. The complement to the ON commands is the OFF commands which acts on all three of the A or B side torquers simultaneously. The OFF command enables a pulse to the opposite coil of the latching relay removing the drives from the torquers.

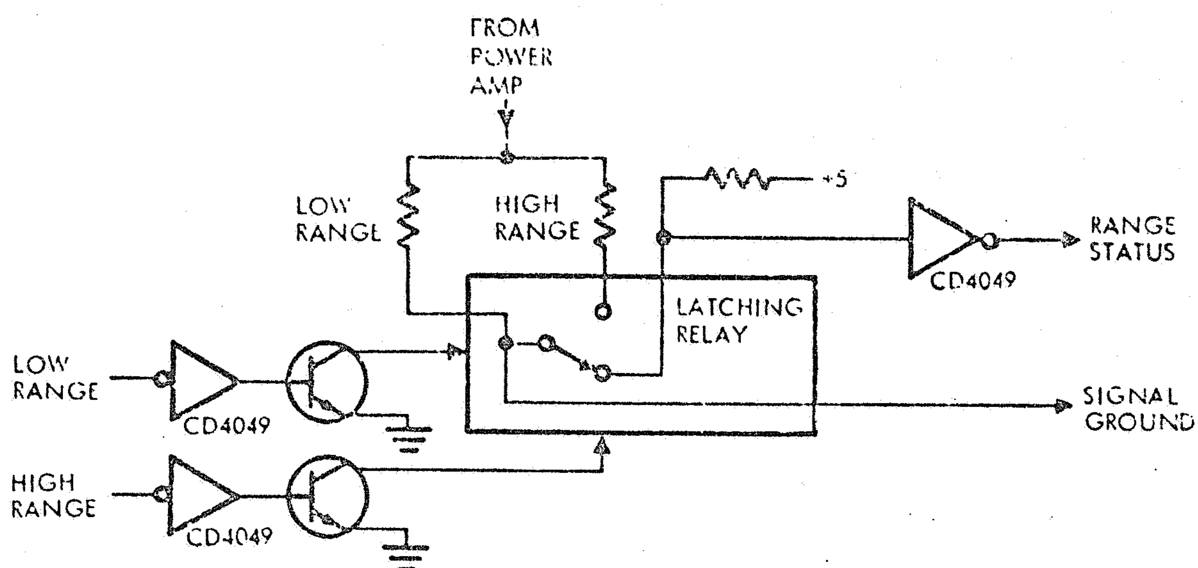

Figure 3.6-6. IRU Rate Range Selection Discrete Command Interface

Telemetry verification of torquer status is indicated via the bilevel telemetry points listed in Table 3.6-1. A bilevel one indicates torquer ON, zero OFF.

3.6.1.14 SRW Power Control

ROLL WHEEL POWER ON
PITCH WHEEL POWER ON
YAW WHEEL POWER ON
SKEW WHEEL POWER ON

ROLL WHEEL POWER OFF
PITCH WHEEL POWER OFF
YAW WHEEL POWER OFF
SKEW WHEEL POWER OFF

The function of thee eight discrete commands is to control SRW power. The functional schematic for these commands is illustrated in Figure 3.6-7. The operation, functional schematic, complement and telemetry verification are identical for each wheel.

WHEEL POWER ON command enables a pulse to one coil of a latching relay in the PSU, switching power to the associated wheel electronics. The complement is the POWER OFF command which enables a pulse to the opposite coil of the latching relay, removing power.

Telemetry verification of torquer status is indicated via bilevel telemetry points AXWHED, AYWHED, AZWHED and ASWHED for the roll, pitch, yaw and skew wheels respectively. A bilevel one indicates enabled, zero disabled.

3.6.1.15 MACS Heater Control

MACS HEATER GROUP 1 ON
MACS HEATER GROUP 2 ON
MACS HEATER GROUP 3 ON

MACS HEATER GROUP 1 OFF
MACS HEATER GROUP 2 OFF
MACS HEATER GROUP 3 OFF

The function of these six discrete commands is to control MACS heater power. The functional schematic for these commands is illustrated in Figure 3.6-4. The operation, functional schematic, complement and telemetry verification are identical for each heater group.

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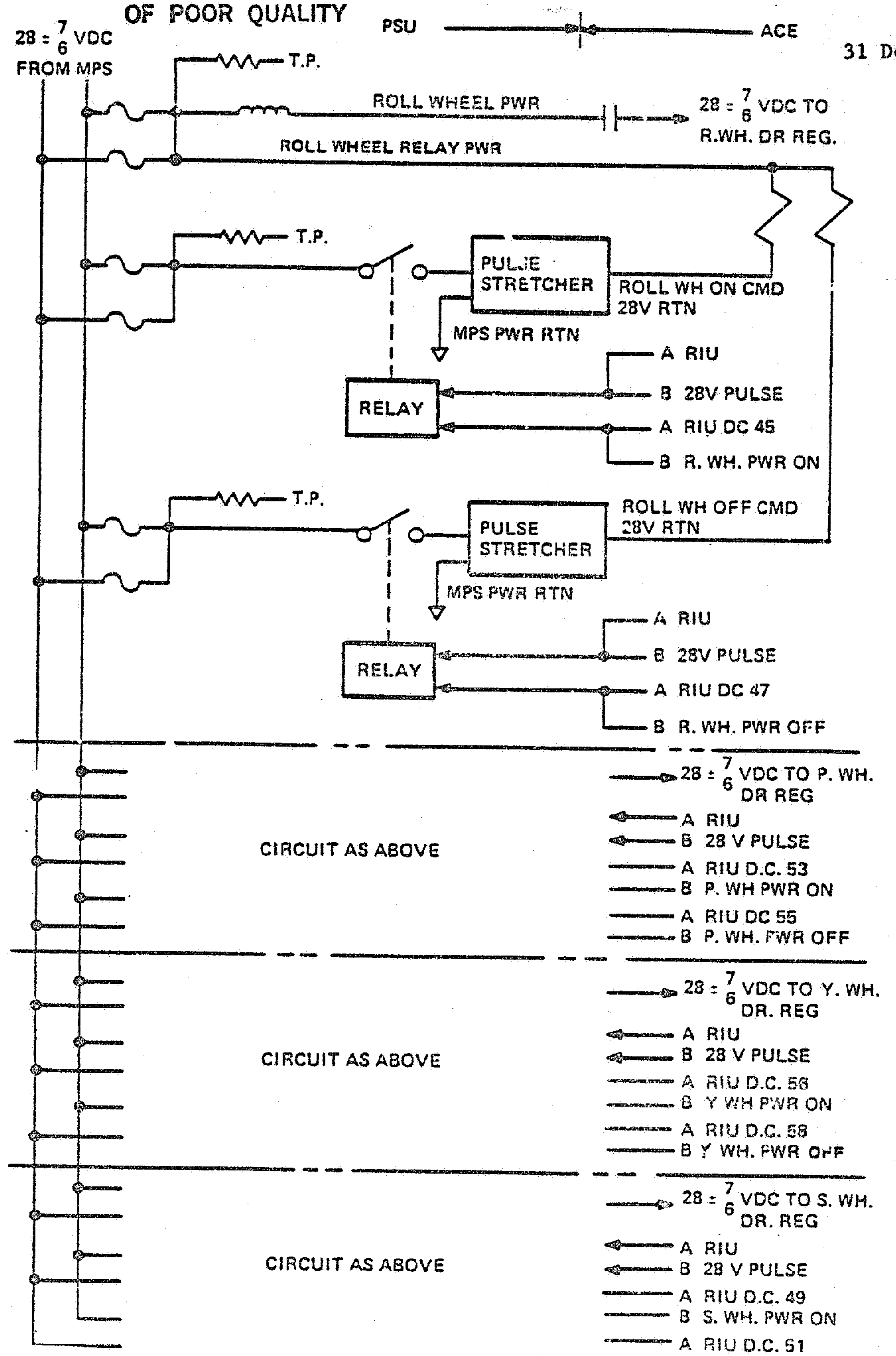

Figure 3.6-7. SRW Power Control Command Interface

MACS HEATER GROUP ON COMMAND enables a pulse to one coil of a latching relay in the PSU, switching +28 VDC power to the associated heater group. The complement to the POWER ON command is the OFF command. This command enables a pulse to the opposite coil of the latching relay, removing the +28 VDC power from the heater circuit.

Telemetry verification of heater group power status is indicated via the bilevel telemetry points listed in Table 3.6-1. A bilevel one indicates heater power off, zero on.

3.6.1.16 FHST Heater Control

FHST 1 HEATER ON
FHST 2 HEATER ON
FHST 1 and 2 HEATER OFF

The function of these three discrete commands is to control FHST 1 and 2 heater power. The functional schematic for these commands is illustrated in Figure 3.6-8. Operation of the HEATER POWER ON command is identical for FHST 1 and 2.

The HEATER ON command enables a pulse to one coil of a latching relay in the PSU, switching +28 VDC power to the associated FHST heater circuit. Power to each FHST heater is controlled independently. The complement to the POWER ON command is the OFF command which acts on both FHST heater circuits simultaneously. The OFF command enables a pulse to the opposite coils of the latching relays to both heater circuits, causing them to open, removing the +28 VDC power.

Telemetry verification of FHST heater power status is indicated via bilevel telemetry points ATR1HTA, ATR1HTB, ATR2HTA and ATR2HTB for FHST 1 A/B and FHST 2 A/B heaters respectively. A bilevel one indicates HEATER POWER OFF, zero ON.

3.6.1.17 FHST Control

FHST 1 CONTROL
FHST 2 CONTROL

The function of these two serial magnitude commands is to control the operation of FHST 1 and 2. The functional schematic for these commands is illustrated in Figure 3.6-9. The operation, functional schematic, and telemetry verification is identical for each tracker.

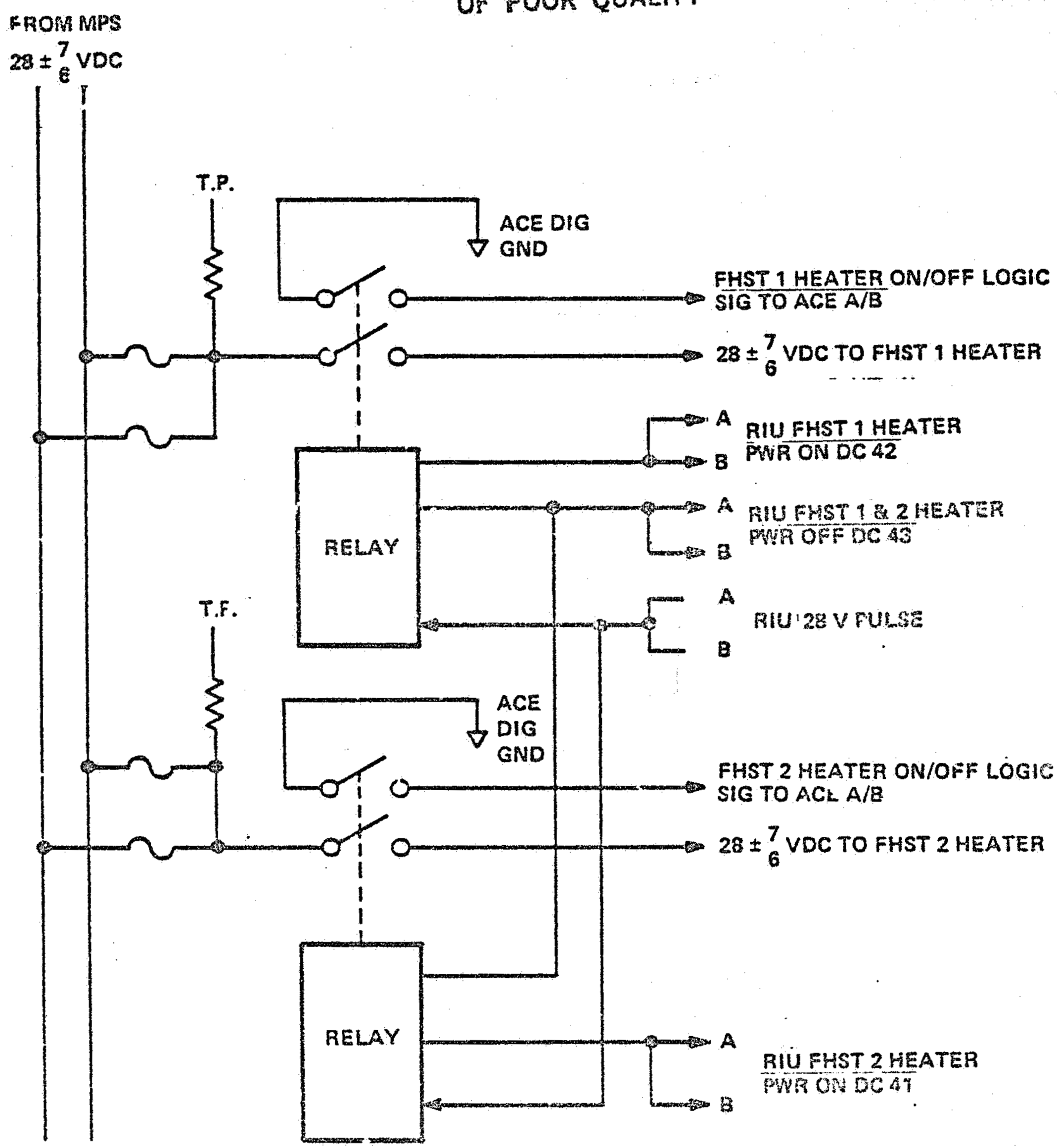

Figure 3.6-8. FHST Heater Power Control Command Interface

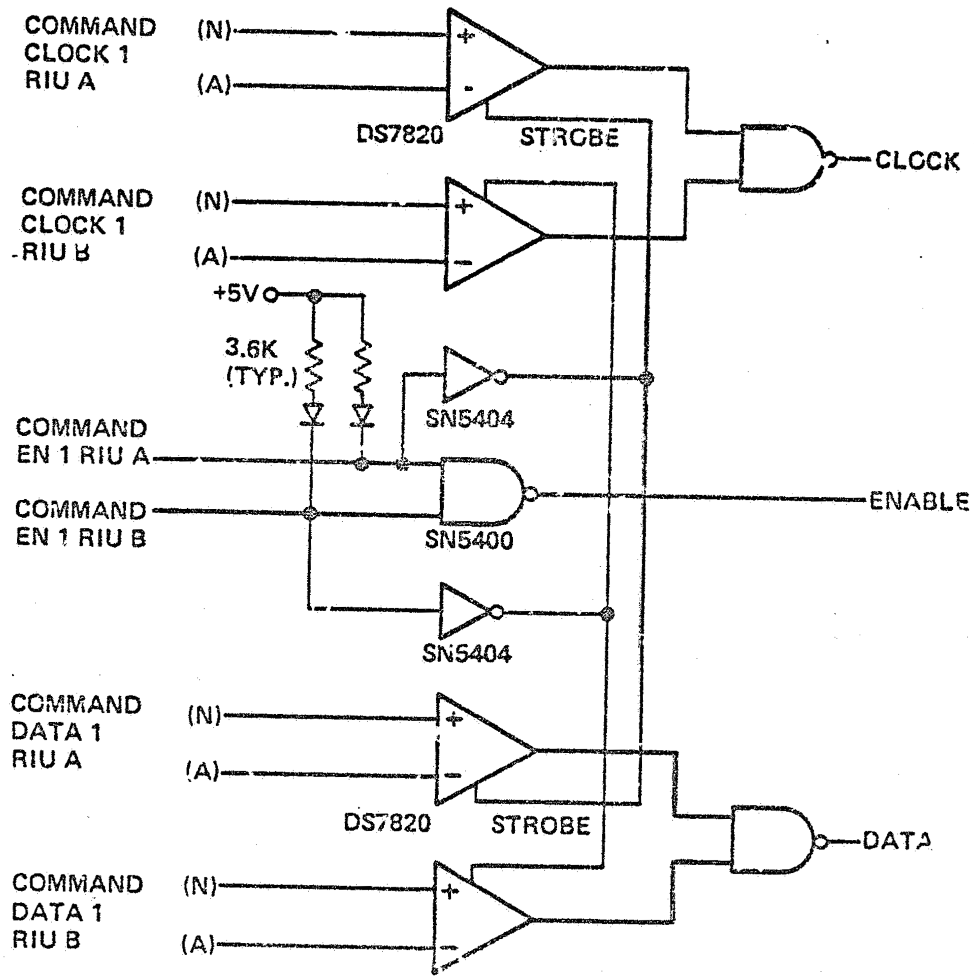

Figure 3.6-9. FHST Serial Magnitude Command Interface

FHST control command definition is presented in Table 3.6-4, and includes the following functions:

- The required star brightness threshold for star acquisition is commanded by bits 2 through 4
- The Offset Mode for star acquisition is commanded by bits 8 through 16
- The tracker shutter can be commanded open by bits 1 and 5 even though it had been closed by the BOS or a Target Suppress signal
- The Break Track Command (bit 6) will return the FHST from the "track" mode to the "search" mode. It will also unlatch the shutter and retrun it to normal operation if it had been latched by a TS signal

3.6.1.18 ACE Command Word 1

ACE A COMMAND WORD 1
ACE B COMMAND WORD 1

The function of these two serial magnitude commands is to provide commanded wheel and torquer drive capabilities. The functional schematic for these commands is illustrated in Figure 3.6-10. The operation of COMMAND WORD 1 is identical for both ACE A and B.

COMMAND WORD 1 definition is presented in Table 3.6-5. Included in this command is the capability to command drives to each of the reaction wheel and magnetic torquers. In addition, magnetic torquer and TAM biases can also be commanded.

The four wheel drive commands are processed by the SM command receiver, are decoded in accordance with their address and distributed to the proper storage register and D/A Converter as shown in Figure 3.6-11. Each 9 bit plus sign SM wheel drive command is converted to an analog voltage and processed by the ACE Wheel Drive Electronics, with a positive voltage from the D/A Converter commanding a positive wheel torque and negative spacecraft torque.

Table 3.6-4. FHST Serial Magnitude Command Definition

COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25)
FHST 1 CONTROL		
	COMMAND ENABLE BITS 00 = CONTROL OF BITS 5-15 01 = CONTROL OF BITS 2,3 & 5 10 = CONTROL OF BITS 4,5 11 = CONTROL OF BITS 2-5	00, 01
	THRESHOLD SET 00 = 6TH MAG 01 = 4TH MAG 10 = 5TH MAG 11 = 3RD MAG	02, 03
	SHUTTER OPEN (BOA PROTECT) CMD 0 = NO CHANGE 1 = OPEN SHUTTER	04
	BREAK TRACK COMMAND 0 = NO CHANGE 1 = BREAK TRACK	05
	UNUSED BIT (SET TO ZERO)	06
	OFFSET MODE COMMAND 0 = NO CHANGE 1 = UTILIZE OFFSET (BITS 8-11 & 12-15)	07

Table 3.6-4. FHST Serial Magnitude Command Definition

COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
FHST 1 CONTROL (CONT)	HORIZONTAL OFFSET COORDINATE BIT 8 IS THE MSB OF A 4 BIT OFFSET. VERTICAL OFFSET COORDINATE BIT 12 IS THE MSB OF A 4 BIT OFFSET.	
FHST 2 CONTROL (SAME BIT STRUCTURE AS FHST 1 COMMAND)		

DEG	HORIZ	VERT
-3.75	0000	0000
-3.25	1000	1000
-2.75	0100	0100
-2.25	1100	1100
-1.75	0010	0010
-1.25	1010	1010
-0.75	0110	0110
-0.25	1110	1110
+0.25	0001	0001
+0.75	1001	1001
+1.25	0101	0101
+1.75	1101	1101
+2.25	0011	0011
+2.75	1011	1011
+3.25	0111	0111
+3.75	1111	1111

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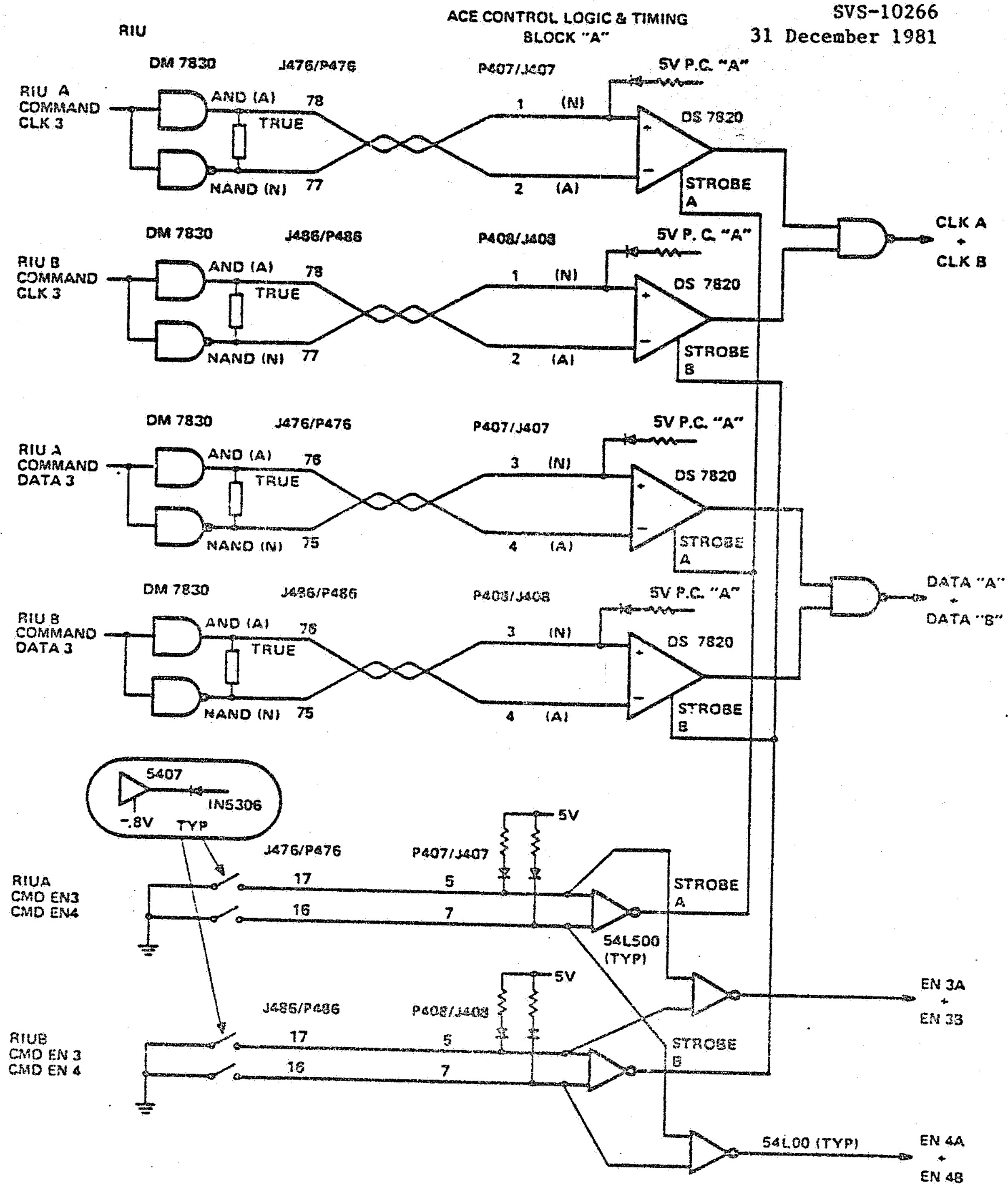

Figure 3.6-10. ACE Serial Magnitude Command Interface

Table 3.6-5. ACE Command Word 1 Definition

COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
ACE A CMD WORD 1																	
	COMMAND ADDRESS BITS 0001 = ROLL SRW DRIVE 0010 = PITCH SRW DRIVE 0011 = YAW SRW DRIVE 0100 = SKEW SRW DRIVE 0101 = MAG ROLL AXIS (X) COMPENSATION 0110 = MAG PITCH AXIS (Y) COMPENSATION 0111 = MAG YAW AXIS (Z) COMPENSATION 1000 = UNUSED 1001 = ROLL (X) M/T DRIVE 1010 = ROLL (X) M/T BIAS 1011 = PITCH (Y) M/T DRIVE 1100 = PITCH (Y) M/T BIAS 1101 = YAW (Z) M/T DRIVE 1110 = YAW (Z) M/T BIAS 1111 = UNUSED 0000 = UNUSED																
	SIGN BIT 0 = POS 1 = NEG																
	9 BITS OF ROLL, PITCH, YAW OR SKEW WHEEL DRIVE. BIT 13 IS LSB, = 0.01953033 VDC * BITS 14 & 15 ARE UNUSED															0	0
	7 BITS MAG AXIS (X,Y,Z) COMP OR 7 BITS ROLL, PITCH OR YAW M/T DRIVE OR BIAS. BIT 11 IS LSB = 0.0781 ; VDC * BITS 12-15 ARE UNUSED													0	0	0	0

* ALL ZERO'S = +0.000 VDC ALL ONE'S = -0.005 VDC
ALL NEG VALUES ARE IN ONE'S COMPLEMENT +(-0.005VDC)

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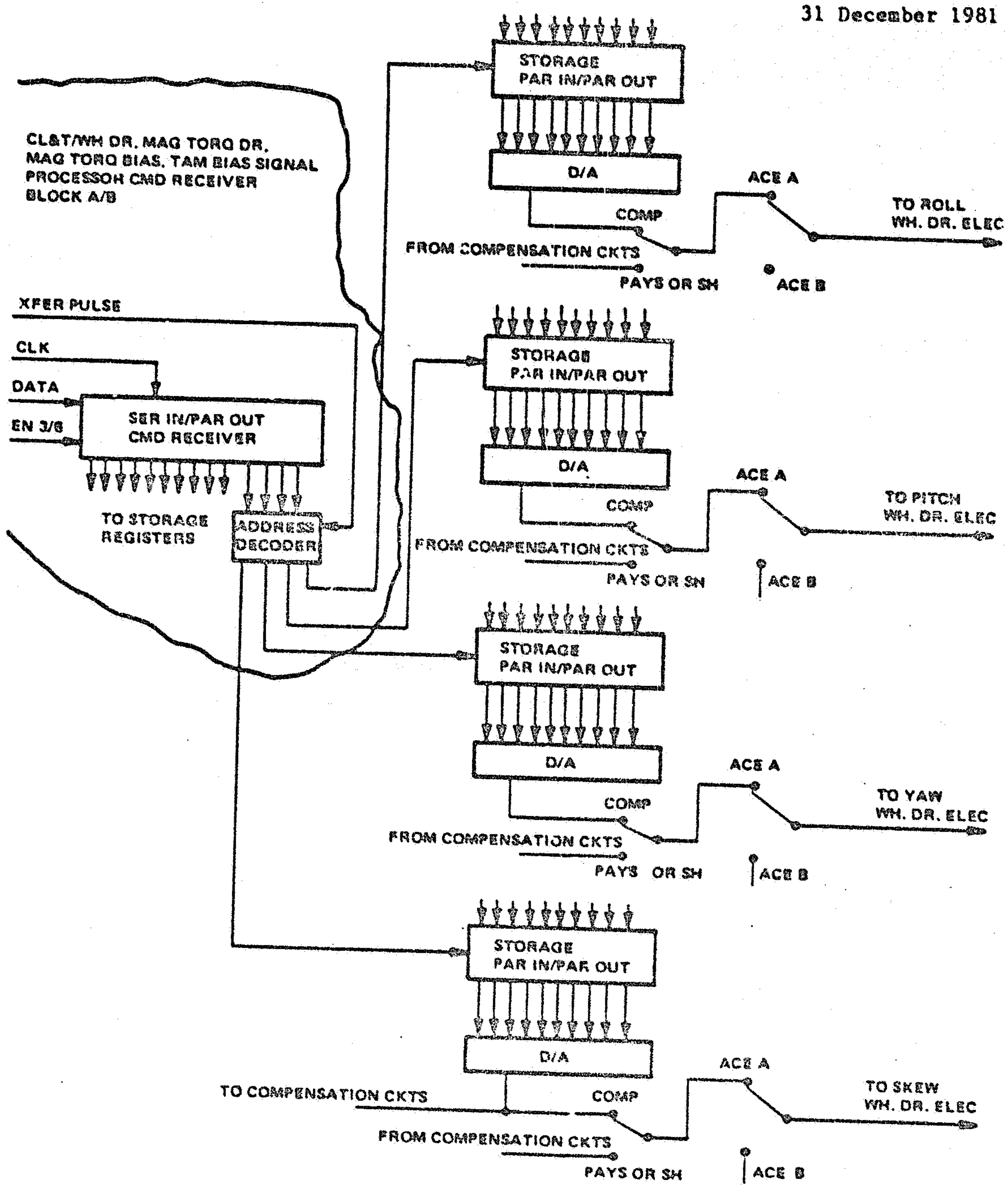

Figure 3.6-11. Wheel Drive Signal Processor

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The three magnetic torquer drive commands are processed in a similar manner as shown in Figure 3.6-12. Each 7 bit plus sign SM magnetic torquer drive command is converted to an analog voltage. During Computer Mode operation each analog voltage is processed by the ACE Magnetic Torquer Drive Electronics, with a positive voltage from the D/A Converter commanding a positive magnetic dipole.

The three magnetic torquer bias commands are processed in a similar manner as shown in Figure 3.6-12. Each 7 bit plus sign Magnetic Torquer Bias input is available to the Magnetic Torquer Drive Electronics in the Safehold Mode. The X and Y Magnetic Torquer Bias SM commands have a scale factor of 0.451 ma/count (510 POLE-CM/count) for the X_A, X_B, Y_A and Y_B magnetic torquers. The Z Magnetic Torquer Bias SM Command has a scale factor of 1.122 ma/count (527 POLE-CM/count) for the Z_A and Z_B magnetic torquers. A positive Magnetic Torquer Bias SM count will provide a negative magnetic dipole to bias out a positive spacecraft magnetic dipole and vice versa. The Magnetic Torquer Bias Commands may be entered into the appropriate storage registers of the powered ACE block during the Computer Mode ~~or~~ Safehold Mode but they are effective only during Safehold. Control of the magnetic torquers may be exercised by ground command during Safehold via Magnetic Torquer Bias SM commands.

The three TAM bias commands are processed in a similar manner as shown in Figure 3.6-1. For Safehold Mode operation, the contribution of unwanted magnetic field is countered by TAM signal compensation and TAM Bias commands. The MACS ACE Safehold Electronics provides feedback compensation, derived from the magnetic torquer current circuits, to each of the three axes signals received by the ACE from each TAM. This compensates each TAM signal to the ACE for that portion of its sensed magnetic field generated by the magnetic torquers. TAM biases to counter spacecraft generated magnetic fields, sensed by the TAMS, are available via SM commands. Each 7 bit plus sign TAM Bias SM commands has a scale factor of 1 count per 3.125 milligauss bias required, with a maximum range of ± 397 milligauss. Once the TAM X, Y and Z components of the sensed magnetic field due to the spacecraft generated fields have been determined, the TAM X, Y and Z Bias SM Commands for Safehold can be identified. For positive magnetic field components at the TAM locations generated by the spacecraft, positive count (sign bit = 0) SM TAM Bias commands are required to bias out their effect and vice versa. X, Y and Z axes TAM 1 or TAM 2 Bias commands may be entered into the appropriate TAM Bias storage registers of the powered ACE block. Since each ACE block has storage registers for a single TAM, the Bias commands entered must correspond to the TAM to be selected for Safehold operation. TAM bias commands may be entered into the appropriate storage registers during operation in either the Computer of Safehold modes but they are effective only during Safehold.

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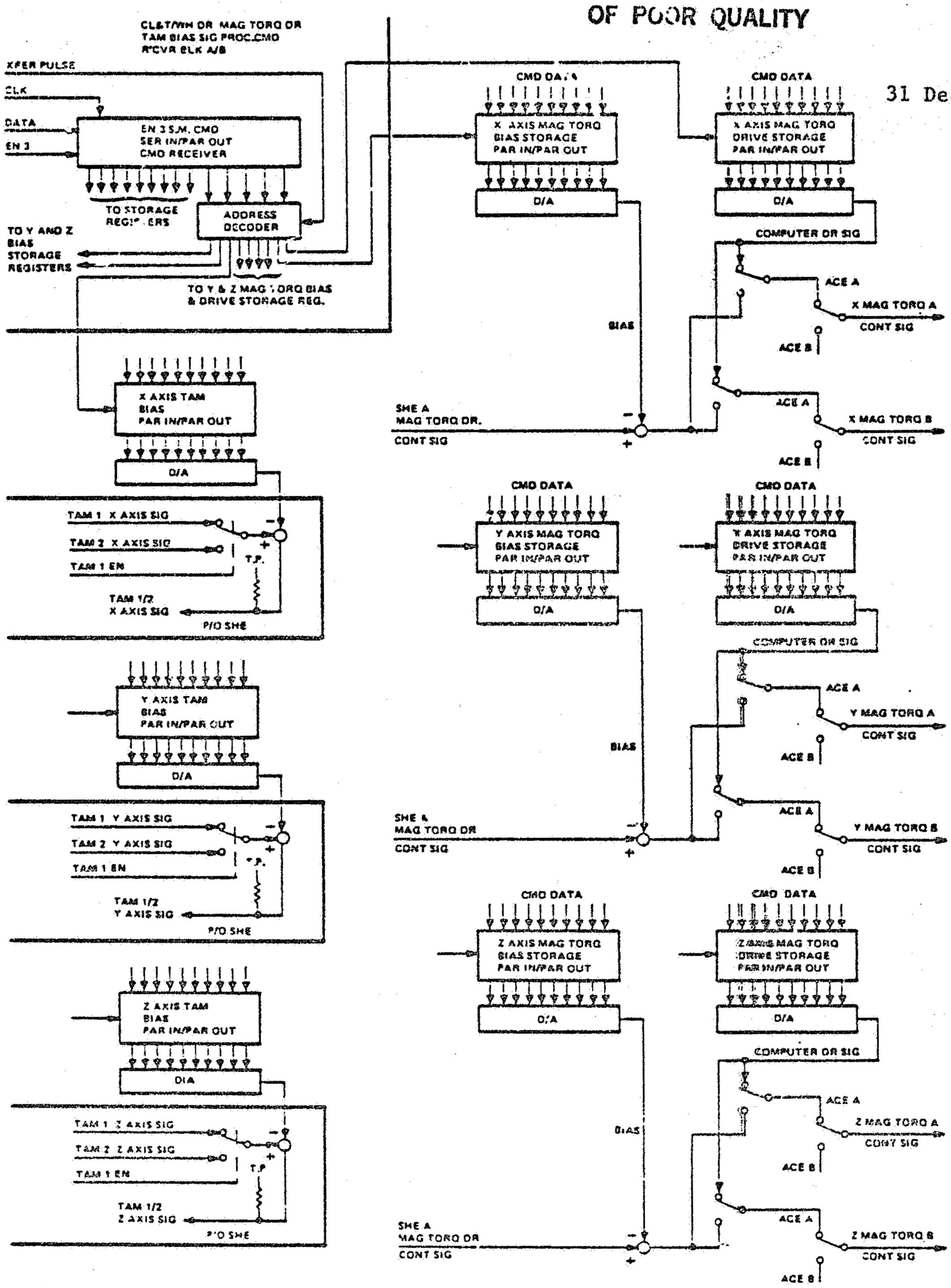

Figure 3.6-12. Magnetic Torquer Drive Signal Processor

3.6.1.19 ACE Command Word 2

ACE A COMMAND WORD 2
ACE B COMMAND WORD 2

The function of these two serial magnitude commands is to provide control for the selection of wheel drive inputs, TAM selection, thruster unload selection, thruster control selection, gyro rate selection, position sensor selection and gyro rate bias selection. The functional schematic for these commands is illustrated in Figure 3.6-10, and is defined in Table 3.6-6. Operation of COMMAND WORD 2 is identical for both ACE A and B.

The Device Mode Select, Safehold Gyro Rate Signal Select and the Safehold Posn Signal Select are processed by the SM command receiver, decoded in accordance with their address, and distributed to the proper storage register and decoder to provide bilevel outputs correspnding to the bit pattern of the SM commands. The bilevel control status logic associated with this bit pattern is given in Table 3.6-6. Five bits of the Device Mode Select word, including an enable bit, provide logic signals to select OBC or Payload Sensor (PAYS) Enable signals to control the reaction wheels in the Computer Mode. These five bits are initialized as zeros, or computer input select, at power turn ON. Two bits of the Device Mode select word, including an enable bit provide logic signals to select AM 1 or TAM 2 inputs to the Safehold Electronics and three bits, including an enable bit, are employed to enable Safehold Thruster Control and/or Thruster Unload logic outputs to the Propulsion Module.

The four bit Safehold Gyro Rate Select SM command provides bilevel logic for switching of the IRU 1 or IRU 2 analog rate signals, on each axis, to the Safehold Electronics. The 12 bit Safehold Position Sensor Select SM command provides bilevel logic for switching CSS1 or CSS2 or ES or IRU Position input signals to the Safehold Electronics. In each case the SM command enable bit must be a logic "1" to execute a change in the function it governs.

CMD AND TITLE	COMMAND FUNCTION	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
ACE CMD WORD 2																	
	DEVICE MODE SELECT	0	0	0	1												
	ROLL WHEEL DRIVE INPUT 0 = COMPUTER 1 = PAYS																
	PITCH WHEEL DRIVE INPUT 0 = COMPUTER 1 = PAYS																
	YAW WHEEL DRIVE INPUT 0 = COMPUTER 1 = PAYS																
	SKEW WHEEL DRIVE INPUT 0 = COMPUTER 1 = PAYS																
	CONTROL OF BITS 4-7																
	UNUSED BIT																
	TAM INPUT SELECT 0 = TAM 2 1 = TAM 1																
	CONTROL OF BIT 10																

Header of bit columns: MAGNITUDE DATA (C10 THROUGH C25)

Table 3.6-6. ACE Command Word 2 Definition

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COMMAND TITLE	COMMAND FUNCTION	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
ACE CMD WORD 2 (CONT)																	
	UNUSED BIT													[ ]			
	THRUSTER UNLOAD SELECT 0 = NO UNLOAD 1 = UNLOAD														[ ]		
	THRUSTER CONTROL SELECT 0 = NO CONTROL 1 = CONTROL															[ ]	
	CONTROL OF BITS 13 & 14																[ ]
	SAFE HOLD GYRO RATE SELECT	0	0	1	0												
	UNUSED BITS					[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]				
	ROLL GYRO RATE SELECT 0 = GYRO 2 1 = GYRO 1													[ ]			
	PITCH GYRO RATE SELECT 0 = GYRO 2 1 = GYRO 1														[ ]		
	YAW GYRO RATE SELECT 0 = GYRO 2 1 = GYRO 1															[ ]	

The bit columns are headed MAGNITUDE DATA (C10 THROUGH C25).

Table 3.6-6. ACE Command Word 2 Definition

COMMAND TITLE	COMMAND FUNCTION	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
ACE CMD WORD 2 (CONT)																	
	CONTROL OF BITS 12-14																
	SAFE HOLD POSITION	0	0	1	1												
	IRU ROLL POSN INPUT SELECT 000 = NO SENSORS 001 = CSS 1 010 = CSS 2 011 = FSS 100 = GYRO 1 101 = GYRO 2																
	CONTROL OF BITS 4-6																
	IRU PITCH POSN INPUT SELECT 000 = NO SENSORS 001 = CSS 1 010 = CSS 2 011 = FSS 100 = GYRO 1 101 = GYRO 2																
	CONTROL OF BITS 8-10																
	IRU YAW POSN INPUT SELECT 000 = NO SENSORS 001 = CSS 1 010 = CSS 2 011 = FSS 100 = GYRO 1 101 = GYRO 2																
	CONTROL OF BITS 12-14																

The bit-number columns sit under the heading MAGNITUDE DATA (C10 THROUGH C25).

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Table 3.6-6. ACE Command Word 2 Definition

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COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
ACE CMD WORD 2 (CONT)	GY O RATE BIAS ADDRESS BITS 1 00 = IRU ROLL 1 1 01 = IRU PITCH 1 1 10 = IRU YAW 1 1 11 = IRU ROLL 2 1 00 = IRU PITCH 2 1 01 = IRU YAW 2	00–03
	SI N BIT 0 = POSITIVE 1 = NEGATIVE	04
	MAGNITUDE BITS HI RATE: LSB = 0.8 ARC SEC LO RATE: LSB = 0.05 ARC SEC ALL ZERO'S = +0.000 ALL ONE'S = - 0.005 ALL NEGATIVE VALUES ARE IN ONE'S COMPLEMENT + (0.005VDC)	05–11 (LSB)
	UNUSED BITS	12–15

Table 3.6-6. ACE Command Word 2 Definition

Provision has been made in the MACS Computer Mode operation to provide the appropriate gyro bias corrections via the MACS update filter as part of the OBC computations. For the Safehold Mode operation, without the OBC, the appropriate biases to counter gyro drift are entered into the ACE ITP memory via the IRU Gyro Bias SM commands. The magnitude and sign of these gyro drifts will be available upon completion of IRU In-Orbit calibration or, in lieu of that, from the IRU gyro acceleration insensitive drift performance data. The IRU Gyro Bias SM commands are designed to improve the Safehold Inertial Hold Mode performance for Shuttle Retrieval. The commands may be entered into the MACS by ground command in preparation for Shuttle Retrieval. It should be noted that the IRU Gyro Bias SM commands can be entered into the ACE ITP memory any time after the ACE block is powered, but the bias count is inhibited from being combined with the IRU POSN word unless the ACE is operating in the Safehold Mode. Further the IRU Rate Bias is only applicable to IRU High Rate Range operation.

The range of each 7 bit plus sign IRU Gyro Rate bias word, that can be stored in the ITP memory, is equivalent to $\pm$101.6 arc seconds (+127 count) when the IRU is operating in the HIGH RATE RANGE. Considering that each IRU Gyro Rate bias word is summed with the corresponding 24 bit IRU POSN word in the ITP memory every 8 seconds during SAFEHOLD, this yields a rate bias range of $\pm$12.7 arc seconds per second. This provides a scale factor of 16 count per arc second per second, an ample range over the maximum IRU gyro acceleration insensitive drift performance of 7.2 arc seconds per second. An IRU gyro axis that exhibits a drift in a positive direction contributes negative counts to the corresponding IRU POSN word. An IRU Gyro Rate Bias SM command having the appropriate positive count (sign bit = 0) is required to bias out the effect of the positive gyro drift. Similarly an IRU Gyro Bias SM command having the appropriate negative count (sign bit = 1) is required to bias out the effect of negative gyro drift. The IRU gyro bias SM commands are presented in the one's complement format.

3.6.1.20 ESA Power Control

ESA 1 POWER ON
ESA 1 POWER OFF

ESA 2 POWER ON
ESA 2 POWER OFF

The function of these four discrete commands is to control the +28 VDC power to ESA 1 and 2. The functional schematic for these commands is illustrated in Figure 3.6-13. The operation, functional schematic, complement and telemetry verification of these commands is identical for both ESA 1 and 2.

ESA 1/2 POWER ON command enables a pulse to one side of a latching relay, closing it, enabling +28 VDC power to the ESA 1/2 power supply. The complement of the POWER ON command is the ESA 1/2 POWER OFF command. ESA 1/2 POWER OFF command enables a pulse to the opposite coil of the latching relay, causing the relay to open, removing the +28 VDC from the power supply.

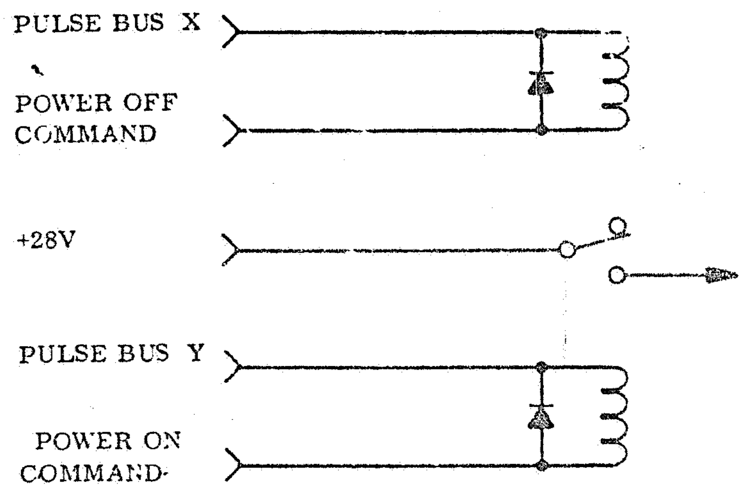

Figure 3.6-13. ESA Heater and Logic Enable/Disable Commands

Telemetry indication of POWER ON/OFF state is made via the corresponding ESA 1/2 sensor status signal. Sensor status signal is a multi-level analog telemetry point. In the normal on orbit mode with power on, heater disabled, scanner rotating and no sun presence, sensor status telemetry will indicate 3.66 ±0.04 volts. With power off, sensor status telemetry will indicate 0.00 ±0.04 volts.

3.6.1.21 ESA Logic/Heater Control

ESA 1 LOGIC ENABLE
ESA 1 HEATER ENABLE
ESA 1 LOGIC/HEATER DISABLE

ESA 2 LOGIC ENABLE
ESA 2 HEATER ENABLE
ESA 2 LOGIC/HEATER DISABLE

The function of these six discrete commands is to control ESA 1/2 logic and +28 V_{HTR} heater power. Logic and heater power are enabled independently, but disabled jointly by a single command. The functional schematic for these commands is illustrated in Figure 3.6-14. The operation, functional schematic, complement and telemetry verification of these commands is identical for both ESA 1 and 2.

ESA 1/2 LOGIC ENABLE command enables a pulse to one side of a latching relay, closing it, enabling +5 V to the logic signal. ESA 1/2 HEATER ENABLE command enables a pulse to one side of a latching relay, closing it, enabling +28 V_{HTR} to the heater control circuit. The complement to these commands is the ESA 1/2 LOGIC/HEATER DISABLE command. This command enables a pulse to the opposite coil of both the logic and heater power relays, causing them to open, simultaneously removing the +5 V from the logic signal and the +28 V_{HTR} from the heater circuit.

Telemetry indication of LOGIC ENABLE/DISABLE state is made via the corresponding ESA 1/2 signal status monitor. Signal status monitor is a multi-level analog telemetry point. In the normal on orbit mode with LOGIC ENABLED, signal status telemetry will indicate 5.00 ±0.04 volts. With LOGIC DIABLED, signal status telemetry will indicate 4.66 ±0.04 volts.

Telemetry indication of HEATER POWER ENABLE/DISABLE state is made via the corresponding ESA 1/2 sensor status signal. Sensor status signal is a multi-level analog telemetry point. In the normal on orbit mode with power on, heater disabled, scanner rotating and no sun presence sensor status telemetry will indicate 3.66 ±0.04 volts. With HEATER POWER ENABLED, sensor status telemetry will indicate 3.33 ±0.04 volts.

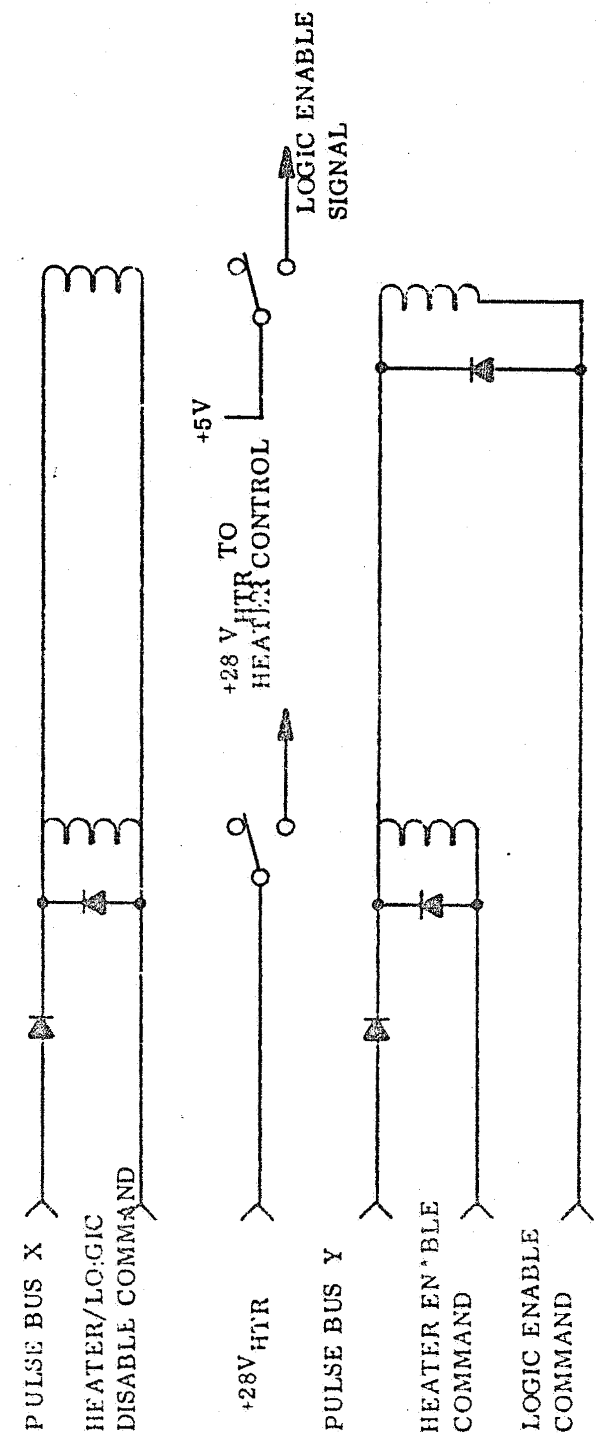

Figure 3.6-14. ESA Logic/Heater Control

3.6.2 COMMAND SEQUENCES

This section lists the command sequences associated with the operation of the MACS and ESAM. The command sequences are included in the following tables:

Table 3.6-7 A-Side Initialization Sequence
Table 3.6-8 A-Side Register Initialization
Table 3.6-9 A-Side Component Turn-On and Selection
Table 3.6-10 B-Side Initialization Sequence
Table 3.6-11 B-Side Register Initialization
Table 3.6-12 B-Side Component Turn-On and Selection

3.6.3 COMMAND RESTRAINTS

This section lists the command restraints associated with the operation of the MACS and ESAM. The following restraints apply:

- It is a recommended operating procedure that a 60 second delay be inserted between IRU Channel A, B and C power turn on.

- After switching power on to an ACE, all ACE serial magnitude command registers must be initialized by issuing the following commands:

  Zero Wheel Drives
  Zero Magnetic Torquer Drives
  Zero Magnetic Torque Bias
  Zero TAM Bias
  Zero IRU Bias

3.6.4 FUNCTIONAL SCHEMATICS

This section provides functional schematics of the command circuits referenced in the proceeding paragraphs. The schematics have been simplified and are provided as an aid to understanding the command interfaces.

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Table 3.6-7. A-Side Initialization Sequence

Command Type	Description	Octal/Discrete ID	Comments
D	RIU A ON STANDBY	00	RIU2A
D	RIU A ON/B OFF	63	RIU2A
D	ACE A PWR ON/B OFF	07	RIU2A
D	CSM A INHIBIT	05	RIU2A
D	CSM B INHIBIT	06	RIU2A
D	ACE A SAFEHOLD OFF	20	RIU2A
D	ACE B SAFEHOLD OFF	36	RIU2A
D	IRU CH A PWR OFF	23	RIU2A
D	IRU CH B PWR OFF	40	RIU2A
D	IRU CH C PWR OFF	57	RIU2A
D	FHST 1 AND 2 PWR OFF	15	RIU2A
D	TAM 1 AND 2 PWR OFF	19	RIU2A
D	ROLL SRW PWR OFF	47	RIU2A
D	PITCH SRW PWR OFF	55	RIU2A
D	YAW SRW PWR OFF	58	RIU2A
D	SKEW SRW PWR OFF	51	RIU2A
D	FSS PWR OFF	11	RIU2A
D	FHST 1 AND 2 HTRS OFF	43	RIU2A
D	MACS HTR GROUP 1 OFF	35	RIU2A
D	MACS HTR GROUP 2 OFF	39	RIU2A
D	MACS HTR GROUP 3 OFF	50	RIU2A
D	ACE A MAG TORQUER OFF	31	RIU2A
D	ACE B MAG TORQUER OFF	32	RIU2A
D	RIUA ON STANDBY	00	RIU4A
D	RIU A ON/B OFF	63	RIU4A
D	ESA 1 HTR/LOGIC DISABLE	25	RIU4A
D	ESA 2 HTR/LOGIC DISABLE	54	RIU4A
D	ESA 1 PWR OFF	13	RIU4A
D	ESA 2 PWR OFF	34	RIU4A

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Table 3.6-8. A-Side Register Initialization

Command Type	Description	Octal B1 ---> C25
S	ACE A ROLL SRW ZERO VOLTS	604610000
S	ACE A PITCH SRW ZERO VOLTS	604620000
S	ACE A YAW SRW ZERO VOLTS	604630000
S	ACE A SKEW SRW ZERO VOLTS	604640000
S	ACE A ROLL TAM BIAS ZERO VOLTS	604650000
S	ACE A PITCH TAM BIAS ZERO VOLTS	604660000
S	ACE A YAW TAM BIAS ZERO VOLTS	604670000
S	ACE A ROLL TORQUE DRIVE ZERO VOLTS	604710000
S	ACE A PITCH TORQUE DRIVE ZERO VOLTS	604730000
S	ACE A YAW TORQUE DRIVE ZERO VOLTS	604750000
S	ACE A ROLL TORQUE BIAS ZERO VOLTS	604720000
S	ACE A PITCH TORQUE BIAS ZERO VOLTS	604740000
S	ACE A YAW TORQUE BIAS ZERO VOLTS	604760000
S	ACE A ROLL 1 IRU BIAS ZERO	605100000
S	ACE A PITCH 1 IRU BIAS ZERO	605110000
S	ACE A YAW 1 IRU BIAS ZERO	605120000
S	ACE A ROLL 2 IRU BIAS ZERO	605130000
S	ACE A PITCH 2 IRU BIAS ZERO	605140000
S	ACE A YAW 2 IRU BIAS ZERO	605150000

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Table 3.6-9. A-Side Component Turn-On and Selection

Command Type	Description	Octal/Discrete ID	Comments
D	ESA 1 PWR ON	18	RIU4A
D	ESA 2 PWR ON	07	RIU4A
D	ESA 1 LOGIC ENABLE	60	RIU4A
D	ESA 2 LOGIC ENABLE	39	RIU4A
D	IRU CH A PWR ON	21	RIU2A
D	IRU CH B PWR ON	22	RIU2A
D	IRU CH C PWR ON	59	RIU2A
D	FHST 1 PWR ON	13	RIU2A
D	FHST 2 PWR ON	14	RIU2A
S	FHST 1 INITIALIZE CMD 1	604340000	RIU2A
S	FHST 1 INITIALIZE CMD 2	604202000	RIU2A
S	FHST 2 INITIALIZE CMD 1	604540000	RIU2A
S	FHST 2 INITIALIZE CMD 2	604402000	RIU2A
D	TAM 1 PWR ON	17	RIU2A
D	TAM 2 PWR ON	18	RIU2A
D	FSS PWR ON	09	RIU2A
S	SAFEHOLD DEVICE MODE SEL	AS REQUIRED	RIU2A
S	SAFEHOLD GYRO RATE SEL	AS REQUIRED	RIU2A
S	SAFEHOLD POSITION SENSOR SEL	AS REQUIRED	RIU2A

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Table 3.6-10. B-Side Initialization Sequence

Command Type	Description	Octal/Discrete ID	Comments
D	RIU B ON STANDBY	00	RIU2B
D	RIU B ON/OFF A	63	RIU2B
D	ACE B PWR ON/OFF A	61	RIU2B
D	CSM A INHIBIT	05	RIU2B
D	CSM B INHIBIT	06	RIU2B
D	ACE A SAFEHOLD OFF	20	RIU2B
D	ACE B SAFEHOLD OFF	36	RIU2B
D	IRU CH A PWR OFF	23	RIU2B
D	IRU CH B PWR OFF	40	RIU2B
D	IRU CH C PWR OFF	57	RIU2B
D	FHST 1 AND 2 PWR OFF	15	RIU2B
D	TAM 1 AND 2 PWR OFF	19	RIU2B
D	ROLL SRW PWR OFF	47	RIU2B
D	PITCH SRW PWR OFF	55	RIU2B
D	YAW SRW PWR OFF	58	RIU2B
D	SKEW SRW PWR OFF	51	RIU2B
D	FSS PWR OFF	11	RIU2B
D	FHST 1 AND 2 HTRS OFF	43	RIU2B
D	MACS HTR GROUP 1 OFF	35	RIU2B
D	MACS HTR GROUP 2 OFF	39	RIU2B
D	MACS HTR GROUP 3 OFF	50	RIU2B
D	ACE A MAG TORQUER OFF	31	RIU2B
D	ACE B MAG TORQUER OFF	32	RIU2B
D	RIU B ON STANDBY	00	RIU4B
D	RIU B ON/OFF A	63	RIU4B
D	ESA 1 HTR/LOGIC DISABLE	25	RIU4B
D	ESA 2 HTR/LOGIC DISABLE	54	RIU4B
D	ESA 1 PWR OFF	13	RIU4B
D	ESA 2 PWR OFF	34	RIU4B

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Table 3.6-11. B-Side Register Initialization

Command Type	Description	Octal B1 ---> C25
S	ACE B ROLL SRW ZERO VOLTS	605410000
S	ACE B PITCH SRW ZERO VOLTS	605420000
S	ACE B YAW SRW ZERO VOLTS	605430000
S	ACE B SKEW SRW ZERO VOLTS	605440000
S	ACE B ROLL TAM BIAS ZERO VOLTS	605450000
S	ACE B PITCH TAM BIAS ZERO VOLTS	605460000
S	ACE B YAW TAM BIAS ZERO VOLTS	605470000
S	ACE B ROLL TORQUE DRIVE ZERO VOLTS	605510000
S	ACE B PITCH TORQUE DRIVE ZERO VOLTS	605530000
S	ACE B YAW TORQUE DRIVE ZERO VOLTS	605550000
S	ACE B ROLL TORQUE BIAS ZERO VOLTS	605520000
S	ACE B PITCH TORQUE BIAS ZERO VOLTS	605540000
S	ACE B YAW TORQUE BIAS ZERO VOLTS	605560000
S	ACE B ROLL 1 IRU BIAS ZERO	605700000
S	ACE B PITCH 1 IRU BIAS ZERO	605710000
S	ACE B YAW 1 IRU BIAS ZERO	605720000
S	ACE B ROLL 2 IRU BIAS ZERO	605730000
S	ACE B PITCH 2 IRU BIAS ZERO	605740000
S	ACE B YAW 2 IRU BIAS ZERO	605750000

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Table 3.6-12. B-Side Component Turn-On and Selection

Command Type	Description	Octal/Discrete ID	Comments
D	ESA 1 PWR ON	18	RIU4B
D	ESA 2 PWR ON	07	RIU4B
D	ESA 1 LOGIC ENABLE	60	RIU4B
D	ESA 2 LOGIC ENABLE	39	RIU4B
D	IRU CH A PWR ON	21	RIU2B
D	IRU CH B PWR ON	22	RIU2B
D	IRU CH C PWR ON	59	RIU2B
D	FHST 1 PWR ON	13	RIU2B
D	FHST 2 PWR ON	14	RIU2B
S	FHST 1 INITIALIZE CMD 1	604340000	RIU2B
S	FHST 1 INITIALIZE CMD 2	604202000	RIU2B
S	FHST 2 INITIALIZE CMD 1	604540000	RIU2B
S	FHST 2 INITIALIZE CMD 2	604402000	RIU2B
D	TAM 1 PWR ON	17	RIU2B
D	TAM 2 PWR ON	18	RIU2B
D	FSS PWR ON	09	RIU2B
S	SAFEHOLD DEVICE MODE SEL	AS REQUIRED	RIU2B
S	SAFEHOLD GYRO RATE SEL	AS REQUIRED	RIU2B
S	SAFEHOLD POSITION SENSOR SEL	AS REQUIRED	RIU2B

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3.7 MACS TELEMETRY

Operation of the Modular Attitude Control Subsystem is monitored using 101 telemetry channels of which 66 are active analog, 16 are conditioned (passive) analog, four are bi-level digital, and 15 are serial digital.

The telemetry points are listed in Table 3.7-1 and described in Paragraphs 3.7.1.1 through 3.7.2.11; telemetry limits are shown in Table 3.7-2. Paragraph 3.7.3 describes the telemetry for the Earth Sensor Assembly Module (ESAM). Functional Schematics for the telemetry derivation circuits are grouped in Paragraph 3.7.4. (NOTE: the schematics are simplified versions of the actual circuits and are provided only as an aid in understanding the telemetry interface.

For information regarding calibration curves for the telemetered functions, see Appendix A.3.

3.7.1 ANALOG TELEMETRY MONITORS

The Modular Attitude Control Subsystem utilizes 82 analog telemetry monitors, including 66 active and 16 passive analog telemetry points. These points are listed by user ID in Tables 3.7-1 and 3.7-2 for telemetry matrix location and operating limits respectively. The following paragraphs describe these telemetry monitors.

3.7.1.1 Standard Reaction Wheel Temperature Monitors

Roll SRW Temp (MACS-20)
Pitch SRW Temp (MACS-21)
Yaw SRW Temp (MACS-22)
Skew SRW Temp (MACS-23)

These telemetry points monitor the temperature of the four SRW's as measured by passive temperature probes indicating spin bearing temperature. Identical circuits are used to monitor all SRW temperatures, with a typical circuit illustrated in Figure 3.7-1.

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Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-01	FSS 32-Bit Data:						3.7.2.1
	FSS Angular Data Y-axis (14 Bits)	AFSSOUTY	S0-7	96(02)	96(02)	02-00	
			S0-5	97(02)	97(02)		
	FSS Sun Presence	AFSSSUNP	S6	97(02)	97(02)	02-00	
	Unused Bit		S7	97(02)	97(02)	02-00	
	FSS Angular Data X-Axis (14 Bits)	AFSSOUTX	S0-7	98(02)	98(02)	02-00	
			S0-5	99(02)	99(02)		
	FSS Power Status	AFSSPWR	S6-7	99(02)	99(02)	02-00	
MACS-02	ACE A 144 Bit IRU Data		SER	N/A	N/A	02-01	3.7.2.2
MACS-03	ACE A 64 Bit TACH Data		SER	N/A	N/A	02-02	3.7.2.3
MACS-04	ACE A Component Status:						3.7.2.4
	ACE A 4 Hz Clock ON/OFF	A4HZCLAA	S0	96(05)	96(05)	02-03	
	ACE B 4 Hz Clock ON/OFF	A4HZCLBA	S1	96(05)	96(05)	02-03	
	ACE A FHST 1 HEATER PWR OFF/ON	ATR1HTA	S2	96(05)	96(05)	02-03	
	ACE A FHST 2 HEATER PWR OFF/ON	ATR2HTA	S3	96(05)	96(05)	02-03	
	ACE A HEATER 1A POWER OFF/ON	AHTRA1A	S4	96(05)	96(05)	02-03	
	ACE A HEATER 1B POWER OFF/ON	AHTRA1B	S5	96(05)	96(05)	02-03	
	ACE A HEATER 2A POWER OFF/ON	AHTRA2A	S6	96(05)	96(05)	02-03	
	ACE A HEATER 2B POWER OFF/ON	AHTRA2B	S7	96(05)	96(05)	02-03	
	ACE A HEATER 3A POWER OFF/ON	AHTRA3A	S0	97(05)	97(05)	02-03	
	ACE A HEATER 3B POWER OFF/ON	AHTRA3B	S1	97(05)	97(05)	02-03	
	ACE A YAW MAG TORQUER B ON/OFF	AAZTRQB	S2	97(05)	97(05)	02-03	
	ACE A YAW MAG TORQUER A ON/OFF	AAZTRQA	S3	97(05)	97(05)	02-03	
	ACE A PITCH MAG TORQUER 3 ON/OFF	AAYTRQB	S4	97(05)	97(05)	02-03	
	ACE A PITCH MAG TORQUER A ON/OFF	AAYTRQA	S5	97(05)	97(05)	02-03	
	ACE A ROLL MAG TORQUER B ON/OFF	AAXTRQB	S6	97(05)	97(05)	02-03	
	ACE A ROLL MAG TORQUER A ON/OFF	AAXTRQA	S7	97(05)	97(05)	02-03	
MACS-05	ACE A SHE STATUS:						3.7.2.5
	ACE A ROLL CSS 1 ON/OFF	AAXCSS1	S0	96(61)	96(61)	02-04	
	ACE A ROLL CSS 2 ON/OFF	AAXCSS2	S1	96(61)	96(61)	02-04	
	ACE A ROLL ES-GYC ON/OFF	AAXESGYC	S2	96(61)	96(61)	02-04	
	ACE A ROLL IRU 1 POSITION ON/OFF	AAXIRU1	S3	96(61)	96(61)	02-04	
	ACE A ROLL IRU 2 POSITION ON/OFF	AXXIRU2	S4	96(61)	96(61)	02-04	
	ACE A ROLL IRU 1/2 RATE ON	AAXRATE	S5	96(61)	96(61)	02-04	
	UNUSED BIT		S6	96(61)	96(61)	02-04	
	ACE A THRUSTER CONTROL ON/OFF	AATHRST	S7	96(61)	96(61)	02-04	
	ACE A YAW CSS 1 ON/OFF	AAZCSS1	S0	97(61)	97(61)	02-04	
	ACE A YAW CSS 2 ON/OFF	AAZCSS2	S1	97(61)	97(61)	02-04	
	ACE A YAW ES-GYC ON/OFF	AAZESGYC	S2	97(61)	97(61)	02-04	
	ACE A YAW IRU 1 POSITION ON/OFF	AAZIRU1	S3	97(61)	97(61)	02-04	
	ACE A YAW IRU 2 POSITION ON/OFF	AAZIRU2	S4	97(61)	97(61)	02-04	
	ACE A PITCH IRU 1/2 RATE ON	AAYRATE	S5	97(61)	97(61)	02-04	
	ACE A TAM 2/1 SELECTED	AATAM	S6	97(61)	97(61)	02-04	
	ACE A THRUSTER UNLOAD ON/OFF	AATHRUN	S7	97(61)	97(61)	02-04	

Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
	ACE A PITCH CSS 1 ON/OFF	AAYCSS1	S0	98(61)	98(61)	02-04	
	ACE A PITCH CSS 2 ON/OFF	AAYCSS2	S1	98(61)	98(61)	02-04	
	ACE A PITCH ES-GYC ON/OFF	AAYESGYC	S2	98(61)	98(61)	02-04	
	ACE A PITCH IRU 1 POSITION ON/OFF	AAYIRU1	S3	98(61)	98(61)	02-04	
	ACE A PITCH IRU 2 POSITION ON/OFF	AAYIRU2	S4	98(61)	98(61)	02-04	
	ACE A YAW IRU 1/2 RATE ON	AAZRATE	S5	98(61)	98(61)	02-04	
	ACE A SAFEHOLD ON/OFF	AASFHLD	S6	98(61)	98(61)	02-04	
	ACE A SHUTTLE RETRIEVAL ON/OFF	AASHLRT	S7	98(61)	98(61)	02-04	
MACS-06	FHST 1 WORD 1 16-BIT DATA:						3.7.2.6
	FHST 1 HOR STAR POSITION (12 BITS)	AST1HORZ	S0-7	96(57)[1]	96(57)[1]	02-08	
			S0-3	97(57)[1]	97(57)[1]		
	UNUSED BIT		S4	97(57)[1]	97(57)[1]	02-08	
	FHST 1 OPTICS SHTR CLOSED BY BOA YES/NO	AST1SHBO	S5	97(57)[1]	97(57)[2]	02-08	
	FHST 1 STAR PRESENT YES/NO	AST1STAR	S6	97(57)[1]	97(57)[1]	02-08	
	FHST 1 OPTICS SHTR CLOSED BY TS YES/NO	AST1SHTS	S7	97(57)[1]	97(57)[1]	02-08	
MACS-07	FHST 1 WORD 2 16-BIT DATA:						3.7.2.6
	FHST 1 VERT STAR POSITION (12 BITS)	AST1VERT	S0-7	96(58)[2]	96(58)[2]	02-09	
			S0-3	97(58)[2]	97(58)[2]	97(58)	02-09
	UNUSED BIT		S4	97(58)[2]	97(58)[2]	02-09	
	FHST 1 PWR SUP OUT OF TOLER NO/YES	AST1TOL	S5	97(58)[2]	97(58)[2]	02-09	
	UNUSED BITS		S6-7	97(58)[2]	9/(58)[2]	02-09	

rences:

[1] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 121.
[2] SAMPLE RATE = 2: ALSO SAMPLED IN MINOR FRAME 122.

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Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-08	FHST 2 WORD 1 16-BIT DATA:						3.7.2.6
	FHST 2 HOR STAR POSITION (12 BITS)	AST2HORZ	S0-7	96(59)[3]	96(59)[3]	02-10	
			S0-3	97(59)[3]	97(59)[3]	02-10	
	UNUSED BIT		S4	97(59)[3]	97(59)[3]	02-10	
	FHST 2 OPTICS SHTR CLOCED BY BOA YES/NO	AST2SHBO	S5	97(59)[3]	97(59)[3]	02-10	
	FHST 2 STHR PRESENT YES/NO	AST2STAR	S6	97(59)[3]	97(59)[3]	02-10	
	FHST 2 OPTICS SHTR CLOSED BY TS YES/NO	AST2SHTS	S7	97(59)[3]	97(59)[4]	02-10	
MACS-09	FHST 2 WORD 2 16-BIT DATA:						3.7.2.6
	FHST 2 VERT STAR POSITION (12 BITS)	AST2VERT	S0-7	95(60)[4]	96(60)[4]	02-11	
			S0-3	97(60)[4]	97(6		
	UNUSED BIT		S4	97(60)[4]	97(60)[4]	02-11	
	FHST 2 PWR SUP OUT OF TOLER NO/YES	AST2TOL	S5	97(60)[4]	97(60)[4]	02-11	
	UNUSED BITS		S6-7	97(60)[4]	97(60)[4]	02-11	
MACS-10	ACE B 144 BIT IRU DATA		SER	N/A	N/A	02-12	3.7.2.2
MACS-11	ACE B 64 BIT TACH DATA		SER	N/A	N/A	02-13	3.7.2.3

erences:
[3] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 123.
[4] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 124.

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Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-12	ACE B COMPONENT STATUS:						
	ACE A 4 HZ CLOCK ON/OFF	A4HZCLAB	S0	96(68)	96(68)	02-14	3.7.2.4
	ACE B 4 HZ CLOCK ON/OFF	A4HZCLBB	S1	96(68)	96(68)	02-14	
	ACE B FHST 1 HEATER POWER OFF/ON	ATR1HTB	S2	96(68)	96(68)	02-14	
	ACE B FHST 2 HEATER POWER OFF/ON	ATR2HTB	S3	96(68)	96(68)	02-14	
	ACE B HEATER 1A POWER OFF/ON	AHTRB1A	S4	96(68)	96(68)	02-14	
	ACE B HEATER 1B POWER OFF/ON	AHTRB1B	S5	96(68)	96(68)	02-14	
	ACE B HEATER 2A POWER OFF/ON	AHTRB2A	S6	96(68)	96(68)	02-14	
	ACE B HEATER 2B POWER OFF/ON	AHTRB2B	S7	96(68)	96(68)	02-14	
	ACE B HEATER 3A POWER OFF/ON	AHTRB3A	S0	97(68)	97(68)	02-14	
	ACE B HEATER 3B POWER OFF/ON	AHTRB3B	S1	97(68)	97(68)	02-14	
	ACE B YAW MAG TORQUER B ON/OFF	ABZTRQB	S2	97(68)	97(68)	02-14	
	ACE B YAW MAG TORQUER A ON/OFF	ABZTRQA	S3	97(68)	97(68)	02-14	
	ACE B PITCH MAG TORQUER B ON/OFF	ABYTRQB	S4	97(68)	97(68)	02-14	
	ACE B PITCH MAG TORQUER A ON/OFF	ABYTRQA	S5	97(68)	97(68)	02-14	
	ACE B ROLL MAG TORQUER B ON/OFF	ABXTRQB	S6	97(68)	97(68)	02-14	
	ACE B ROLL MAG TORQUER A ON/OFF	ABXTRQA	S7	97(68)	97(68)	02-14	
MACS-13	ACE B SHE STATUS:						
	ACE B ROLL CSS 1 ON/OFF	ABXCSS1	S0	96(62)	96(62)	02-15	3.7.2.5
	ACE B ROLL CSS 2 ON/OFF	ABXCSS2	S1	96(62)	96(62)	02-15	
	ACE B ROLL ES-GYC ON/OFF	ABXESGYC	S2	96(62)	96(62)	02-15	
	ACE B ROLL IRU 1 POSITION ON/OFF	ABXIRU1	S3	96(62)	96(62)	02-15	
	ACE B ROLL IRU 2 POSITION ON/OFF	ABXIRU2	S4	96(62)	96(62)	02-15	
	ACE B ROLL IRU 1/2 RATE ON	ABXRATE	S5	96(62)	96(62)	02-15	
	UNUSED BIT		S6	96(62)	96(62)	02-15	
	ACE B THRUSTER CONTROL ON/OFF	ABTHRST	S7	96(62)	96(62)	02-15	
	ACE B YAW CSS 1 ON/OFF	ABZCSS1	S0	97(62)	97(62)	02-15	
	ACE B YAW CSS 2 ON/OFF	ABZCSS2	S1	97(62)	97(62)	02-15	
	ACE B YAW ES-GYC ON/OFF	ABZESGYC	S2	97(62)	97(62)	02-15	
	ACE B YAW IRU 1 POSITION ON/OFF	ABZIRU1	S3	97(62)	97(62)	02-15	
	ACE B YAW IRU 2 POSITION ON/OFF	ABZIRU2	S4	97(62)	97(62)	02-15	
	ACE B PITCH IRU 1/2 RATE ON	ABTRATE	S5	97(62)	97(62)	02-15	
	ACE B TAM 2/1 SELECTED	ABTAM	S6	97(62)	97(62)	02-15	
	ACE B THRUSTER UNLOAD ON/OFF	ABTHRUN	S7	97(62)	97(62)	02-15	
	ACE B PITCH CSS 1 ON/OFF	ABYCSS1	S0	98(62)	98(62)	02-15	
	ACE B PITCH CSS 2 ON/OFF	ABYCSS2	S1	98(62)	98(62)	02-15	
	ACE B PITCH ES-GYC ON/OFF	ABYESGYC	S2	98(62)	98(62)	02-15	
	ACE B PITCH IRU 1 POSITION ON/OFF	ABYIRU1	S3	98(62)	98(62)	02-15	
	ACE B PITCH IRU 2 POSITION ON/OFF	ABYIRU2	S4	98(62)	98(62)	02-15	
	ACE B YAW IRU 1/2 RATE ON	ABZRATE	S5	98(62)	98(62)	02-15	
	ACE B SAFEHOLD ON/OFF	ABSFHLD	S6	98(62)	98(62)	02-15	
	ACE B SHUTTLE RETRIEVAL ON/OFF	ABSHLRT	S7	98(62)	98(62)	02-15	
MACS-14	ACE A 24-BIT COMPUTER/PAYS WORD 1:						
	ROLL SRW PAYS/OBC ENABLE	AAXWHEN	S0	96(76)	96(76)	02-06	3.7.2.7
	PITCH SRW PAYS/OBC ENABLE	AAYWHEN	S1	96(76)	96(76)	02-06	
	YAW SRW PAYS/OBC ENABLE	AAZWHEN	S2	96(76)	96(76)	02-06	

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Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	PIU-CH	Reference Paragraph
	SKEW SPW PATS/OBC ENABLE	AASWHEN	53	96(76)	96(76)	02-06	
	SEPARATION SW A CLOSED/OPEN	AASPSWA	54	96(76)	96(76)	02-06	
	SEPARATION SW B CLOSED/OPEN	AASPSWB	55	96(76)	96(76)	02-06	
	UNUSED BITS		56-7	96(76)	96(76)	02-06	
	ACE A 24-BIT COMPUTER/PATS WORD 2	AACOMPW2	50-7	97(76)	97(76)	02-06	
	ACE A 24-BIT COMPUTER/PATS WORD 3	ACOMPW3	50-7	98(76)	98(76)	02-06	
MACS-15	ACE B 24-BIT COMPUTER/PATS WORD 1:						3.7.2.7
	ROLL SPW PATS/OBC ENABLE	ABXWHEN	50	96(77)	96(77)	02-07	
	PITCH SPW PATS/OBC ENABLE	ABYWHEN	51	96(77)	96(77)	02-07	
	YAW SPW PATS/OBC ENABLE	ABZWHEN	52	96(77)	96(77)	02-07	
	SKEW SPW PATS/OBC ENABLE	ABSWHEN	53	96(77)	96(77)	02-07	
	SEPARATION SW A CLOSED/OPEN	ABSPSWA	54	96(77)	96(77)	02-07	
	SEPARATION SW B CLOSED/OPEN	ABSPSWB	55	96(77)	96(77)	02-07	
	UNUSED BITS		56-7	96(77)	96(77)	02-07	
	ACE B 24-BIT COMPUTER/PATS WORD 2	ABCOMPW2	50-7	97(77)	97(77)	02-07	
	ACE B 24-BIT COMPUTER/PATS WORD 3	ABCOMPW3	50-7	98(77)	98(77)	02-07	
MACS-16	BILEVEL WORD 01:						3.7.2.8
	IRU CHANNEL A RANGE LOW/HIGH	AIRUARNG	B0	96(72)	96(72)	02-32	
	IRU CHANNEL B RANGE LOW/HIGH	AIRUBRNG	B1	96(72)	96(72)	02-33	
	IRU CHANNEL C RANGE LOW/HIGH	AIRUCRNG	B2	96(72)	96(72)	02-34	
	IRU CHANNEL A POWER ON/OFF	AIRUAPWR	B3	96(72)	96(72)	02-35	
	IRU CHANNEL B POWER ON/OFF	AIRUBPWR	B4	96(72)	96(72)	02-36	
	IRU CHANNEL C POWER ON/OFF	AIRUCPWR	B5	96(72)	96(72)	02-37	
	FHST 1 POWER ON/OFF	AST1PWR	B6	96(72)	96(72)	02-38	
	FHST 2 POWER ON/OFF	AST2PWR	B7	96(72)	96(72)	02-39	
MACS-17	BILEVEL WORD 02:						3.2.7.9
	TAM 1 POWER ON/OFF	ATAM1PWR	B0	97(72)	97(72)	02-64	
	TAM 2 POWER ON/OFF	ATAM2PWR	B1	97(72)	97(72)	02-65	
	ACE A POWER ON/ACE B POWER ON	AAONBOFF	B2	97(72)	97(72)	02-66	
	LAUNCH MODE A YES/NO	ALMA	B3	97(72)	97(72)	02-67	
	S/A INDEX 1 STATUS	ASAIND1	B4	97(72)	97(72)	02-68	
	S/A INDEX 2 STATUS	ASAIND2	B5	97(72)	97(72)	02-69	
	COM A TIMER TIMEOUT/NO TIMEOUT	ACSMATM	B6	97(72)	97(72)	02-70	
	COM B TIMER TIMEOUT/NO TIMEOUT	ACSMBTM	B7	97(72)	97(72)	02-71	
MACS-18	BILEVEL WORD 03:						3.7.2.10
	COM A INHIBITED/ENABLED	ACSMAED	B0	98(72)	98(72)	02-96	
	COM B INHIBITED/ENABLED	ACSMBED	B1	98(72)	98(72)	02-97	
	ROLL WHEEL ENABLED/DISABLED	AXWHED	B2	98(72)	98(72)	02-98	
	PITCH WHEEL ENABLED/DISABLED	AYWHED	B3	98(72)	98(72)	02-99	
	YAW WHEEL ENABLED/DISABLED	AZWHED	B4	98(72)	98(72)	02-100	
	SKEW WHEEL ENABLED/DISABLED	ASWHED	B5	98(72)	98(72)	02-101	
	LAUNCH MODE B YES/NO	ALMB	B6	98(72)	98(72)	02-102	

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Table 3.7-1. MACS Telemetry List

User ID	TIM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-19	BILEVEL WORD 04:						3.7.2.11
	RIU 02 MATE STANDBY 1/OFF	ARIUMATE	B6	96(13)	96(13)	02-46	
	RIU 02 B ON/A ON	ARIUID	B7	96(13)	96(13)	02-47	
MACS-20	ROLL SRW TEMP	AXWHLTMP	P	96(41)	96(41)	02-16	3.7.1.1
MACS-21	PITCH SRW TEMP	AYWHLTMP	P	96(42)	96(42)	02-17	3.7.1.1
MACS-22	YAW SRW TEMP	AZWHLTMP	P	97(41)	97(41)	02-18	3.7.1.1
MACS-23	SKEW SRW TEMP	ASWHLTMP	P	97(42)	97(42)	02-19	3.7.1.1
MACS-24	OPTICAL BENCH TEMP (FHST)	ASTOBTMP	P	97(53)	97(53)	02-20	3.7.1.2
MACS-25	PSU TEMP	APSUTMP	P	98(68)	98(68)	02-21	3.7.1.3
MACS-26	FSS TEMP	AFSSTMP	P	97(07)	97(07)	02-22	3.7.1.4
MACS-27	RIU 02 TEMP	ARIU2TMP	P	96(07)	96(07)	02-23	3.7.1.5
MACS-28	ACE A POWER CONDITIONER TEMP	AAPWRCDT	P	98(75)	98(75)	02-24	3.7.1.6
MACS-29	ACE B POWER CONDITIONER TEMP	ABPWRCDT	P	98(78)	98(78)	02-25	3.7.1.6
MACS-30	SRW DRIVE ELECTRONICS TEMP	AWHDRELT	P	98(08)	98(08)	02-26	3.7.1.7
MACS-31	TORQ DRIVE ELECTRONICS TEMP	ATQDRELT	P	98(60)	98(60)	02-27	3.7.1.8
MACS-32	IRU CHANNEL A TEMP	AIRUATMP	P	96(73)	96(73)	02-28	3.7.1.9
MACS-33	IRU CHANNEL B TEMP	AIRUBTMP	P	96(74)	96(74)	02-29	3.7.1.9
MACS-34	IRU CHANNEL C TEMP	AIRUCTMP	P	96(75)	96(75)	02-30	3.7.1.9
MACS-35	OPTICAL BENCH TEMP (IRU)	AIRUOBTP	P	97(80)	97(80)	02-31	3.7.1.2
MACS-36	FHST 1 TEMP	AST1TEMP	A	98(111)	98(111)	02-54	3.7.1.10
MACS-37	FHST 2 TEMP	AST2TEMP	A	98(100)	98(100)	02-55	3.7.1.10
MACS-38	IRU CHANNEL A REG VOLTAGE	AIRUAVLT	A	96(45)	96(45)	02-40	3.7.1.11
MACS-39	IRU CHANNEL B REG VOLTAGE	AIRUBVLT	A	97(45)	97(45)	02-41	3.7.1.11
MACS-40	IRU CHANNEL C REG VOLTAGE	AIRUCVLT	A	98(45)	98(45)	02-42	3.7.1.11

Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-41	IRU CHANNEL A MOTOR CURRENT	AIRUAMTI	A	97(73)	97(73) 23	02-43	3.7.1.12
MACS-42	IRU CHANNEL B MOTOR CURRENT	AIRUBMTI	A	97(74)	97(74) 24	02-44	3.7.1.12
MACS-43	IRU CHANNEL C MOTOR CURRENT	AIRUCMTI	A	97(75)	97(75) 25	02-45	3.7.1.12
MACS-44	FHST 1 STAR INTENSITY	AST1MAG	A	97(12)	97(12)	02-52	3.7.1.13
MACS-45	FHST 2 STAR INTENSITY	AST2MAG	A	98(12)	98(12)	02-53	3.7.1.13
MACS-46	CSS 1 PITCH POSITION ERROR	ACSS1Y	A	97(13)	97(13) 60	02-48	3.7.1.14
MACS-47	CSS 1 YAW POSITION ERROR	ACSS1Z	A	97(100)	97(100) 62	02-49	3.7.1.14
MACS-48	CSS 2 PITCH POSITION ERROR	ACSS2Y	A	97(101)	97(101) 61	02-50	3.7.1.14
MACS-49	CSS 2 YAW POSITION ERROR	ACSS2Z	A	97(102)	97(102) 63	02-51	3.7.1.14
MACS-50	TAM 1 ROLL ERROR SIGNAL	ATAM1X	A	96(43)	96(43)	02-56	3.7.1.15
MACS-51	TAM 1 PITCH ERROR SIGNAL	ATAM1Y	A	97(43)	97(43)	02-57	3.7.1.15
MACS-52	TAM 1 YAW ERROR SIGNAL	ATAM1Z	A	98(43)	98(43)	02-58	3.7.1.15
MACS-53	TAM 2 ROLL ERROR SIGNAL	ATAM2X	A	96(44)	96(44)	02-59	3.7.1.15
MACS-54	TAM 2 PITCH ERROR SIGNAL	ATAM2Y	A	97(44)	97(44)	02-60	3.7.1.15
MACS-55	TAM 2 YAW ERROR SIGNAL	ATAM2Z	A	98(44)	98(44)	02-61	3.7.1.15
MACS-56	ROLL MAG TORQ DRIVE A	AXMAGDRA	A	96(06)	96(06) 26	02-72	3.7.1.16
MACS-57	ROLL MAG TORQ DRIVE B	AXMAGDRB	A	96(66)	96(66) 27	02-73	3.7.1.16
MACS-58	PITCH MAG TORQ DRIVE A	AYMAGDRA	A	97(06)	97(06) 28	02-74	3.7.1.16
MACS-59	PITCH MAG TORQ DRIVE B	AYMAGDRB	A	97(66)	97(66) 29	02-75	3.7.1.16

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Table 3.7-1. MACS Telemetry List

User ID	TM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-60	YAW MAG TORQ DRIVE A	AZMAGDRA	A	98(06)	98(06) 30	02-76	3.7.1.16
MACS-61	YAW MAG TORQ DRIVE B	AZMAGDRB	A	98(66)	98(66) 31	02-77	3.7.1.16

Table 3.7-1. MACS Telemetry

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-62	IRU ROLL RATE 1	AXRATE1	A	96(39)[5]	96(39)[5] 77	02-82	3.7.1.17
MACS-63	IRU PITCH RATE 1	AYRATE1	A	97(39)[5]	97(39)[5] 79	02-83	3.7.1.17
MACS-64	IRU YAW RATE 1	AZRATE1	A	98(39)[5]	98(39)[5] 81	02-84	3.7.1.17
MACS-65	IRU ROLL RATE2	AXRATE 2	A	96(40)[6]	96(40)[6] 22	02-85	3.7.1.17
MACS-66	IRU PITCH RATE 2	AYRATE2	A	97(40)[6]	97(40)[6] 80	02-86	3.7.1.17
MACS-67	IRU YAW RATE 2	AZRATE2	A	98(40)[6]	98(40)[6] 82	02-87	3.7.1.17
MACS-68	ROLL SRW DRIVE CONTROL	AXWHDRVA	A	98(31)[7]	98(31)[7] 56	02-104	3.7.1.18
MACS-69	PITCH SRW DRIVE CONTROL	AYWHDRVA	A	98(32)[8]	98(32)[8] 57	02-105	3.7.1.18
MACS-70	YAW SRW DRIVE CONTROL	AXWHDRVA	A	98(63)[9]	98(63)[9] 58	02-106	3.7.1.18

References:

[5] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 103.
[6] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 103.
[7] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 95.
[8] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 96.
[9] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 127.

Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-71	SKEW SRW DRIVE CONTROL	ASWHDRVA	A	98(34)[10]	98(34)[10] 59	02-107	3.7.1.18
MACS-72	ROLL SRW MOTOR VOLTS	AXWHDRVB	A	96(46)[11]	96(46)[11] 52	02-108	3.7.1.19
MACS-73	PITCH SRW MOTOR VOLTS	AYWHDRVB	A	96(36)[12]	96(36)[12] 53	02-109	3.7.1.19
MACS-74	YAW SRW MOTOR VOLTS	AZWHDRVB	A	96(37)[13]	96(37)[13] 54	02-110	3.7.1.19
MACS-75	SKEW SRW MOTOR VOLTS	ASWHDRVB	A	96(38)[14]	96(38[14] 55	02-111	3.7.1.19
MACS-76	ROLL SRW TACH A	AXTACHA	A	96(31)[15]	96(31)[15] 44	02-112	3.7.1.20
MACS-77	PITCH SRW TACH A	AYTACHA	A	96(32)[16]	96(32)[16] 46	02-113	3.7.1.20

References:

[10] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 98.
[11] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 110.
[12] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 100.
[13] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 101.
[14] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 102.
[15] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 95.
[16] SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 96.

Table 3.7-1. MACS Telemetry L.

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph

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Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-62	IRU ROLL RATE 1	AXRATE1	A	96(39)[5]	96(39)[5] 77	02-82	3.7.1.17
MACS-63	IRU PITCH RATE 1	AYRATE1	A	97(39)[5]	97(39)[5] 79	02-83	3.7.1.17
MACS-64	IRU YAW RATE 1	AZRATE1	A	98(39)[5]	98(39)[5] 81	02-84	3.7.1.17
MACS-65	IRU ROLL RATE2	AXRATE 2	A	96(40)[6]	96(40)[6] 22	02-85	3.7.1.17
MACS-66	IRU PITCH RATE 2	AYRATE2	A	97(40)[6]	97(40)[6] 80	02-86	3.7.1.17
MACS-67	IRU YAW RATE 2	AZRATE2	A	98(40)[6]	98(40)[6] 82	02-87	3.7.1.17
MACS-68	ROLL SRW DRIVE CONTROL	AXWHDRVA	A	98(31)[7]	98(31)[7] 56	02-104	3.7.1.18
MACS-69	PITCH SRW DRIVE CONTROL	AYWHDRVA	A	98(32)[8]	98(32)[8] 57	02-105	3.7.1.18
MACS-70	YAW SRW DRIVE CONTROL	AXWHDRVA	A	98(63)[9]	98(63)[9] 58	02-106	3.7.1.18

References:

5 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 103.
6 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 103.
7 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 95.
8 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 96.
9 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 127.

Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-71	SKEW SRW DRIVE CONTROL	ASWHDRVA	A	98(34)[10]	98(34)[10] 59	02-107	3.7.1.18
MACS-72	ROLL SRW MOTOR VOLTS	AXWHDRVB	A	96(46)[11]	96(46)[11] 52	02-108	3.7.1.19
MACS-73	PITCH SRW MOTOR VOLTS	AYWHDRVB	A	96(36)[12]	96(36)[12] 53	02-109	3.7.1.19
MACS-74	YAW SRW MOTOR VOLTS	AZWHDRVB	A	96(37)[13]	96(37)[13] 54	02-110	3.7.1.19
MACS-75	SKEW SRW MOTOR VOLTS	ASWHDRVB	A	96(38)[14]	96(38[14] 55	02-111	3.7.1.19
MACS-76	ROLL SRW TACH A	AXTACHA	A	96(31)[15]	96(31)[15] 44	02-112	3.7.1.20
MACS-77	PITCH SRW TACH A	AYTACHA	A	96(32)[16]	96(32)[16] 46	02-113	3.7.1.20

References:

10 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 98.
11 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 110.
12 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 100.
13 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 101.
14 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 102.
15 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 95.
16 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 96.

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Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-78	YAW SRW TACH A	AZTACHA	A	96(63)[17]	96(63)[17] 48	02-114	3.7.1.20
MACS-79	SKEW SRW TACH A	ASTACHA	A	96(34)[18]	96(34)[18] 50	02-115	3.7.1.20
MACS-80	ROLL SRW TACH B	AXTACHB	A	97(31)[15]	97(31)[15] 45	02-116	3.7.1.20
MACS-81	PITCH SRW TACH B	AYTACHB	A	97(32)[16]	97(32)[16] 47	02-117	3.7.1.20
MACS-82	YAW SRW TACH B	AZTACHB	A	97(63)[17]	97(63)[17] 49	02-118	3.7.1.20
MACS-83	SKEW SRW TACH B	ASTACHB	A	97(34)[18]	97(34)[18] 51	02-119	3.7.1.20
MACS-84	ACE A/B +5 V REG VOLTAGE	AP5VOLT	A	96(91)	96(91)	02-123	3.7.1.21
MACS-85	ACE A/B +15 V REG VOLTAGE	AP15VOLT	A	97(91)	97(91)	02-124	3.7.1.22
MACS-86	ACE A/B -15 V REG VOLTAGE	AN15VOLT	A	96(92)	96(92)	02-125	3.7.1.23
MACS-87	ACE A/B +28 V REG VOLTAGE	AP28VOLT	A	96(93)	96(93)	02-127	3.7.1.24
MACS-88	ACE A -18 V REG VOLTAGE	AAN18VLT	A	97(92)	97(92)	02-122	3.7.1.25
MACS-89	ACE B -18 V REG VOLTAGE	ABN18VLT	A	97(93)	97(93)	02-126	3.7.1.25

References:

17 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 127.
18 SAMPLE RATE = 2; ALSO SAMPLED IN MINOR FRAME 98.

Table 3.7-1. MACS Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
MACS-90	ACE A TAM ROLL COMPENSATED SIGNAL	AAXTAMCP	A	96(08)	96(08)	02-78	3.7.1.26
MACS-91	ACE A TAM PITCH COMPENSATED SIGNAL	AAYTAMCP	A	96(09)	96(09)	02-79	3.7.1.26
MACS-92	ACE A TAM YAW COMPENSATED SIGNAL	AAZTAMCP	A	96(10)	96(10)	02-88	3.7.1.26
MACS-93	ACE B TAM ROLL COMPENSATED SIGNAL	ABXTAMCP	A	97(08)	97(08)	02-89	3.7.1.26
MACS-94	ACE B TAM PITCH COMPENSATED SIGNAL	ABYTAMCP	A	97(09)	97(09)	02-120	3.7.1.26
MACS-95	ACE B TAM YAW COMPENSATED SIGNAL	ABZTAMCP	A	97(10)	97(10)	02-121	3.7.1.26
MACS-96	ACE A IRU ROLL POSITION	AAIRUXPN	A	96(15)[19]	96(15)[19] 75	02-90	3.7.1.27
MACS-97	ACE A IRU PITCH POSITION	AAIRUYPN	A	98(21)[20]	98(21)[20] 42	02-91	3.7.1.27
MACS-98	ACE A IRU YAW POSITION	AAIRUZPN	A	98(25)[21]	98(25)[21] 43	02-92	3.7.1.27
MACS-99	ACE B IRU ROLL POSITION	ABIRUXPN	A	97(15)[19]	97(15)[19] 74	02-93	3.7.1.27
MACS-100	ACE B IRU PITCH POSITION	ABIRUYPN	A	98(22)[22]	98(22)[22] 106	02-94	3.7.1.27
MACS-101	ACE B IRU YAW POSITION	ABIRUZPN	A	98(26)[23]	98(26)[23] 107	02-95	3.7.1.27

References:

19 SAMPLE RATE = 4; ALSO SAMPLED IN MINOR FRAMES 47, 79, 111.
20 SAMPLE RATE = 4; ALSO SAMPLED IN MINOR FRAMES 53, 85, 117.
21 SAMPLE RATE = 4; ALSO SAMPLED IN MINOR FRAMES 57, 89, 121.
22 SAMPLE RATE = 4; ALSO SAMPLED IN MINOR FRAMES 54, 86, 118.
23 SAMPLE RATE = 4; ALSO SAMPLED IN MINOR FRAMES 58, 90, 122.

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Table 3.7-2. MACS Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	Eng. Units
MACS-20	AXWHLTMP	ROLL WHEEL ENA	0	55	$0^{\circ}C$
MACS-21	AYWHLTMP	PITCH WHEEL ENA	0	55	$0^{\circ}C$
MACS-22	AZWHLTMP	YAW WHEEL ENA	0	55	$0^{\circ}C$
MA S-23	ASWHLTMP	SKEW WHEEL ENA	0	55	$0^{\circ}C$
MACS-24	ASTOBTMP		10	35	$0^{\circ}C$
MACS-25	APSUTMP	PSU ON	0	45	$0^{\circ}C$
MACS-26	AFSSTMP	FSS ENA	0	45	$0^{\circ}C$
MACS-27	ARIU2TMP	RIU 02 ON	0	50	$0^{\circ}C$
MACS-28	AAPWRCDT	ACE A ON	0	50	$0^{\circ}C$
MACS-29	ABPWRCDT	ACE B ON	0	50	$0^{\circ}C$
MACS-30	AWHDRELT	WHEEL DRIVE ELECTRONICS ENA	0	50	$0^{\circ}C$
MACS 31	ATQDRELT	TORQ DRIVE ELECTRONICS ENA	0	50	$0^{\circ}C$
MACS-32	AIRUATMP	IRU CHANNEL A ON	24	55	$0^{\circ}C$
MACS-33	AIRUBTMP	IRU CHANNEL B ON	24	55	$0^{\circ}C$
MACS-34	AIRUCTMP	IRU CHANNEL C ON	24	55	$0^{\circ}C$
MACS-35	AIRUOBTP		10	45	$0^{\circ}C$
MACS-36	AST1TEMP	FST1 ON	5	50	$0^{\circ}C$
MACS-37	AST2TEMP	FST2 ON	5	50	$0^{\circ}C$
MACS-38	AIRUAVLT	IRU CHANNEL A ON	1.5	2.5	VOLTS
MACS-39	AIRUBVLT	IRU CHANNEL B ON	1.5	2.5	VOLTS
MACS-40	AIRUCVLT	IRU CHANNEL C ON	1.5	2.5	VOLTS
MACS-41	AIRUAMIT	IRU CHANNEL A ON	0.020	0.090	AMPS
MACS-42	AIRUBMIT	IRU CHANNEL B ON	0.020	0.090	AMPS
MACS-43	AIRUCMIT	IRU CHANNEL C ON	0.020	0.090	AMPS

Table 3.7-2. MACS Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	Eng. Units
MACS-84	AP5VOLT		4.5	5.5	VOLTS
MACS-85	AP15VOLT		14.5	15.5	VOLTS
MACS-87	AP28VOLT		25.2	30.8	VOLTS

3.7.1.2 Optical Bench Temperature Monitors

Optical Bench Temp (FHST) (MACS-24)
Optical Bench Temp (IRU) (MACS-35)

These telemetry points monitor optical bench temperature as measured by passive temperature probes indicating temperatures near the FHST and IRU baseplates. Identical circuits are used to monitor each temperature, with a typical circuit illustrated in Figure 3.7-1.
3.7.4, Telemetry Response Functions.

3.7.1.3 Power Switching Unit Temperature Monitor

PSU Temp (MACS-25)

This telemetry point monitors PSU temperature as measured by a passive temperature probe located internal to the PSU assembly. Figure 3.7-1 illustrates the circuit used to derive this temperature signal.

Functions.

3.7.1.4 Fine Sun Sensor Temperature Monitor

FSS Temp (MACS-26)

This telemetry point monitors FSS temperature as measured by a passive temperature probe located within the electronics package. Figure 3.7-1 illustrates the circuit used to derive this temperature signal.

3.7.1.5 Remote Interface Unit Temperature Monitor

RIU 02 Temp (MACS-27)

This telemetry point monitors RIU 02 temperature as measured by a passive temperature probe located within the RIU. Figure 3.7-1 illustrates the circuit used to derive this temperature signal.

3.7.1.6 ACE Power Conditioner Temperature Monitor

ACE A Power Conditioner Temp (MACS-28)
ACE B Power Conditioner Temp (MACS-29)

These telemetry points monitor the temperature of ACE A/B power conditioners as measured by passive temperature probes indicating DC-DC converter temperature. Identical circuits are used to monitor each power conditioner temperature, with a typical circuit illustrated in Figure 3.7-1.

3.7.1.7 SRW Drive Electronics Temperature Monitor

SRW Drive Electronics Temp (MACS-30)

This telemetry point monitors wheel drive electronics temperature as measured by a passive temperature probe located within the drive electronics. Figure 3.7-1 illustrates the circuit used to derive this temperature signal.

3.7.1.8 Magnetic Torquer Drive Electronics Temperature Monitor

Torq Drive Electronics Temp (MACS-31)

This telemetry point monitors magnetic torquer drive electronics temperature as measured by a passive temperature probe located in the vicinity of the drive electronics. Figure 3.7-1 illustrates the circuit used to derive this temperature signal.

3.7.1.9 IRU Temperature Monitors

IRU Channel A Temp (MACS-32)
IRU Channel B Temp (MACS-33)
IRU Channel C Temp (MACS-34)

These telemetry points monitor IRU temperature as measured by passive temperature probes indicating individual gyro temperature. Identical circuits are used to monitor each gyro temperature, with a typical circuit illustrated in Figure 3.7-1.

3.7.1.10 Star Tracker Temperature Monitors

FHST 1 Temp (MACS-36)
FHST 2 Temp (MACS-37)

These telemetry points monitor the temperature of each FHST as measured by active temperature probes indicating star tracker temperature. Identical circuits are used to monitor the temperature of each FHST, with a typical circuit illustrated in Figure 3.7-2. The active temperature telemetry is linear with a nominal gain of $31^{o}C/TLM\ V$.

3.7.1.11 IRU Regulated Voltage Monitors

IRU Channel A Reg Voltage	(MACS-38)
IRU Channel B Reg Voltage	(MACS-39)
IRU Channel C Reg Voltage	(MACS-40)

These telemetry points serve to monitor the regulated voltage supplies from each IRU channel, indicating the combined satus of the +5 VDC and +15 VDC supplies. The nominal output is 2.0 $\pm$0.1 VDC. Identical circuits are used to monitor all channels, with a typical circuit illustrated in Figure 3.7-3.

3.7.1.12 IRU Motor Current Monitors

IRU Channel A Motor Current	(MACS-41)
IRU Channel B Motor Current	(MACS-42)
IRU Channel C Motor Current	(MACS-43)

These telemetry points monitor gyro spin motor current in each of the three IRU channels. Nominal motor current for each gyro is 45 $\pm$15 ma. Identical circuits are used to monitor motor current in each channel, with a typical circuit illustrated in Figure 3.7-4.

3.7.1.13 Star Tracker Star Intensity Monitors

FHST 1 Star Intensity	(MACS-44)
FHST 2 Star Intensity	(MACS-45)

These telemetry points monitor the intensity of the star currently being tracked, as measured in terms of visual magnitude. Identical circuits are used in each tracker to derive star intensity. A typical derivation circuit is illustrated in Figure 3.7-2.

3.7.1.14 CSS Position Error Monitors

CSS 1 Pitch Position Error	(MACS-46)
CSS 1 Yaw Position Error	(MACS-47)
CSS 2 Pitch Position Error	(MACS-48)
CSS 2 Yaw Position Error	(MACS-49)

These telemetry points monitor the two axes position signals from each CSS, after being conditioned and buffered in the ACE. Each CSS axis signal has a linear range of ± 25 degrees. Thus the analog telemetry signal is in saturation for sun angles greater than 25.6 degrees from the CSS null axis. In the saturated region the proper sense is indicated with 0.0 VDC output for negative spacecraft rotations and 5.12 VDC output for positive rotations. Identical circuits are used to derive each telemetry point, with a typical circuit illustrated in Figure 3.7-5.

3.7.1.15 TAM Error Signal Monitors

TAM 1 Roll Error Signal	(MACS-50)
TAM 1 Pitch Error Signal	(MACS-51)
TAM 1 Yaw Error Signal	(MACS-52)
TAM 2 Roll Error Signal	(MACS-53)
TAM 2 Pitch Error Signal	(MACS-54)
TAM 2 Yaw Error Signal	(MACS-55)

These telemetry points monitor the sensed magnetic field in each of three axes with independent signals being generated by TAM 1 and TAM 2. Telemetry outputs of 0 to 5 VDC are derived from sensed magnetic fields in the range ± 1000 milligauss. Identical circuits are used to derive each telemetry point, with a typical circuit illustrated in Figure 3.7-6.

3.7.1.16 Magnetic Torquer Drive Monitors

Roll MAG Torq Drive A	(MACS-56)
Roll MAG Torq Drive B	(MACS-57)
Pitch MAG Torq Drive A	(MACS-58)
Pitch MAG Torq Drive B	(MACS-59)
Yaw MAG Torq Drive A	(MACS-60)
Yaw MAG Torq Drive B	(MACs-61)

These telemetry points monitor the current being used to drive the magnetic torquers, after being conditioned and buffered by the ACE. Similar circuits are used to monitor each axis with a typical derivation circuit illustrated in Figure 3.3-7. Each roll/pitch magnetic torquer drive current provided by the ACE has a linear range of ± 57.8 ma, corresponding to a magnetic dipole range of $\pm 65{,}300$ pole-cm. Each yaw magnetic torquer drive current produced by the ACE has a linear range of ± 143.5 ma, corresponding to a magnetic dipole range of $\pm 67{,}500$ pole-cm.

3.7.1.17 IRU Rate Monitors

IRU Roll Rate 1	(MACS-62)
IRU Pitch Rate 1	(MACS-63)
IRU Yaw Rate 1	(MACS-64)
IRU Roll Rate 2	(MACS-65)
IRU Pitch Rate 2	(MACS-66)
IRU Yaw Rate 2	(MACS-67)

These telemetry points monitor the three axes rate signals 1 and 2 from the IRU, after being conditioned and buffered in the ACE. Each IRU analog telemetry rate signal is linear over the range ± 1.0 deg/sec, remains saturated at 0 VDC over the range -2.0 to -1.0 deg/sec, and remains saturated at 5.1 VDC from 1.0 to 2.0 deg/sec. No useful telemetry is available for rates greater than ± 2.0 deg/sec. Identical circuits are use' to monitor each axis with a typical derivation circuit illustrated in Figure 3.7-8.

3.7.1.18 SRW Drive Control Voltage Monitors

Roll SRW Drive Control	(MACS-68)
Pitch SRW Drive Control	(MACS-69)
Yaw SRW Drive Control	(MACS-70)
Skew SRW Drive Control	(MACS-71)

These telemetry points monitor SRW drive control voltage for each ACE wheel drive electronics channel, with a linear range from 0 to 10.2 VDC. Identical circuits are used to derive each telemetry point, with a typical circuit illustrated in Figure 3.7-9.

3.7.1.19 SRW Motor Voltage Monitors

Roll SRW Motor Volts	(MACS-72)
Pitch SRW Motor Volts	(MACS-73)
Yaw SRW Motor Volts	(MACS-74)
Skew SRW Motor Volts	(MACS-75)

These telemetry points monitor SRW motor voltage for each ACE wheel drive electronics channel, with a linear range from 0 to 25.5 VDC. Identical circuits are used to derive each telemetry point, with a typical circuit illustrated in Figure 3.7-9.

3.7.1.20 SRW Wheel Speed Monitors

Roll SRW TACH A	(MACS-76)
Pitch SRW TACH A	(MACS-77)
Yaw SRW TACH A	(MACS-78)
Skew SRW TACH A	(MACS-79)
Roll SRW TACH B	(MACS-80)
Pitch SRW TACH B	(MACS-81)
Yaw SRW TACH B	(MACS-82)
Skew SRW TACH B	(MACS-83)

These telemetry points monitor SRW TACH output after being conditioned and buffered in the ACE. TACH output is linear over the range $\pm$2400 rpm and is derived as shown in Figure 3.7-10.

3.7.1.21 ACE $\pm$5 V Regulated Voltage Monitor

ACE A/B +5 V REG Voltage (MACS-84)

This telemetry point monitors the ACE A/B +5 V regulated voltage and is derived as shown in Figure 3.7-11. The relationship between the +5 V regulated voltage and the telemetered signal is as follows:

$$V_{+5V\ TLM} = V_{+5\ REG}/2$$

The nominal value of the +5 V regulated voltage is +5 $\pm$0.5 VDC.

3.7.1.22 ACE +15 V Regulated Voltage Monitor

ACE A/B +15 V REG Voltage (MACS-85)

This telemetry point monitors the ACE A/B +15 V regulated voltage and is derived as shown in Figure 3.7-12. The relationship between the +15 V regulated voltage and the telemetered signal is as follows:

$$V_{+15\ TLM} = V_{+15\ REG}/6$$

The nominal value of the +15 V regulated voltage is +15 $\pm$0.5 VDC.

3.7.1.23 ACE -15 V Regulated Voltage Monitor

ACE A/B -15 V REG Voltage (MACS-86)

This telemetry point monitors the ACE A/B -15 V regulated voltage and is derived as shown in Figure 3.7-12. The telemetered signal is also dependent on the +15 V regulated voltage in accordance with the following relationship:

$$V_{-15\ TLM} = \frac{2.625\ V_{+15\ REG} + V_{-15\ REG}}{9.662}$$

The nominal value of the -15 V regulated voltage is -15 ±1.5 TBC.

3.7.1.24 ACE +28 V Regulated Voltage Monitor

ACE A/B +28 V REG Voltage (MACS-87)

This telemetry point monitors the ACE A/B +28 V regulated voltage and is derived as shown in Figure 3.7-13. The relationship between the +28 V regulated voltage and the telemetered signal is as follows:

$$V_{+28\ TLM} = V_{+28\ REG}/11$$

The nominal value of the +28 V regulated voltage is +28 ±2.8 TBC.

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3.7.1.25 ACE -18 V Regulated Voltage Monitors

ACE A -18 V REG Voltage (MACS-88)
ACE B -18 V REG Voltage (MACS-89)

These telemetry points monitor the ACE A/B -18 V regulated voltage and is derived as shown in Figure 3.7-14. The telemetered signal is also dependent on the +15 V regulated voltage in accordance with the following relationship:

$$V_{-18\ TLM} = \frac{3.2425 \times V_{-15\ REG} + V_{-18\ REG}}{12.5}$$

The nominal value of the -18 V regulated voltage is -18 $\pm$1.8 VDC.

3.7.1.26 ACE Compensated TAM Signal Monitors

ACE A TAM Roll Compensated Signal	(MACS-90)
ACE A TAM Pitch Compensated Signal	(MACS-91)
ACE A TAM Yaw Compensated Signal	(MACS-92)
ACE B TAM Roll Compensated Signal	(MACS-93)
ACE B TAM Pitch Compensated Signal	(MACS-94)
ACE B TAM Yaw Compensated Signal	(MACS-95)

These telemetry points monitor the compensated TAM signals used by the ACE, and includes compensation for magnetic torquer field couping together with the addition of any TAM bias signals. Identical circuits are used to derive each monitor, with a typical circuit illustrated in Figure 3.7-15. The compensated TAM signals are linear over the range ± 400 milligauss.

3.7.1.27 ACE IRU Position Monitors

ACE A IRU Roll Position	(MACS-96)
ACE A IRU Pitch Position	(MACS-97)
ACE A IRU Yaw Position	(MACS-98)
ACE B IRU Roll Position	(MACS-99)
ACE B IRU Pitch Position	(MACS-100)
ACE B IRU Yaw Position	(MACS-101)

These telemetry points monitor the three axes gyro position signals after being conditioned and buffered in the ACE. Each analog telemetry position signal is linear over the range ± 58.25 degrees and is derived as shown in Figure 3.7-15.

3.7.2 DIGITAL TELEMETRY MONITORS

The Modular Attitude Control Subsystem utilizes 19 digital telemetry monitors, including 4 bilevel digital and 15 serial digital telemetry points. These points are listed by user ID in Table 3.7-1 and are described in the following paragraphs.

3.7.2.1 FSS 32-Bit Data (MACS-01)

This telemetry function consists of single 32-bit words telemetered in four 8-bit bytes as MACS-01. Included in the 32-bit FSS data are two 14-bit angular data words, sun presence status and FSS power status as defined in Figure 3.7-16, with:

Bits	Acronym	Function
1-14	AFSSOUTY	FSS Angular Data Y-Axis
15	AFSSUNP	FSS sun presence
16		Unused bit
17-30	AFSSONTX	FSS Angular Data X-Axis
31-32	AFSSPWR	FSS Power Status

The FSS maintains current serial data in its output shift register with a maximum time interval between updating of 16 milliseconds. Data word updating is inhibited during data reads until four serial data enables have been received. The Major Frame Rate signal is used as an initialization signal that causes the first byte (bits 1-8) of the FSS serial telemetry word to be transferred to the RIU during the next FSS serial data enable received from the RIU. The FSS serial telemetry output circuit functional block diagram is shown in Figure 3.7-17.

The FSS Y axis sun angle data word is all zeros for a +32 degree rotation about the FSS Y axis and the FSS X axis sun angle shall be all zeros for a -32 degree rotation about the FSS X axis. The coding format of FSS serial telemetry word angle data bits is in Unsigned Integer Binary format as indicated in Figure 3.7-18.

3.7.2.2 IRU 144-Bit Data

ACE A 144 Bit IRU Data (MACS-02)
ACE B 144 Bit IRU Data (MACS-10)

These telemetry functions consist of a single 144-bit IRU data word telemetered in 18 8-bit bytes. The 144-bit IRU data is comprised of six 24-bit position words, i.e., channel 1 and 2 roll, pitch and yaw signals, as shown in Figure 3.7-19. The IRU position word can be processed to the telemetry downlink via the C&DH RIU in the Computer Mode. In the IRU Low Rate Mode the IRU Posn Word LSB is equal to 0.05 arc seconds and the word range is ±116.5 degrees. In the IRU High Rate Mode the IRU Posn Word LSB is equal to 0.8 arc sec and the word range is ±1864 degrees. The ACE ITP maintains current IRU data in its memory with a maximum time interval between updating of 16 milliseconds with no interference from data word updating during data reads. The Major Frame Rate signal is used as an initialization sync that causes the first byte of the IRU Posn Word to be transferred to the RIU during the next IRU Position Serial Data Enable received from the RIU.

3.7.2.3 SRW 64-Bit TACH Data

ACE A 64 Bit TACH Data (MACS-03)
ACE B 64 Bit TACH Data (MACS-11)

The TACH Serial Data word is defined in Figure 3.7-20. Eight successive Serial Data telemetry requests in the Supervisory Line RIU Channel Address-Computer Only slots will transfer the four 16 bit TACH words, in the 8 bit byte order shown in Figure 3.7-20, from the ACE via the RIU and over the Reply Line to the CU and OBC. In the Computer Mode the TACH Serial Data word can be processed from the OBC to the telemetry downlink via the C&DH RIU. Each TACH LSB is equal to 1/240 SRW revolution. Each TACH 16 bit word range is $\pm$32,767/240 = 136.53 revolutions, ample margin considering the 40 Rev/sec SRW sync speed. the ACE ITP maintains current TACH Serial Data in its memory with a maximum time interval between updating of 16 milliseconds and with no interference from data word updating during data reads. The Major Frame Rate signal is used as an initialization sync that causes the first byte of the TACH word to be transferred to the RIU during the next TACH Serial Data Enable received from the RIU. The TACH Serial Data word should not be enabled from the RIU when the MACS is operating in the Safehold Mode.

3.7.2.4 ACE Component Status

ACE A Component Status (MACS-04)
ACE B Component Status (MACS-12)

Component Status Serial Telemetry is provided as shown in Figure 3.7-21, which consists of two 8-bit bytes. This telemetry function defines or partially defines magnetic torquer drive, heater power and the status of the ACE 4 Hz clock. The magnetic torquer power bit is an indication that the 15 V has been switched to the corresponding torquer drive electronics. A logic "1" indicatess 15 V power on. The heater power bit is derived from the PSU relay contact indicating 28 V power has been switched to the corresponding heater circuit, where a logic "0" indicates heater power on. The ACE 4 Hz clock bits are derived from a countdown of the RIU 1.024 MHz clock and are interpreted as shown in the truth table of Figure 3.7-21.

Two successive Serial Data telemetry requests in the Supervisory Line RIU Channel Address TM/Computer slots transfer the 16 bit Component Status Serial Data word in two 8 bit bytes, in the order shown in Figure 3.7-21, from the ACE to the RIU and over the Reply Line to the CU. The C&DH Telemetry format control will process the SDD to both the OBC and telemetry downlink. The Component Status Serial Data is maintained current in the ACE output shift requester and data word updating is inhibited during data reads. The Major Frame Rate signal is used as an initialization signal that causes the first byte of the Component Status Serial Data word to be transferred during the next Component Status Serial Data Enable received from the RIU.

3.7.2.5 ACE Safehold Status

ACE A SHE Status	(MACS-05)
ACE B SHE Status	(MACS-13)

Safehold Status Serial Telemetry is provided as shown in Figure 3.7-22, which consists of three 8-bit bytes. Three successive Serial Data telemetry requests in the Supervisory Line RIU Channel Address TM/Computer slots transfers the 24 bit Safehold Status Serial Data word in three eight bit bytes, in the order shown in Figure 3.7-22, from the ACE to the RIU and over the Reply Line to the CU. The C&DH telemetry format control will process the Serial Data to both the OBC and telemetry downlink. A logic "1" in the Safehold A/B bit in the Safehold Status A/B word is derived from the 5 VDC power switched to the Safehold Electronics A/B and its associated control circuitry. A logic "1" in the Shuttle Retrieval bit is derived from the receipt of the Shuttle Retrieval discrete command and the setting of a bilevel for control in the Safehold mode. The remaining bits in the Safehold Status Serial Data word are derived from the receipt of SM command 4/7 and the setting of applicable bilevels for selection of sensor inputs and thruster control in the Safehold mode. The Safehold Status Serial Data is maintained current in the ACE output shift register and data updating is inhibited during data reads. The Major Frame Rate signal is used as an initialization signal that causes the first byte of the Safehold Status Serial Data word to be transferred during the next Safehold Status Serial Data Enable received from the RIU.

3.7.2.6 FHST Serial Telemetry

FHST 1 Word 1 16-Bit Data	(MACS-06)
FHST 1 Word 2 16-Bit Data	(MACS-07)
FHST 2 Word 1 16-Bit Data	(MACS-08)
FHST 2 Word 2 16-Bit Data	(MACS-09)

FHST 1/FHST 2 Serial Telemetry consists of two 16-bit words as defined in Figure 3.7-23. The FHST data interface with the RIU is shown in the functional block diagram of Figure 3.7-24. Two successive Serial Data Channel 8 and two successive Channel 9 telemetry requests in the Supervisory Line RIU Channel Address TM/Computer slots will transfer the Serial Data from the FHST 1 via the RIU and over the Reply Line to the CU. The C&DH telemetry format control will process the Serial Data to both the OBC and telemetry downlink. The OBC can also receive the FHST 1 Serial Data in response to Telemetry Address requests in the Supervisory Line RIU Channel Address, Computer Only, slots. Similarly for FHST 2 via channels 10 and 11. In each case the Minor Frame Rate Signal is employed as an initialization signal that causes the first byte (bits 1-8) of each FHST data word to be transferred during the next corresponding SDD Enable signal.

Each FHST word is transferred MSB first with data bits 1 through 12 in 2's Complement format. Each of the remaining status bits in Figure 3.7-23 are true when a logic 1 is present on the Serial Data word.

3.7.2.7 <u>ACE 24-Bit Computer/Pays Status Word</u>

ACE A 24-Bit Computer/Pays Word 1 (MACS-14)
ACE B 24-Bit Computer/Pays Word 1 (MACS-15)

Computer/Pays Status Serial Telemetry is provided as shown in Figure 3.7-25, which consists of three 8-bit bytes. Three successive telemetry requests in Supervisory Line RIU Channel Address TM/Computer slots transfers the 24 bit Serial Data word in three 8 bit bytes in the order shown in Figure 3.7-25, from the ACE to the RIU and over the Reply LIne to the CU. The C&DH telemetry format control will process the Serial Data to both the OBC and telemetry downlink. The four most significant bits of this status word indicate the receipt of an OBC Enable or Payload Sensor (Fine Error Sensor) Enable Select Command for reaction wheel control in the computer mode. (It should be noted that the reaction wheels respond to Safehold Electronics inputs in the Safehold Mode regardless of the Serial Data status telemetry indication.) The fifth and sixth most significant bits of this status Serial ~~Data~~ word indicate the position of Separation Switch A and Separation Switch B and the remaining bits are spares. The status data is maintained current in the ACE output shift register and data word updating is inhibited during data reads. The Major Frame Rate signal is used as an initialization signal that causes the first byte of the Status Serial Data word to be transferred during the next Computer/Pays SDD Enable received from the RIU.

3.7.2.8 Bilevel Word 01 (MACS-16)

This telemetry function consists of eight bilevel status bits combined to form telemetry word MACS-16. The bits define or partially define the status of the IRU and star trackers. Bilevel word 01 is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<------------MACS-16------------->							
Bit ID	B0	B1	B2	B3	B4	B5	B6	B7

Bit	Function
B0	IRU Channel A Range Low/High
B1	IRU Channel B Range Low/High
B2	IRU Channel C Range Low/High
B3	IRU Channel A Power On/Off
B4	IRU Channel B Power On/Off
B5	IRU Channel C Power On/Off
B6	FHST 1 Power On/Off
B7	FHST 2 Power On/Off

Bits 0, 1 and 2 indicate IRU channel A, B and C rate range respectively. Each IRU range status bilevel is derived from a corresponding relay contact in the IRU. An open relay contact corresponds to a bilevel zero, indicating high rate range.

		Bilevel Status	
Bit	Acronym	1	0
B0	AIRUARNG	Low Rate	High Rate
B1	AIRUBRNG	Low Rate	High Rate
B2	AIRUCRNG	Low Rate	High Rate

Bits 3 thru 7 indicate IRU channel, FHST-1 and FHST-2 power status. Each power status bilevel is derived from the corresponding latching relay position in the PSU. A telemetry contact in parallel with each PSU contact, switching power to each IRU channel or FHST, provides the ACE with a logic signal which it conditions and buffers. Bilevel status is defined as:

		Bilevel Status	
Bit	Acronym	1	0
B3	AIRUAPWR	On	Off
B4	AIRUBPWR	On	Off
B5	AIRUCPWR	On	Off

B6	AST1PWR	On	Off
B7	.ST2PWR	On	Off

3.7.2.9 Bilevel Word 02 (MACS-17)

This telemetry function consists of eight bilevel status bits combined to form telemetry word MACS-19. The bits define or partially define the status of the TAM power, ACE power, launch mode, solar array index and CSM timer. Bilevel word 02 is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<------------MACS-16-------------->							
Bit ID	B0	B1	B2	B3	B4	B5	B6	B7

Bit	Function
B0	TAM 1 Power On/Off
B1	TAM 2 Power On/Off
B2	ACF A Power On/ACE B Power On
B3	Launch Mode A Yes/No
B4	S/A Index 1 Status
B5	S/A Index 2 Status
B6	CSM A Timer Timeout/No Timeout
B7	CSM B Timer Timeout/No Timeout

Bits 0 and 1 indicate TAM 1 and TAM 2 power status respectively. A telemetry contact in parallel with each ACE relay contact, switching power to each TAM, provides the logic signal which the ACE conditions and buffers for telemetry.

Bit	Acronym	Bilevel Status 1	0
B0	ATAM1PWR	On	Off
B1	ATAM2PWR	On	Off

Bit 2 indicates ACE A/B power status. ACE logic converts the ACE A and B +5 VDC regulated voltage to a bilevel output defined as follows:

Bit	Acronym	Bilevel Status 1	0
B2	AAONBOFF	ACE A On	ACE B On

Bit 3 indicates launch mode A status, derived from separation switch logic and the separation signal override discrete command.

Bit	Acronym	Bilevel Status 1	0
B3	ALMA	Yes	No

Bits 4 and 5 indicate solar array index switch positions defined as follows:

Bit	Acronym	Bilevel Status 1	0
B4	ASAIND1	Open	Closed
B5	ASAIND1	Open	Closed

Bits 6 and 7 indicate an interruption in the OBC discrete command pulse train to the ACE as derived by each CSM timer. Once having timed out, the CSM timer may be reset by the corresponding CSM inhibit discrete command.

Bit	Acronym	Bilevel Status 1	0
B6	ACSMATM	Timeout	No Timeout
B7	ACSMBTM	timeout	No Timeout

3.7.2.10 Bilevel Word 03 (MACS-18)

This telemetry function consists of eight bilevel status bits combined to form telemetry word MACS-18. The bits define or partially define CSM, SRW and launch mode B status. Bilevel word 03 is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<------------MACS-18-------------->							
Bit ID	B0	B1	B2	B3	B4	B5	B6	B7

Bit	Function
B0	CSM A Inhibited/Enabled
B1	CSM B Inhibited/Enabled
B2	Roll Wheel Enabled/Disabled
B3	Pitch Wheel Enabled/Disabled
B4	Yaw Wheel Enabled/Disabled
B5	Skew Wheel Enabled/Disabled
B6	Launch Mode B Yes/No
B7	Unused Bit

The CSM inhibit bilevel telemetry (B0, B1) is derived from the corresponding CSM inhibit/enable logic as selected via discrete command.

Bit	Acronym	Bilevel Status 1	0
B0	ACSMAED	Inhibited	Enabled
B1	ACSMBED	Inhibited	Enabled

Bits B2 thru B5 indicate reaction wheel status. A wheel enable bilevel becomes a logic 1 only when power has been switched to the corresponding ACE wheel drive electronics and the ACS enable is true.

Bit	Acronym	Bilevel Status 1	0
B2	AXWHED	Enabled	Disabled
B3	AYWHED	Enabled	Disabled
B4	AZWHED	Enabled	Disabled
B5	ASWHED	Enabled	Disabled

Bit 6 indicates launch mode B status, derived from separation switch logic and the separation signal override discrete command.

Bit	Acronym	Bilevel Status 1	0
B6	ALMB	Yes	No

3.7.2.11 Bilevel Word 04 (MACS-19)

This telemetry function consists of eight bilevel status bits combined to form telemetry word MACS-19. The bits define the status of the MACS module remote interface and expander units. Bilevel word 04 is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<------------MACS-19-------------->							
Bit ID	B0	B1	B2	B3	B4	B5	B6	B7

Bit	Function
B0	Unused bit
B1	Unused Bit
B2	Unused Bit
B3	Unused Bit
B4	Unused Bit
B5	Unused Bit
B6	RIU 02 Mate Standby 1/Off
B7	RIU 02 B On/A On

Bits 6 and 7 indicate the status of RIU-EU A/RIU-EU B, either of which can be in one of three modes; Off, Standby 1, or On. Note, both RIU's cannot be on simultaneously. Bit 6 (ARIUMATE) indicates the state of the mate to the current RIU in use. Bit 7 (ARIUID) indicates which RIU is currently in use. Together these two bits define RIU-EU Status, defined as follows:

ARIUID	ARIUMATE	RIU-EU Status	
B7	B6	A	B
0	0	On	Off
0	1	On	Standby 1
1	1	Standby 1	On
1	0	Off	On

C-3

3.7.3 ESAM TELEMETRY

Operation of the Earth Sensor Assembly Module is monitored via 16 active analog telemetry channels. No conditioned (passive) analog, bilevel or serial telemetry is available.

The telemetry points are listed in Table 3.7-3 and described in Paragraphs 3.7.4.1.1 thru 3.7.5.1.4. Telemetry limits appear in Table 3.7-4; derivation circuits appear in Paragraph 3.7.5.3.

Table 3.7-3. ESAM Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
ESAM-01	ESA-1 Pitch Fine Error	EES1YF	A	8	8	04-48	22.7.1.1
ESAM-02	ESA-1 Pitch Coarse Error	EES1YC	A	40	40	04-49	22.7.1.1
ESAM-03	ESA-1 Roll Fine Error	EES1XF	A	72	72	04-50	22.7.1.1
ESAM-04	ESA-1 Roll Coarse Error	EES1XC	A	104	104	04-51	22.7.1.1
ESAM-05	ESA-2 Pitch Fine Error	EES2YF	A	9	9	04-52	22.7.1.1
ESAM-06	ESA-2 Pitch Coarse Error	EES2YC	A	41	41	04-53	22.7.1.1
ESAM-07	ESA-2 Roll Fine Error	EES2XF	A	73	73	04-54	22.7.1.1
ESAM-08	ESA-2 Roll Coarse Error	EES2XC	A	105	105	04-55	22.7.1.1
ESAM-09	ESA-1 Signal Status	EES1SIG	A	38	38	04-59	22.7.1.2
ESAM-10	ESA-2 Signal Status	EES2SIG	A	102	102	04-62	22.7.1.2
ESAM-11	ESA-1 Sensor Status	EES1SEN	A	99(6)[1]	99(6)[1]	04-57	22.7.1.3
ESAM-12	ESA-2 Sensor Status	EES2SEN	A	99(22)[2]	99(22)[2]	04-58	22.7.1.3
ESAM-13	ESA-1 Temperature	EES1TMP	A	33(44)	33(44)	04-56	22.7.1.4
ESAM-14	ESA-2 Temperature	EES2TMP	A	33(46)	33(46)	04-63	22.7.1.4
ESAM-15	ESA-1 Bolometer Temperature	EES1BTMP	A	33(47)	33(47)	04-60	22.7.1.4
ESAM-16	ESA-2 Bolometer Temperature	EES2BTMP	A	33(48)	33(48)	04-61	22.7.1.4

*1 Sample Rate = 4; also sampled in minor frames 38, 70, 102
*2 Sample Rate = 4; also sampled in minor frames 54, 86, 118

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Table 3.7-4. ESAM Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	Eng. Units
ESAM-13	ES11TMP	ES1 PWR ESA	0	35	°C
ESAM-14	ES12TMP	ES2 PWR ESA	0	35	°C
ESAM-15	ES11BTMP	ES1 PWR ESA	0	45	°C
ESAM-16	ES12BTMP	ES2 PWR ESA	0	45	°C

* For those functions not listed, full scale telemetry limits apply

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3.7.4 TELEMETRY DERIVATION CIRCUITS

This section provides functional schematics of the telemetry circuits referenced in the preceding paragraphs. The schematics have been simplified and are provided as an aid to understanding the telemetry interface.

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3.7.3.1 Analog Telemetry Monitors

The Earth Sensor Assembly Module utilizes 16 active analog telemetry points. These points are listed by user ID in Table 3.7-3 and 3.7-4 for telemetry matrix location and operating limits respectively. The following paragraphs describe these telemetry monitors.

3.7.3.1.1 Attitude Monitors

ESA-1 Pitch Fine Error	(ESAM-01)
ESA-1 Pitch Coarse Error	(ESAM-02)
ESA-1 Roll Fine Error	(ESAM-03)
ESA-1 Roll Coarse Error	(ESAM-04)
ESA-2 Pitch Fine Error	(ESAM-05)
ESA-2 Pitch Coarse Error	(ESAM-06)
ESA-2 Roll Fine Error	(ESAM-07)
ESA-2 Roll Coarse Error	(ESAM-08)

These telemetry points monitor the spacecraft pitch and roll attitude errors as measured by earth sensor ESA-1 and ESA-2. A coarse and fine telemetry point is provided in each axis with approximate slopes of 50 mv/deg and 500 mv/deg respectively. Coarse telemetry becomes saturated at approximately ± 35 degrees while fine saturation occurs at ± 5 degrees. A circuit typical of the derivation of these telemetry points is presented in Figure 3.7-26.

3.7.3.1.2 Signal Status Monitors

ESA-1 Signal Status	(ESAM-09)
ESA-2 Signal Status	(ESAM-10)

These telemetry points monitor the status of Earth Sensor ESA-1 and ESA-2 attitude signals. Each telemetry point consists of four bi-levels combined into one analog signal indicating the status of:

	Logic	State
ESA Logic	1 = Enable	0 = Disable
Horizon Crossing Trailing Edge	1 = Present	0 = Not Present
Horizon Crossing Leading Edge	1 = Present	0 = Not Present
Horizon Crossing	1 = Normal	0 = Reversed

The bi-levels are combined as follows:

Signal status (volts) = c[1.0(ESA logic state) +2.0 (trailing edge logic state) + 4.0 (leading edge logic sate + 8.0 (horizon crossings logic state)]

c = 0.333 (volts)

The normal on orbit configuration will be such that all indicators are at a logic level 1, resulting in a signal status voltage of 5.00 volts. The signal status telemetry is formed from the logic circuit shown in Figure 3.7-27.

3.7.3.1.3 Sensor Status Monitors

ESA-1 Sensor Status (ESAM-11)
ESA-2 Sensor Status (ESAM-12)

These telemetry points monitor the operating status of Earth Sensor ESA-1 and ESA-2. Each telemetry point consists of four bi-levels combined into one analog signal indicating the status of:

	Logic State	
ESA Heater	1 = Disable	0 = Enabled
ESA Power	1 = Enabled	0 = Disabled
Scanner Rotation	1 = No Rotation	0 = Rotation
Sun Presence	1 = Not Present	0 = Present

The bi-levels are combined as follows:

Sensor status (volts) = c[1.0(Heater logic state) +2.0 (power logic state) + 4.0 (scanner rotation logic sate + 8.0 (sun presence logic state)]

c = 0.333 (volts)

The normal on orbit configuration will be with the heater disabled, power on, scanner rotating and no sun presence, corresponding to a sensor status voltage of 3.66 volts. The sensor status telemetry signal is formed from the logic circuit shown in Figure 3.7-28.

3.7.3.1.4 Temperature Monitors

ESA-1 Temperature	(ESAM-13)
ESA-2 Temperature	(ESAM-14)
ESA-1 Bolometer Temperature	(ESAM-15)
ESA-2 Bolometer Temperature	(ESAM-16)

These telemetry points monitor Earth Sensor ESA-1 and ESA-2, Assembly and Bolometer temperatures. The assembly temperature telemetry is a monitor of the temperature external to the Earth Sensor scanners, positioned such that it measures the same temperature regulating heater operation. The Bolometer temperature is a monitor of the temperature internal to the scanner. Identical circuits are used to monitor both temperatures as illustrated in Figure 3.7-29.

3.7.3.2 Digital Telemetry Monitors

No digital bi-level or serial telemetry is available from the Earth Sensor Assembly Module.

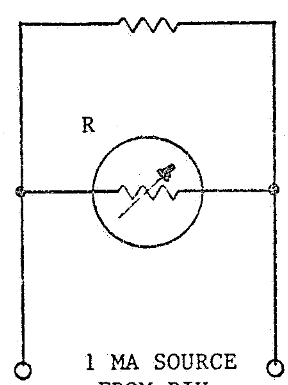

Figure 3.7-1. Passive Analog Temperature Telemetry

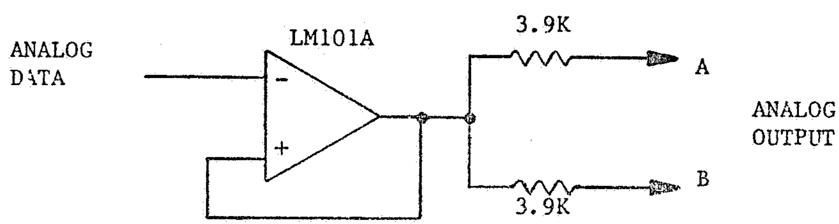

Figure 3.7-2. FHST Analog Telemetry

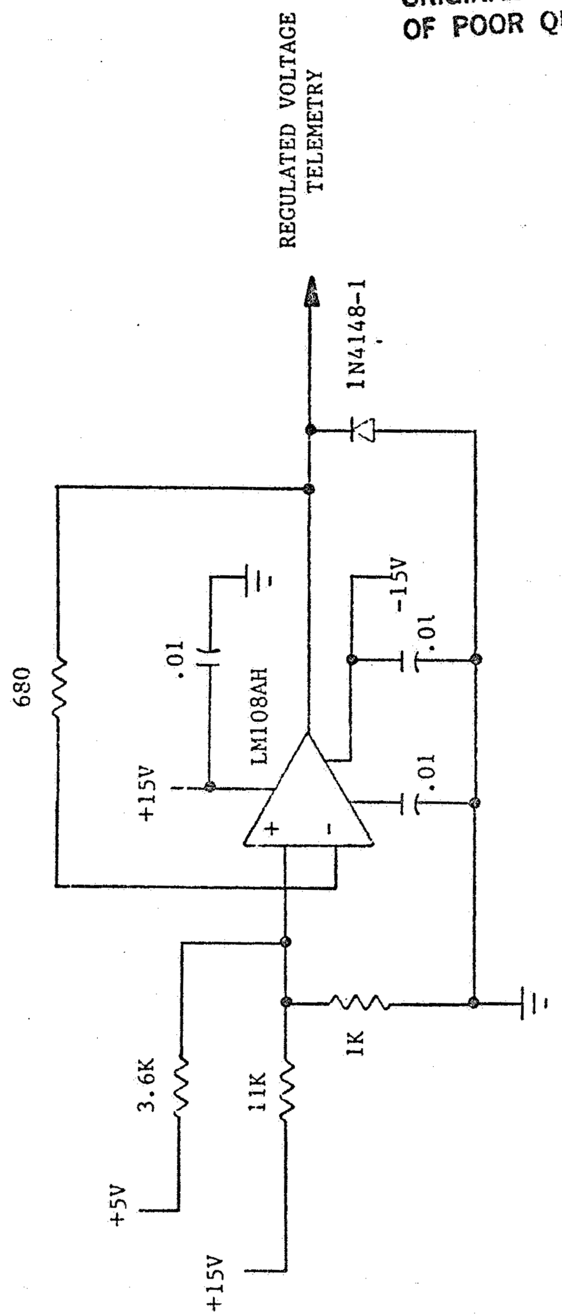

FIGURE 3.7-3 IRU REGULATED VOLTAGE TELEMETRY

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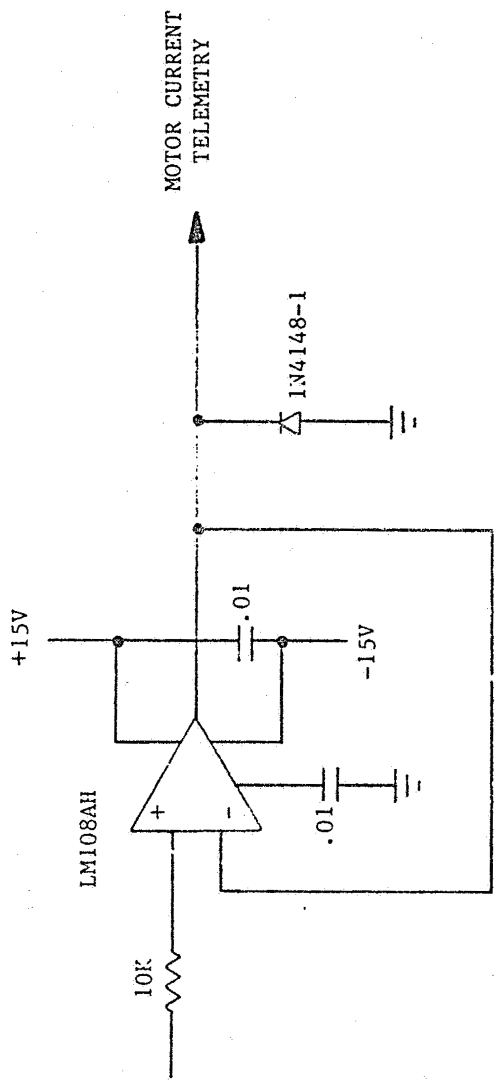

FIGURE 3.7-4 IRU MOTOR CURRENT TELEMETRY

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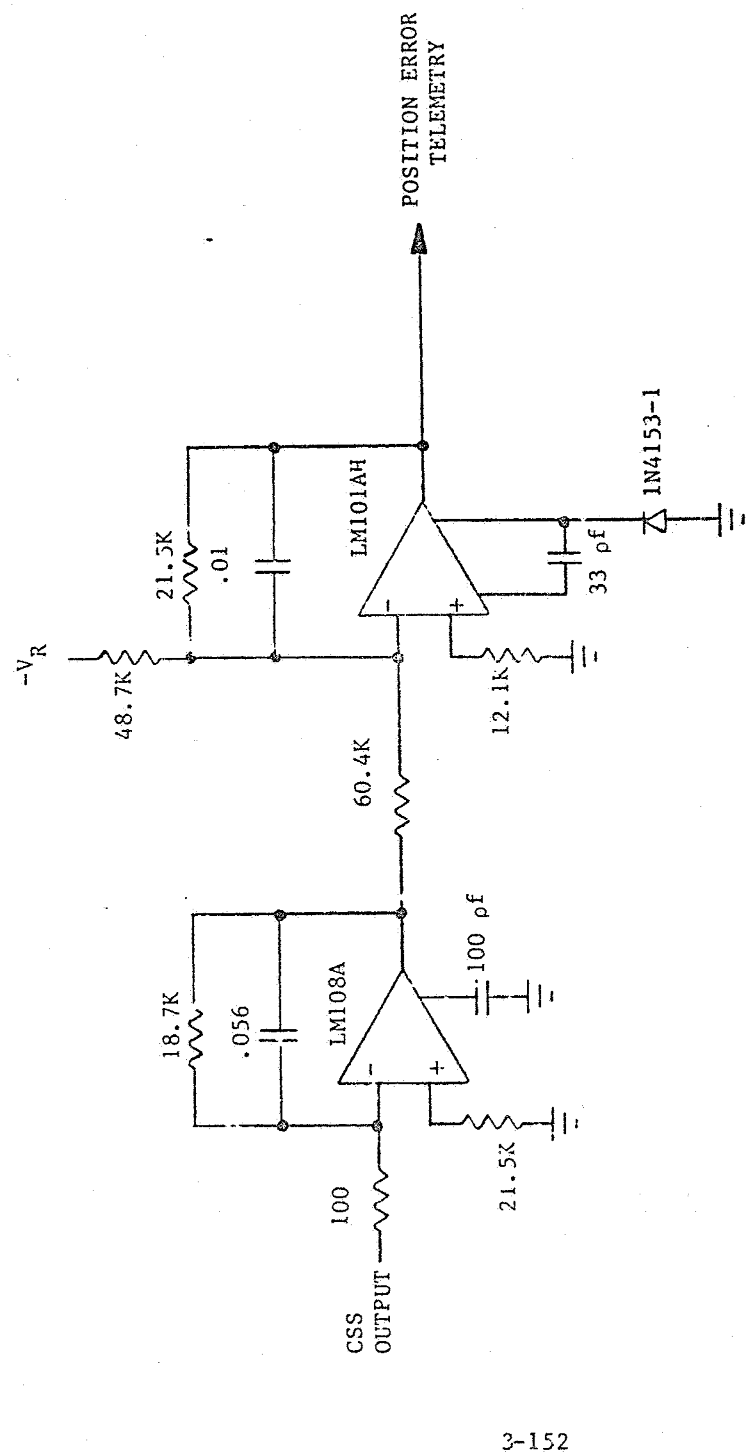

FIGURE 3.7-5 CSS POSITION ERROR TELEMETRY

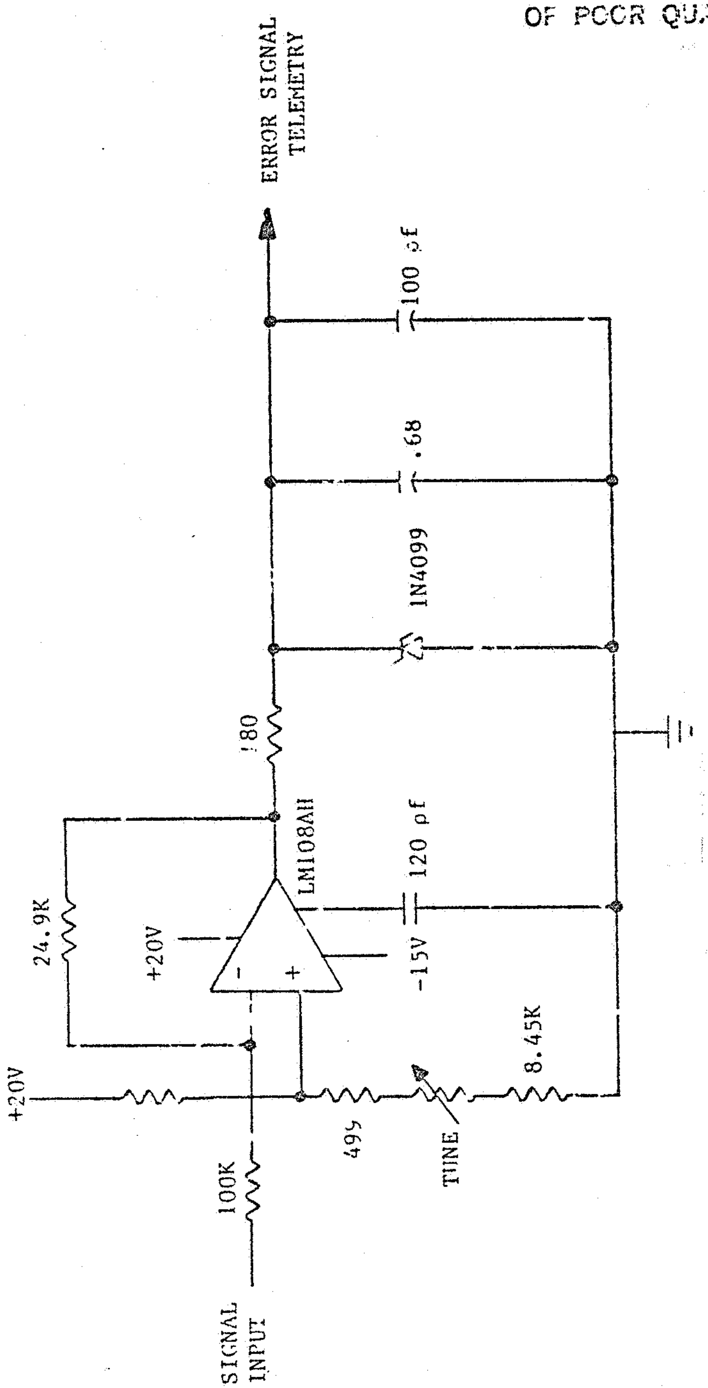

FIGURE 3.7-6 T/M ERROR SIGNAL TELEMETRY

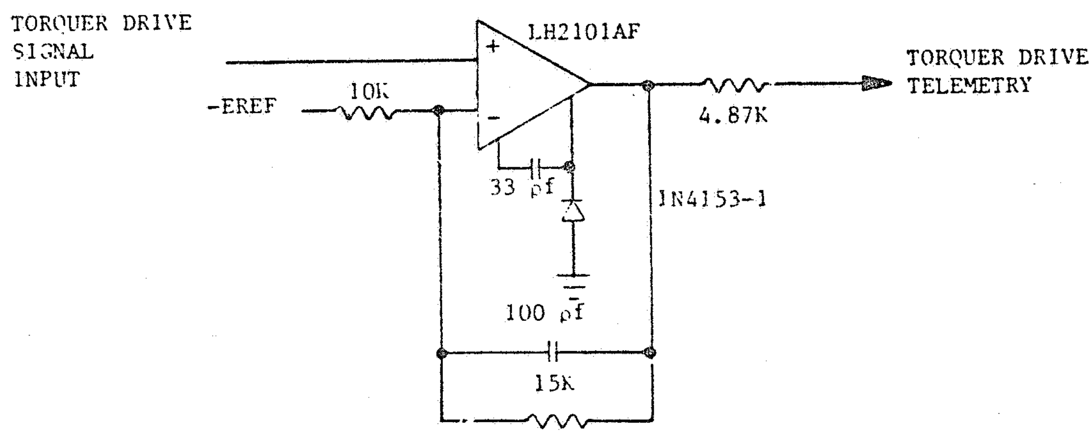

Figure 3.7-7. Magnetic Torquer Drive Telemetry

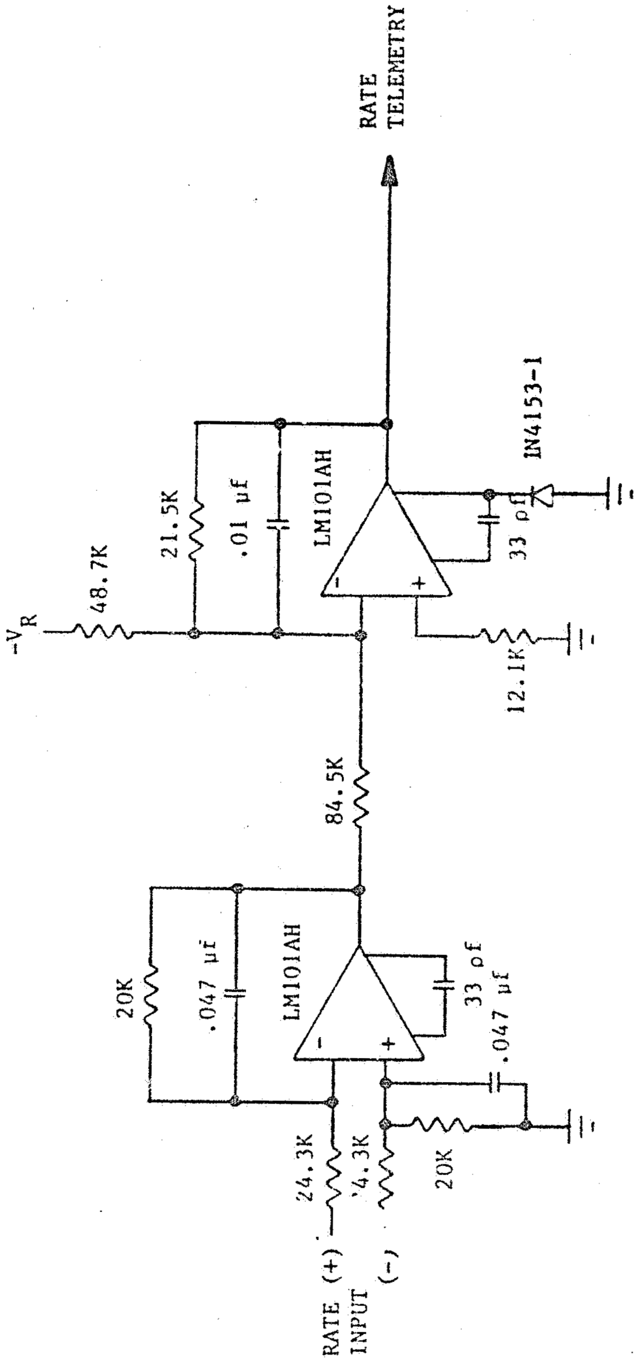

FIGURE 3.7-8 ACE IRU RATE TELEMETRY

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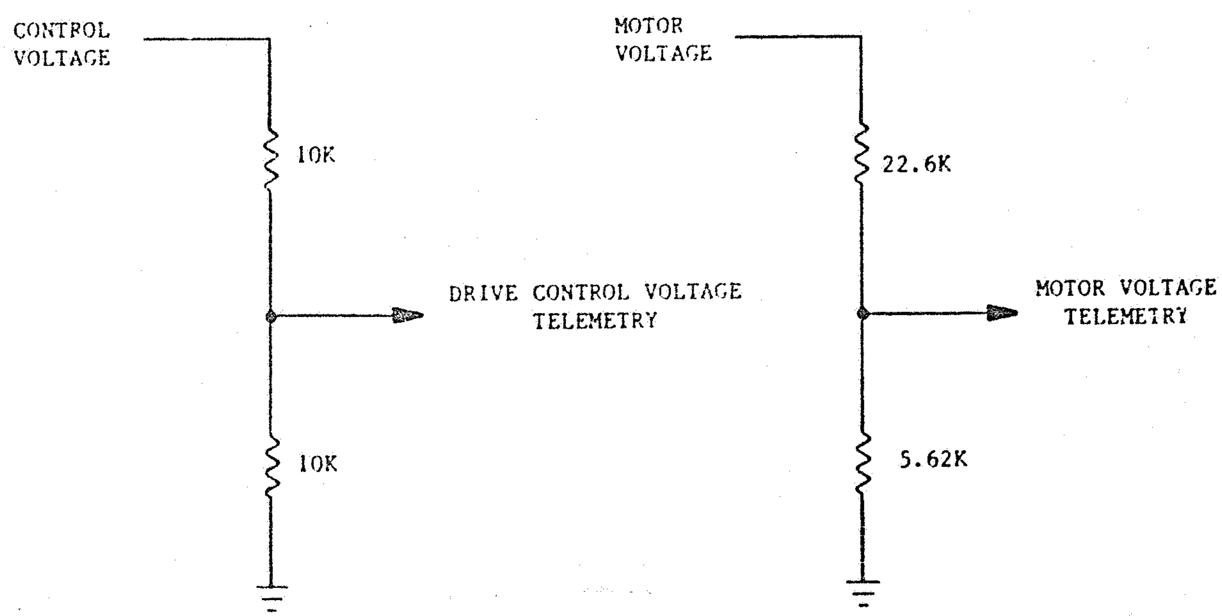

FIGURE 3.7-9   SRW DRIVE CONTROL/MOTOR VOLTAGE TELEMETRY

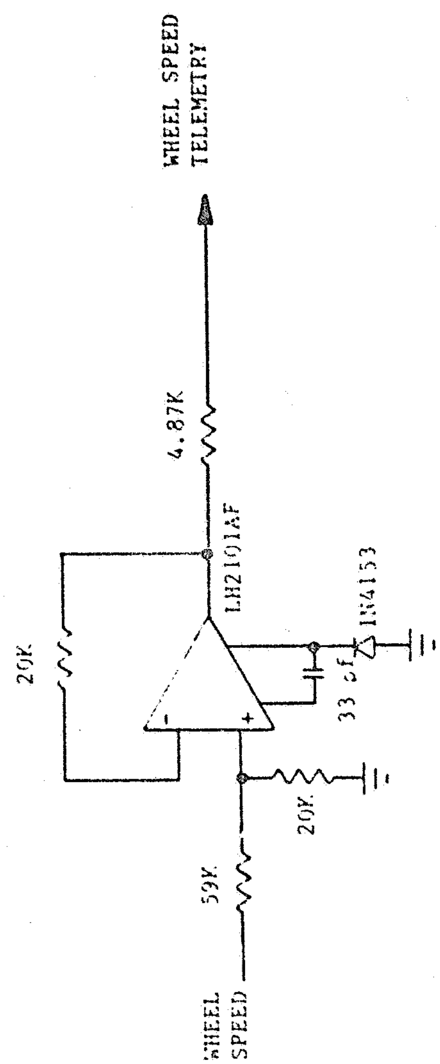

FIGURE 3.7-10 SRW WHEEL SPEED TELEMETRY

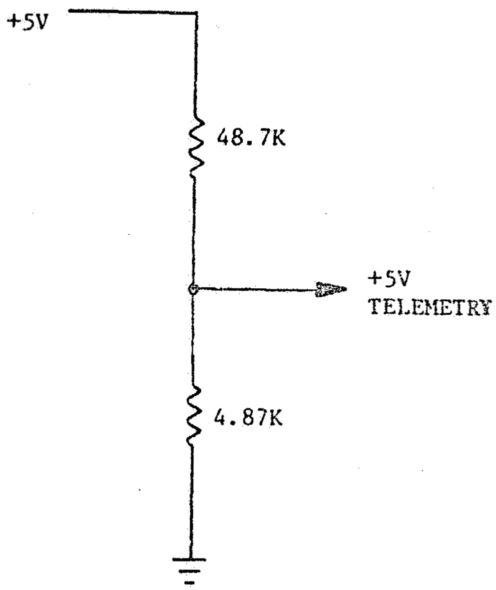

Figure 3.7-11. ACE +5 Volt Telemetry

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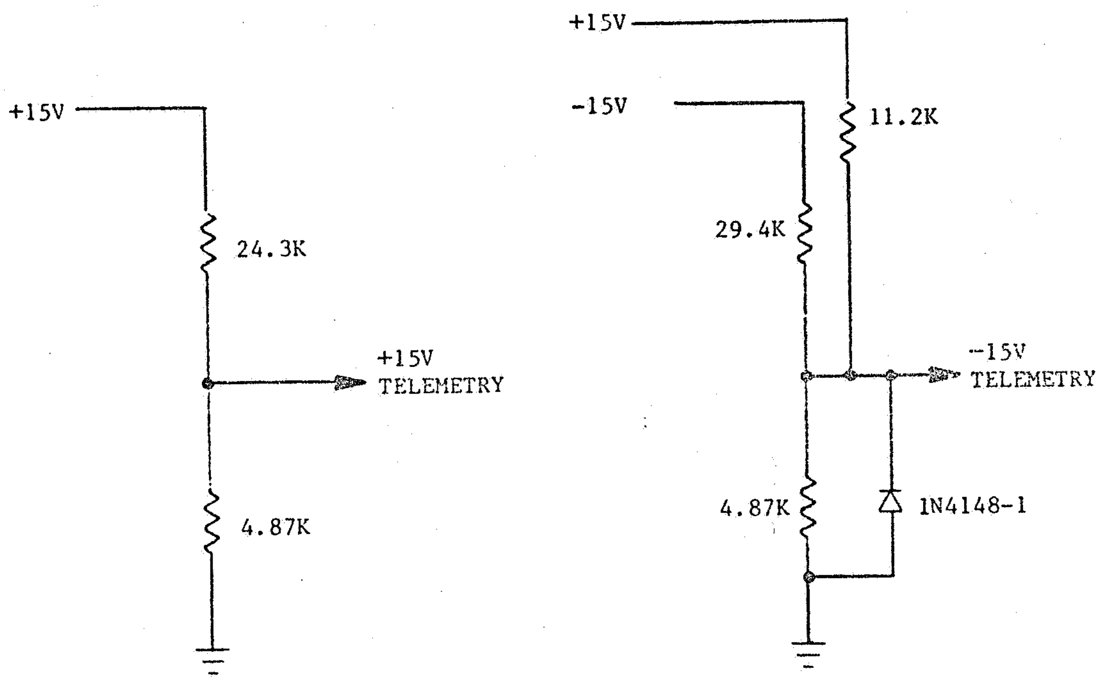

Figure 3.7-12. ACE $\pm$15 Volt Telemetry

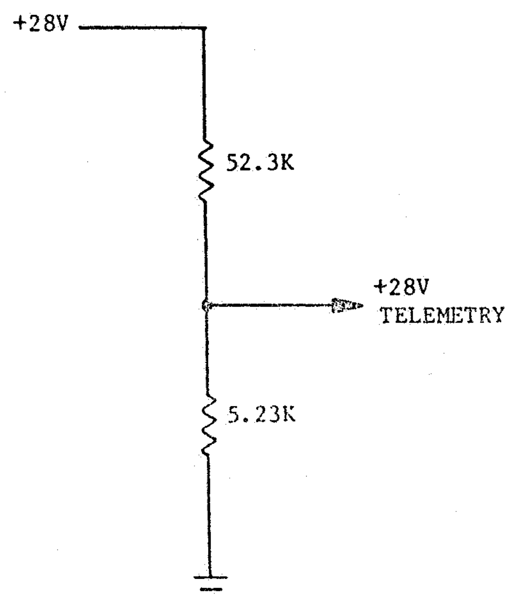

Figure 3.7-13. ACE +28 Volt Telemetry

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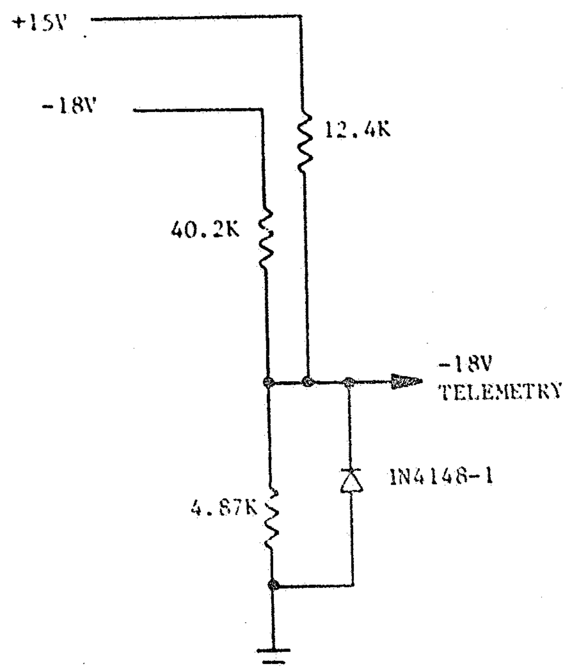

Figure 3.7-14. ACE -18 Volt Telemetry

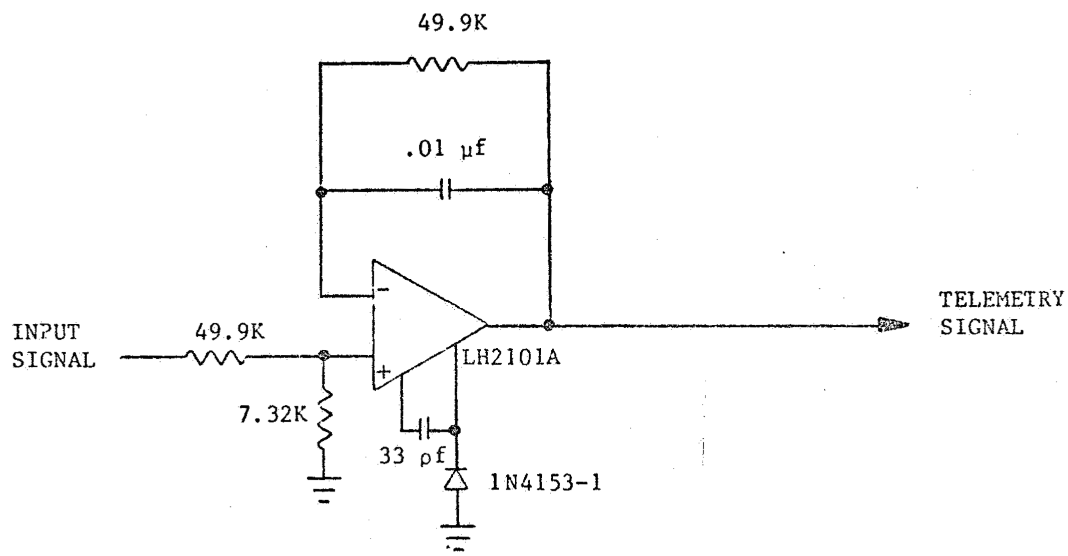

Figure 3.7-15. ACE Compensated TAM/IRU Position Telemetry

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32–31	30–17	16	15	14–1	BIT
PWR STATUS	SUN ANGLE FROM FSS OPTICAL AXIS OPTICAL AXIS ROTATION ABOUT FSSX AXIS SDD MSB IN BIT 17		SUN PRESENCE	SUN ANGLE FROM FSS OPTICAL AXIS OPTICAL AXIS ROTATION ABOUT FSS YAXIS SDD MSB IN BIT 1	MSB SHIFT → OUT FIRST

. . SUN ANGLE DATA BITS IN UNSIGNED INTEGER BINARY FORMAT (SEE TABLE 5.2-7)

POWER STATUS

	BIT 31	BIT 32
OFF	1	1
ON	1	0

SUN PRESENCE
(WHEN FSS PWR ON)

BIT	15
	0
SUN ACQUIRED	1

Figure 3.7-16 FSS SERIAL TELEMETRY FORMAT

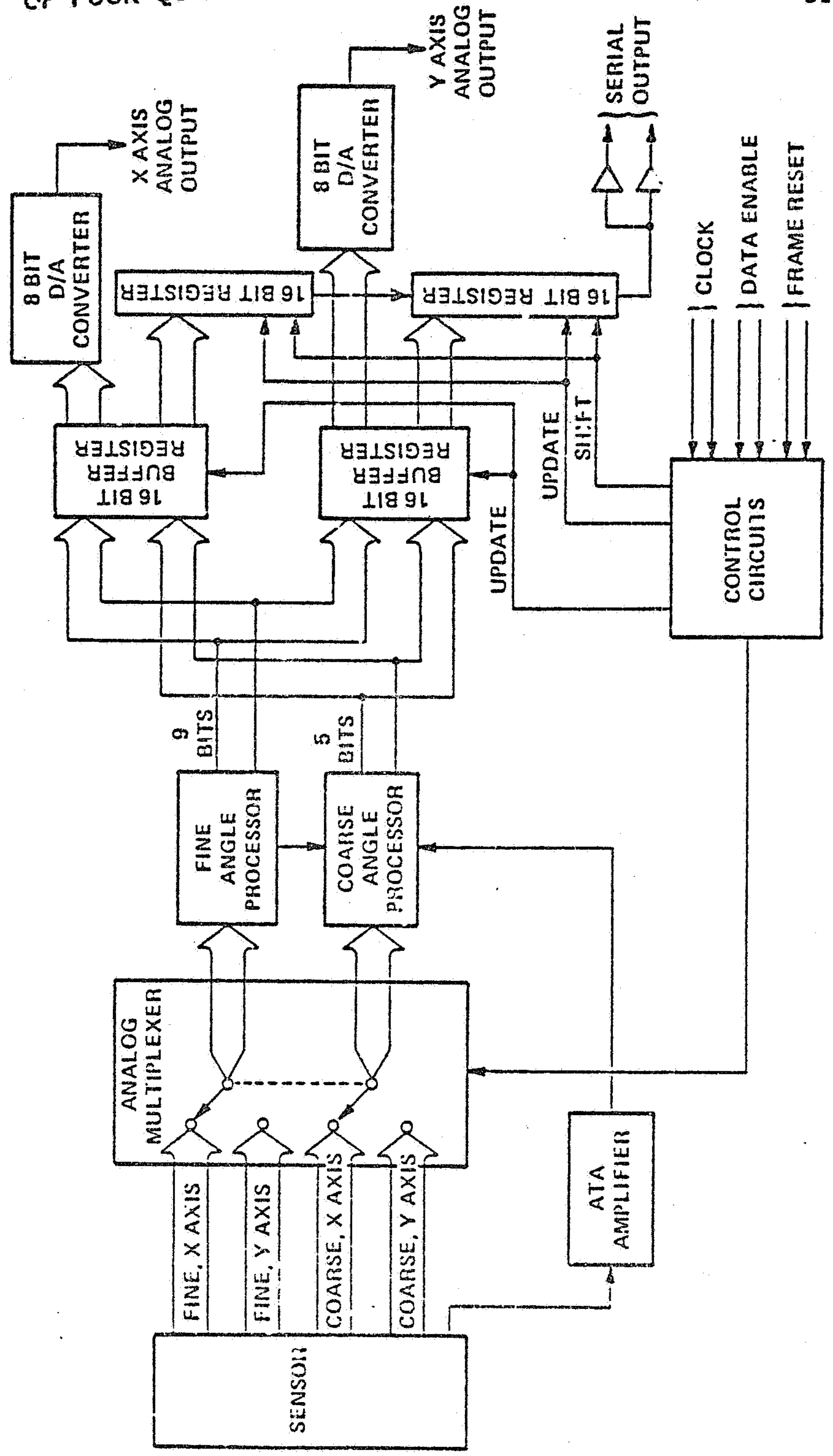

Figure 3.7-17 FSS Functional Block Diagram

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	LSB		FSS Y axis						(FSS SDD BITS 1-14)					MSB
	14	13	12	11	10	9	8	7	6	5	4	3	2	1
+32°	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
+	1	1	1	1	1	1	1	1	1	1	1	1	1	0
−	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
−32°	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	LSB		FSS X AXIS						FSS SDD BITS 17-30					MSB
	30	29	28	27	26	25	24	23	22	21	20	19	18	17
−32°	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
−	1	1	1	1	1	1	1	1	1	1	1	1	1	0
+	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	•	•	•	•	•	•	•
+32°	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Unsigned Integer Binary

Figure 3.7-18. FSS X/Y Axis Attitude Telemetry Format.

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SERIAL DATA BYTE	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
IRU CHANNEL	Y 2	P 2	R 2	Y 1	P 1	R 1	Y 2	P 2	R 2	Y 1	P 1	R 1	Y 2	P 2	R 2	Y 1	P 1	R 1
BYTE DEFINITION	LEAST SIGNIFICANT												MOST SIGNIFICANT					

MSB → OUT FIRST

144 BIT IRU POSITION WORD FORMAT

	LSB																							MSB
BIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BYTE	THIRD (BYTE 13 ABOVE)								SECOND (BYTE 7 ABOVE)								FIRST (BYTE 1 ABOVE)							S*
MAGNITUDE	2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7	2^8	2^9	2^{10}	2^{11}	2^{12}	2^{13}	2^{14}	2^{15}	2^{16}	2^{17}	2^{18}	2^{19}	2^{20}	2^{21}	2^{22}	IGN

MSB → OUT FIRST

*"0" - POSITIVE COUNT
-NEGATIVE INERTIAL ATTITUDE

SINGLE IRU POSITION WORD DEFINITION (ROLL 1 TYPICAL)
.. IN 2's COMPLEMENT FORMAT

Figure 3.7-19 IRU Position Word Serial Digital Data Format

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SERIAL DATA BYTE	8	7	6	5	4	3	2	1	MSB
TACH CHANNEL	S	Y	P	R	S	Y	P	R	OUT FIRST
BYTE DEFINITION	LEAST SIGNIFICANT				MOST SIGNIFICANT				

64 BIT TACHOMETER WORD FORMAT

BIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
BYTE	SECOND (BYTE 5 ABOVE)								FIRST (BYTE 1 ABOVE)							SIGN	MSB
MAGNITUDE	2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7	2^8	2^9	2^{10}	2^{11}	2^{12}	2^{13}	2^{14}		OUT FIRST

* "0" = POSITIVE
= POSITIVE RPM

SINGLE TACHOMETER WORD DEFINITION (ROLL TACH TYPICAL)
IN 2's COMPLEMENT FORMAT

Figure 3.7-20 Tach Word Serial Digital Data Format

	LSB															MSB	
BIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
BYTE	SECOND								FIRST								
FUNCTION STATUS	X TORQ	X TORQ	Y TORQ	Y TORQ	Z TORQ	Z TORQ	HTR 3B	HTR 3A	HTR 2B	HTR 2A	HTR 1B	HTR 1A	FHST2 HTR	FHST1 HTR	ACE B 4Hz	ACE A 4Hz	MSB OUT → FIRST
TRUE STATE	A ON	B ON	A ON	B ON	A ON	B ON	PWR OFF	PWR OFF	PWR OFF	PWR OFF	PWR OFF	PWR OFF	PWR OFF	PWR OFF	CLK ON	CLK ON	

4 Hz PRESENCE TRUTH TABLE

LM STATUS	4 Hz CLK	CPT	BIT 16 (TYP)
$\overline{LM}$	4 Hz	X	1
$\overline{LM}$	$\overline{4\ Hz}$	CPT	0
LM	X	CPT	0

HEATER CKT STATUS TRUTH TABLE (TYPICAL)

		BIT 12
HTR CKT1	OFF	1
28V PWR	ON	0

MAGNETIC TORQ TRUTH TABLE (TYPICAL)

		BIT 1
ROLL TORQ A	OFF	0
±15V PWR	ON	1

Figure 3.7-21 Telemetry Component Status Serial Digital Data Word Format

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																MSB
BIT	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BYTE	SECOND								FIRST							
FUNCTION STATUS TRUE STATE	THRUSTER UNLOAD ON	TAM 2 ON	PITCH IRU1 RATE ON	YAW IRU2 POSN ON	YAW IRU1 POSN ON	YAW GYC ON	YAW CSS2 ON	YAW CSS1 ON	TH CONT ON	SPARE	ROLL IRU1 RATE ON	ROLL IRU2 POSN ON	ROLL IRU1 POSN ON	ROLL ES ON	ROLL CSS2 ON	ROLL CSS1 ON

	LSB							
BIT	1	2	3	4	5	6	7	8
BYTE	THIRD							
FUNCTION STATUS TRUE STATE	SHUTTLE RETRIEVAL ON	SAFE HOLD ON	YAW IRU1 RATE ON	PITCH IRU2 POSN ON	PITCH IRU1 POSN ON	PITCH ES ON	PITCH CSS 2 ON	PITCH CSS 1 ON

THRUSTER CONTROL/UNLOAD TRUTH TABLE

THRUSTER STATUS	OFF	0
	ON	1

SAFE HOLD RATE INPUT TRUTH TABLE

TYPICAL	BIT	19
ROLL IRU RATE INPUT	1 ON	1
	2 ON	0

SAFE HOLD POSN INPUT TRUTH TABLE

TYPICAL	BITS	20	21	22	23	24
ROLL POSN INPUT	CSS 1 ON	0	0	0	0	1
	CSS 2 ON	0	0	0	1	0
	FSS ON	0	0	1	0	0
	IRU 1 ON	0	1	0	0	0
	IRU 2 ON	1	0	0	0	0

SAFE HOLD TAM INPUT SELECT TRUTH TABLE

	BIT 10
TAM 2 ON/TAM 1 OFF	1
TAM 1 ON/TAM 2 OFF	0

Figure 3.7-22 Telemetry Safe Hold Status Serial Digital Data Format

FHST Word 1

Bit 1	Horizontal Star Position (Sign - MSB)
Bits 2 - 12	Horizontal Star Position (Bit 12 - LSB)
Bit 13	Not Used
Bit 14	Optics Shutter Closed by BOA
Bit 15	Star Present
Bit 16	Optics Shutter Closed by TS

FHST Word 2

Bit 1	Vertical Star Position (Sign - MSB)
Bits 2 - 12	Vertical Star Position (Bit 12 - LSB)
Bit 13	Not Used
Bit 14	Power Supply not out of tolerance
Bit 15	Not Used
Bit 16	Not Used

Figure 3.7-23. FHST Serial Telemetry Definition.

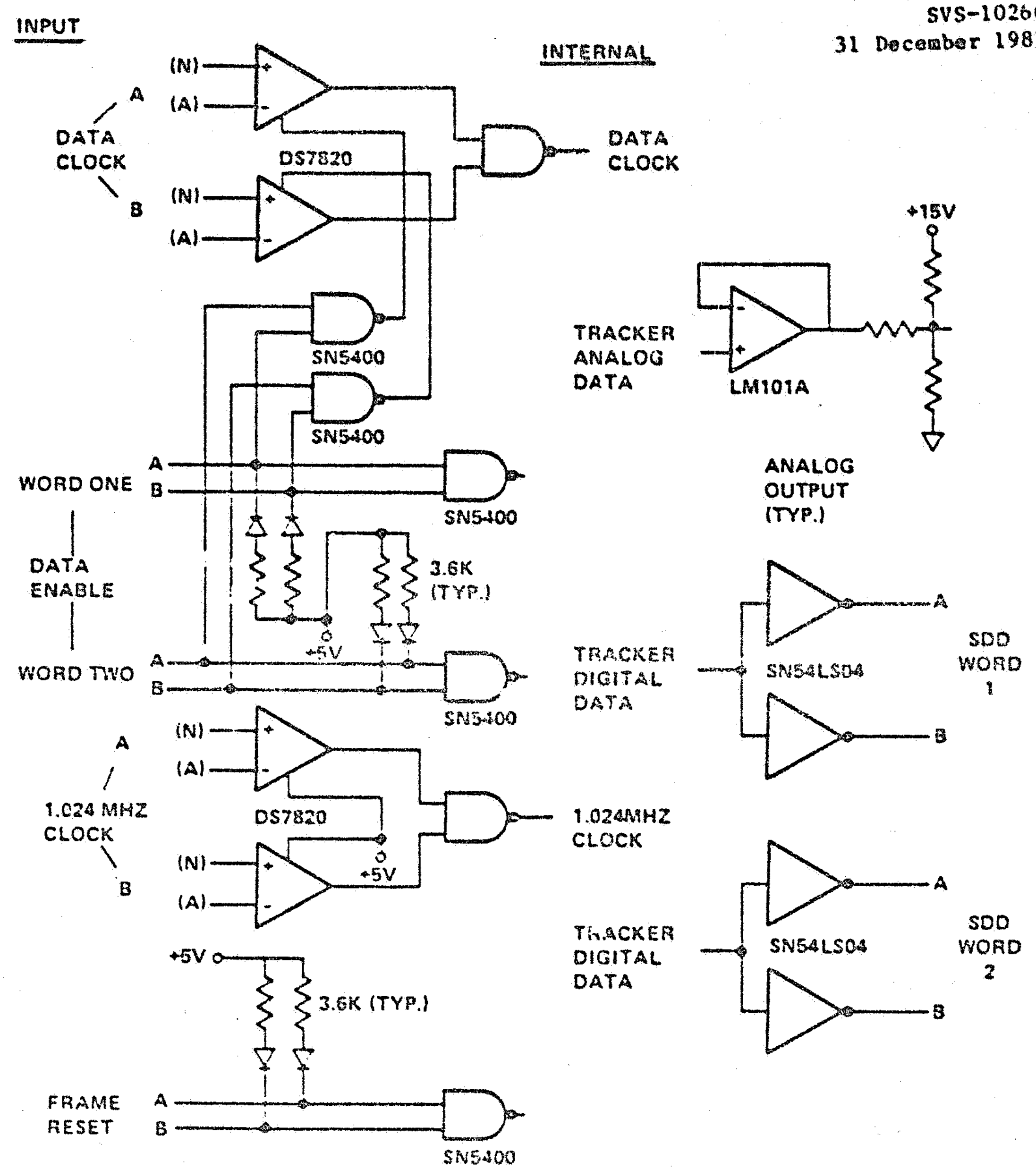

Figure 3.7-24. FHST-RIU Interface

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	LSB																MSB	
BIT	1	2	3		8	9			16	17	18	19	20	21	22	23	24	
BYTE		THIRD					SECOND						FIRST					MSB
												SEP SW B	SEP SW A	S. PAYS EN	Y. PAYS EN	P. PAYS EN	R. PAYS EN	OUT → FIRST

SEPARATION SWITCH TRUTH TABLE

TYPICAL	BIT 20
SEP SW OPEN ($\overline{LM}$)	0
SEP SW CLOSED (LM)	1

Figure 3.7-25 Telemetry Computer/Pays Enable Status SDD Format (MACS Module #2 and Subsequent)

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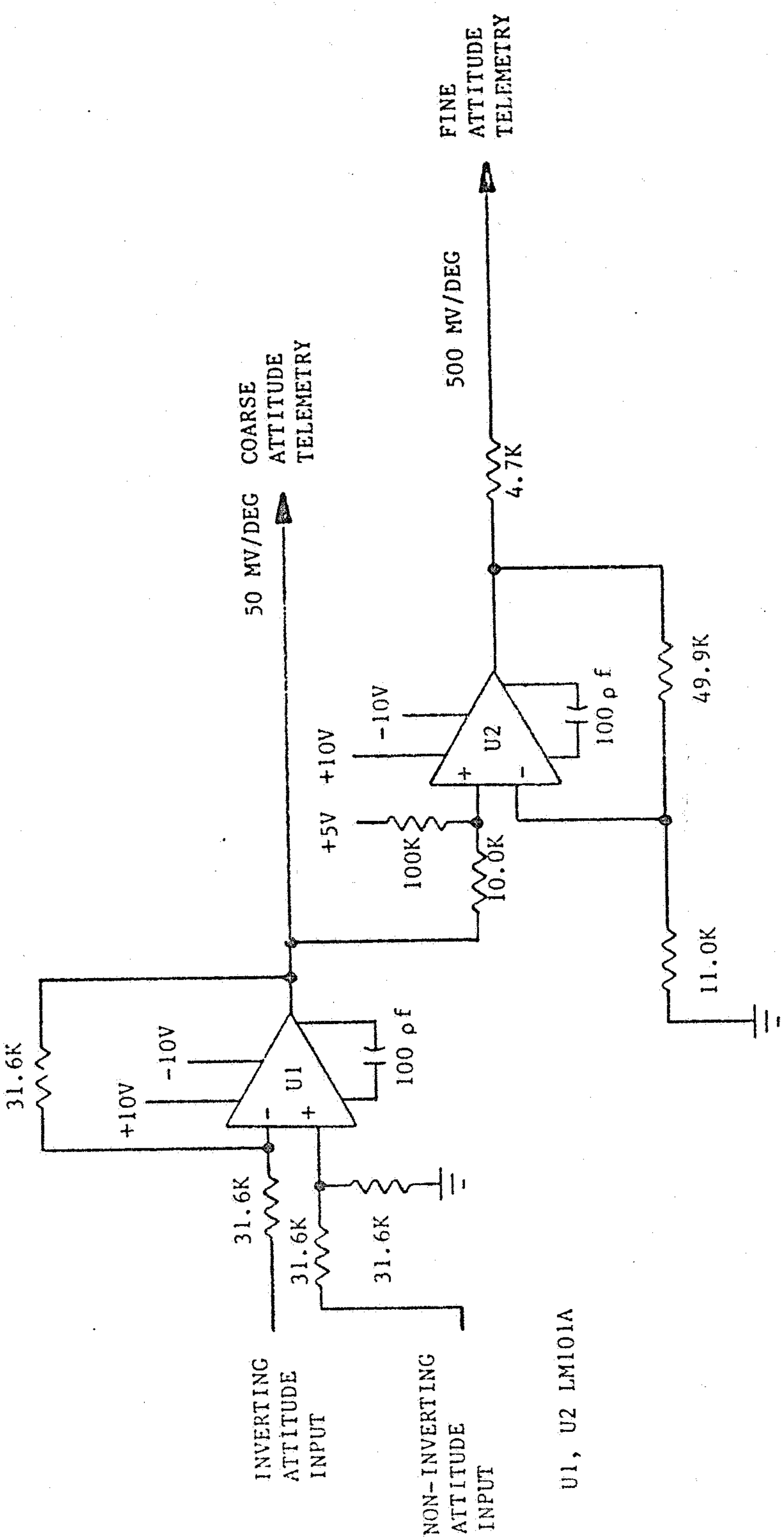
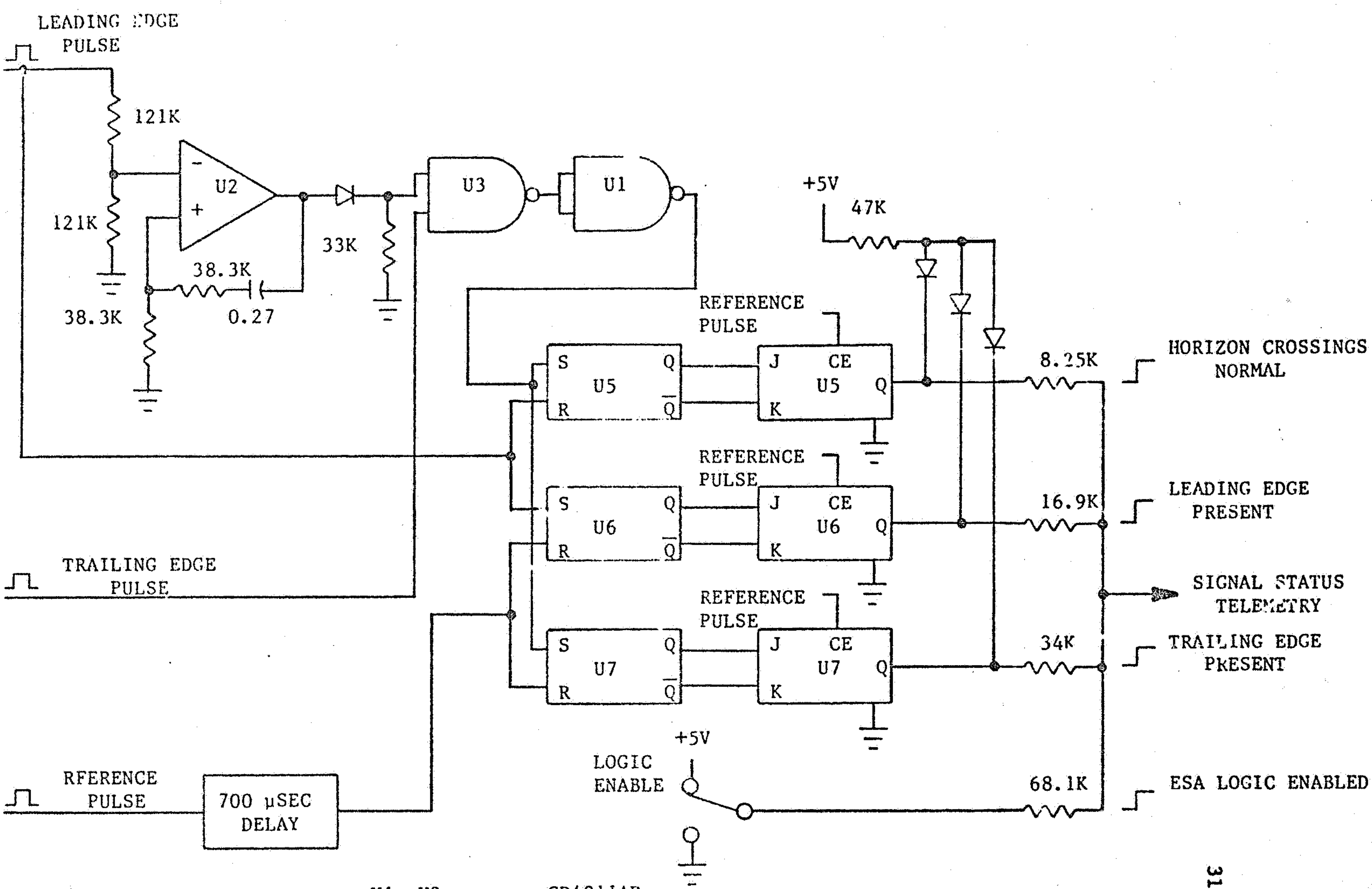


FIGURE 3.7-26 ATTITUDE MONITOR



U1, U3	CD4011AD
U2	LM101A
U5, U6, U7	CD4027AD

FIGURE 3.7-27 SIGNAL STATUS MONITOR

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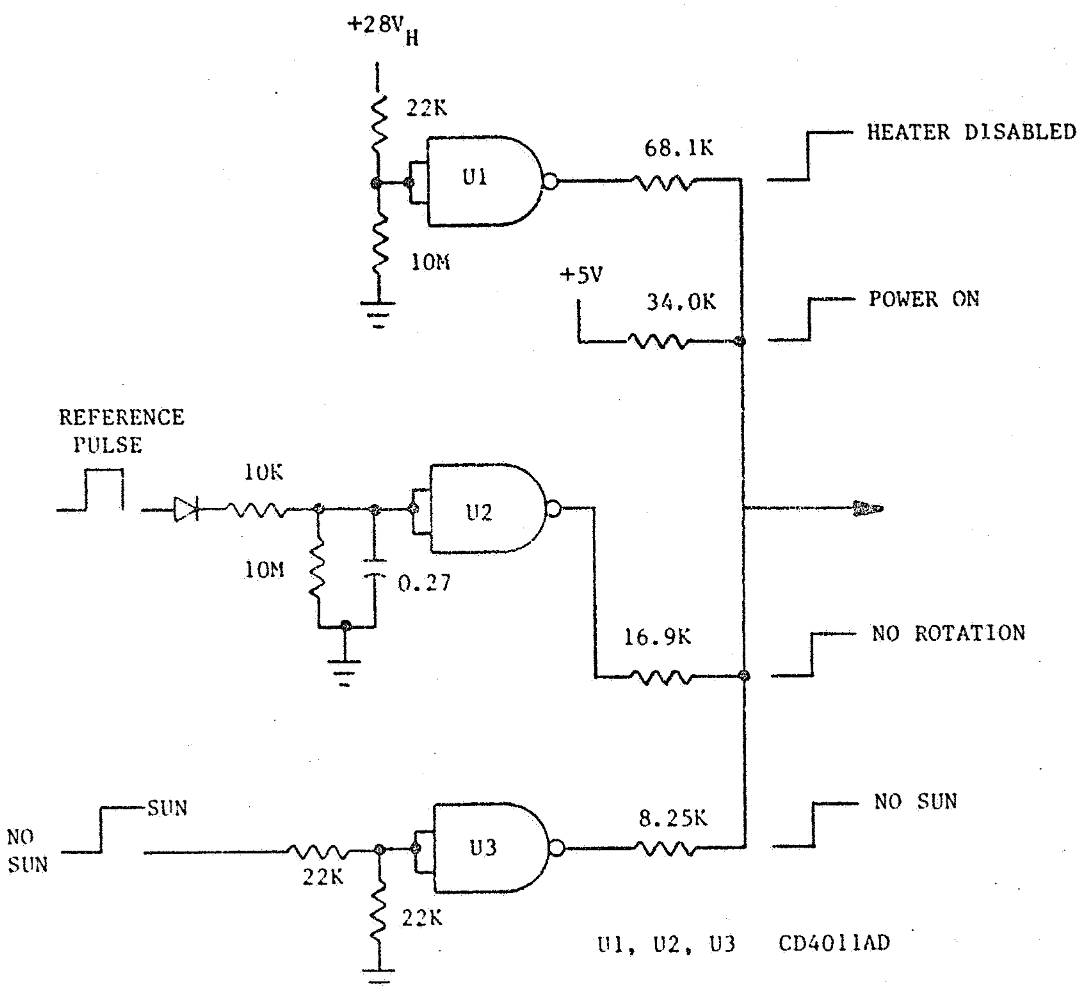

Figure 3.7-28. Sensor Status Monitor

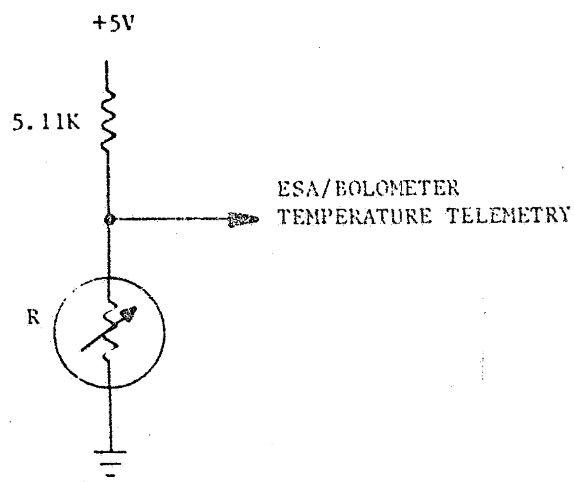

Figure 3.7-29. ESA/Bolometer Temperature Monitor

SECTION 4.0

COMMUNICATIONS AND DATA HANDLING SUBSYSTEM (C&DH)

The Communications and Data Handling Subsystem consists of the following components:

1. On Board Computer (OBC) and Memories
2. Standard Telemetry and Command Components (STACC) Central Unit (CU)
3. STACC Interface Unit (STINT)
4. Multiplex Data Bus (MDB)
5. Bus Coupling Unit (BCU)
6. Remote Interface Unit (RIU)
7. Expander Unit (EU)
8. Power Control Unit (PCU)
9. Pre Modulator Processor (PMP)
10. Narrowband Tape Recorder (NBTR)
11. Transponder
12. R.F. Switch
13. Diplexer
14. S-Band Omni Antenna
15. High Gain Antenna

The Communications and Data Handling (C&DH) module is a integral subsystem of the NASA Multimission Modular Spacecraft (MMS) which is the vehicle for the Landsat-D. The C&DH subsystem provides the capability to transmit Landsat-D telemetry, receive/process and distribute commands, transmit ranging and generate timing data. The spacecraft telemetry consists of realtime telemetry from the various subsystems and High Rate Channel Data which is Computer Memory Dumps, Payload Correction Data or Narrowband Tape Recorder (NBTR) Playback. The subsystem retrieves the telemetry stream from the appropriate source and encodes the telemetry stream into proper modulated form for transmission via the transponder transmitter to either TDRSS, GSTDN or both. Commands received by the Transponder receiver are processed by the C&DH subsystem and distributed to the various spacecraft subsystems. These commands consist of immediate commands, delayed commands and OBC memory loads. The components listed above comprise the C&DH Subsystem and a diagram of the system is shown in Figure 4-1.

4.1 FUNCTIONAL DESCRIPTION

4.1.1 C&DH FUNCTIONAL DESCRIPTIONS

The C&DH Subsystem includes the following components as shown in Figure 4.1-1:

1. On-Board Computer (OBC) and Memories (see Section 6.0)
2. STACC Central Unit (CU)
3. STINT
4. Multiplex Data Bus (MDB)
5. Bus Coupling Unit (BCU)
6. Remote Interface Unit (RIU)
4. Expander Unit (EU)
8. Power Control Unit (PCU)
9. Pre-Modulator Processor (PMP)
10. Narrowband Tape Recorder (NBTR) (see Section 5.0)
11. Transponder
12. R.F. Switch
13. Diplexer
14. Omni Antenna
15. High Gain Antenna, S-band only (see Section 13.0)

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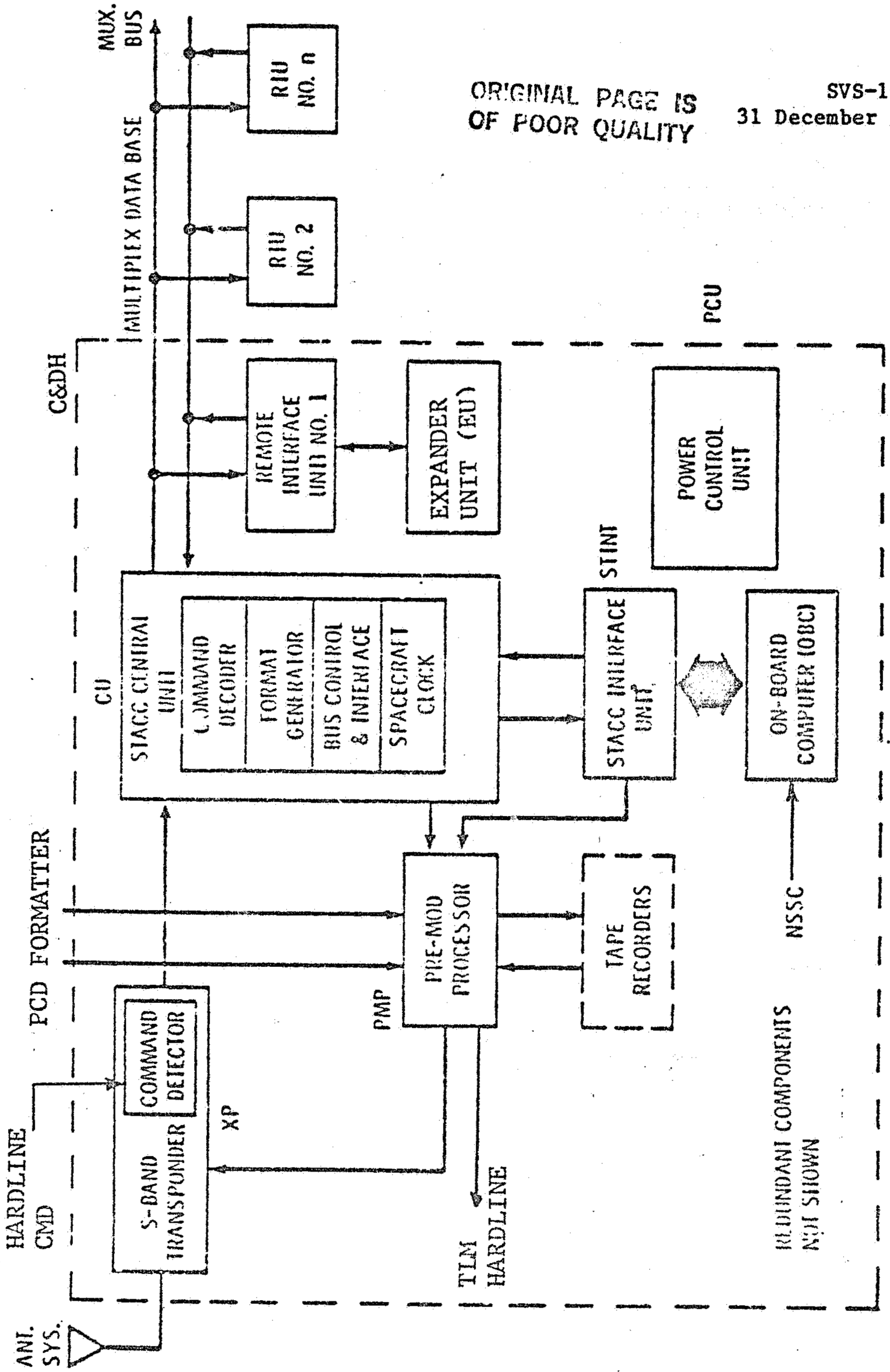

Figure 4-1. Simplified Diagram of C&DH Subsystem

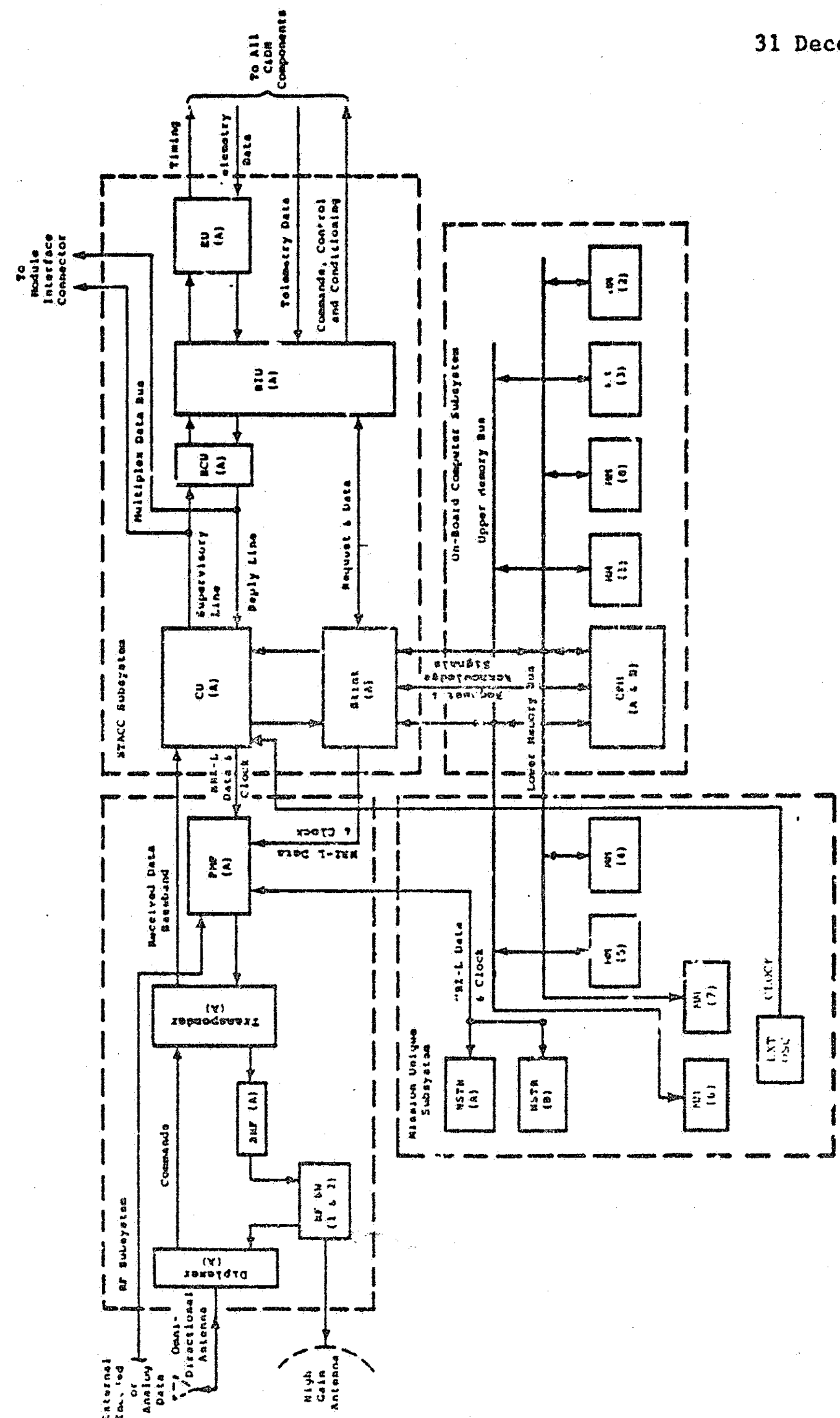

Figure 4.1-1. C&DH Subsystem

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4.1.1.1 RF Antennas and Switching

The RF signals to and from the redundant transponders are applied to the four antenna ports as indicated in the block diagram of Figure 4.1-2. Operation is in the S-Band frequency range. Command controlled, magnetically latched, RF transfer switches are employed in the transmit signal path to allow either transmitter's output signal to be switched between the high gain and omni antenna ports. In the high gain mode, the transfer switches also provide a matched load to the unused diplexer transmit port.

The forward link signals to the transponders' receiver inputs are not switched. These are always connected to the omni ports.

4.1.1.1.1 RF Switch Control

There are four discrete commands associated with the antenna feeds. These are applied to the transfer switches via the PCU and are listed in Section 4.6.

There are three RF configuration commands. In order to effect a configuration command, it is first necessary that the RF Switch 28V Bus selected be consistent with the RIU in use, e.g., for RIU-A the "28V Bus A for RF Switch" discrete command position is required. After the latter latched condition is obtained, the three RF configuration commands can be used to achieve the transmitter feed configurations shown below. Note that each command results in the simultaneous reconfiguration of both transmitter feeds.

Transmitter RF Feed Configurations

ENABLE RF Configuration	Transmitter A Transmit Antenna	Transmitter B Transmit Antenna
I	Omni I	High Gain
II	High Gain	Omni II
III	Omni I	Omni II

The configuration commands can be supplied redundantly from RIU A and B. The bus select commands, however are dedicated to the RIU's as indicated in TBD.

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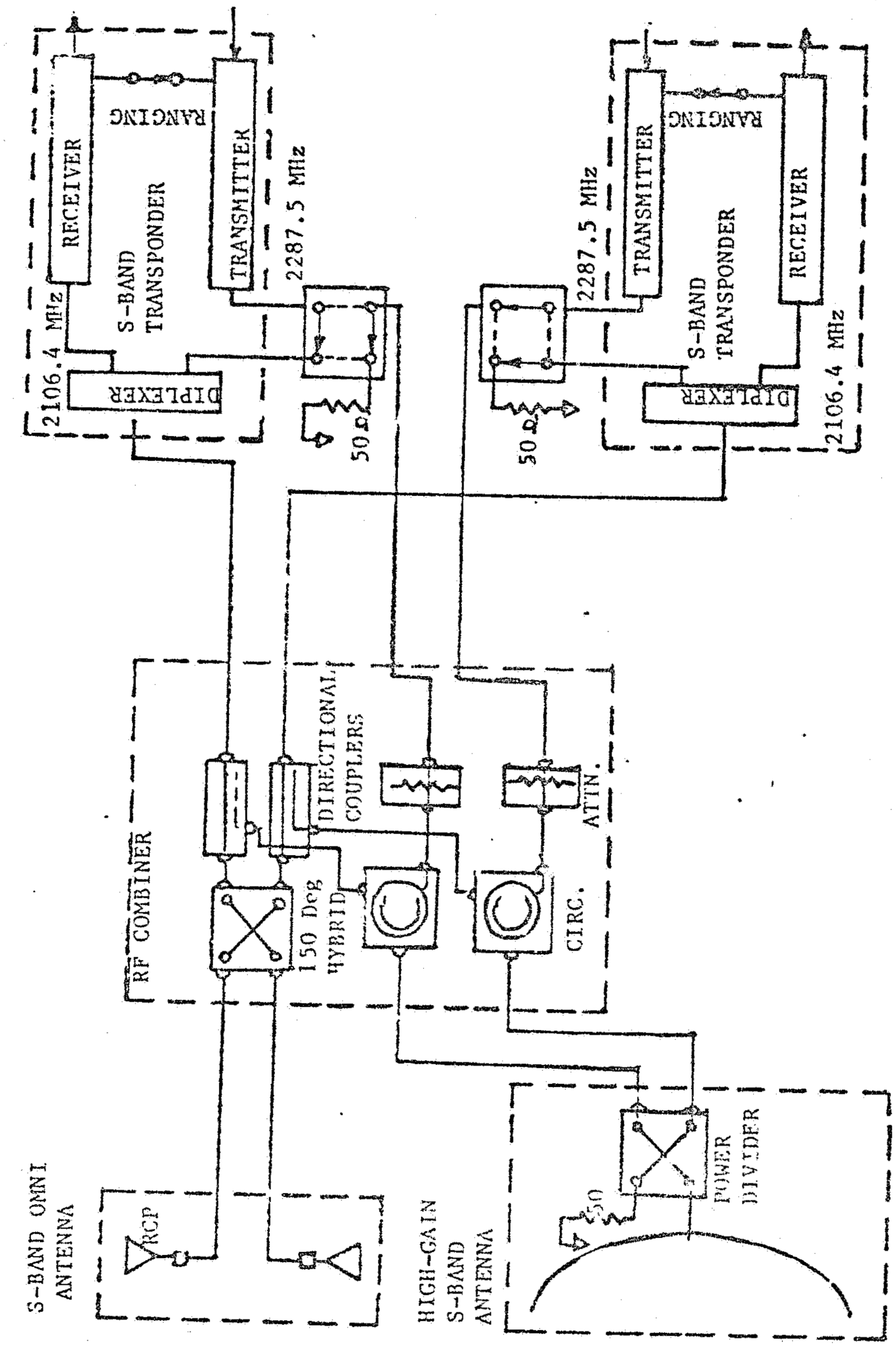

Figure 4.1-2. RF Switching

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4.1.1.2 Transponder

Landsat-D employs redundant transponders. Each transponder consists of separate components: the transmitter-receiver, diplexer, band reject filter, etc. The interconnection between the above three components as a function of the commanded RF configuration is shown in Figure 4.1-3.

The transponder can be configured, by ground command, to provide the capability for both realtime spacecraft telemetry and high rate channel telemetry through the TDRS (single access or multiple access) and the GSTDN simultaneously, if required. Receiver operation is at the assigned frequency of 2106.4 MHz, and transmission frequency is 2287.5 MHz. The same frequency assignments are used for both transponders. Transmit power is 5 watts, nominal. The transponder can be operated in either coherent mode or non-coherent mode.

The GSTDN forward link command (or data) is recovered by detection of the incoming PSK/ØM RF signal. The latter consists of an NRZ-M, 2000 bps baseband signal, PSK modulated ($\pm 90^\circ$) on a 16 KHz subcarrier, which is phase modulated on the carrier. The GSTDN return link transmission employs FDM/ØM with nominally 20% residual carrier. The FDM signal is obtained from the PMP and consists of R/T telemetry data (nominally 8 Kbps) PSK modulated on a 1.024 MHz subcarrier (Bi Ø-M coded), plus High Rate Channel Data (Computer Dump, PCD at 1 Kbps/32 Kbps or NBTR Playback at 128 or 256 Kbps) occupying the frequency spectrum below the subcarrier. The choice of data channels from the PMP is command controlled, and either a single channel or two channels (FDM as above) can be provided to the transmitter.

The TDRSS forward link employs quadrature channels, one for command, the other for ranging. Each is PSK modulated by a nominally 3M-chips per second PN code. The command signal is NRZ-M coded at either 125 bps or 1,000 bps, and is contained as a module 2 addition to the command channel PN code. The ranging PN channel does not contain any superimposed data. The command to ranging channel power ratio is 10:1. The TDRSS return link also utilizes quadrature channels. These are termed I and Q. By command control, either can be PSK modulated with a PN code of 3M chips per second (PN/SQPSK). The I channel, containing the R/T telemetry data will employ the PN code. The Q channel, containing a choice of one of two data channels, the latter under command control from the PMP, will use the PN code. The I channel R/T telemetry data is NRZ-M coded and module 2 added to the PN code. The Q channel baseband data, also NRZ-M coded, provides direct PSK modulation of the quadrature carrier. There are 85 possible PN code sets. Landsat-D uses PN-2 and Landsat-D Prime uses PN-3 (see GSFC STDN 108 for definition). The (quadrature) carriers' Q to I power ratio is 4:1.

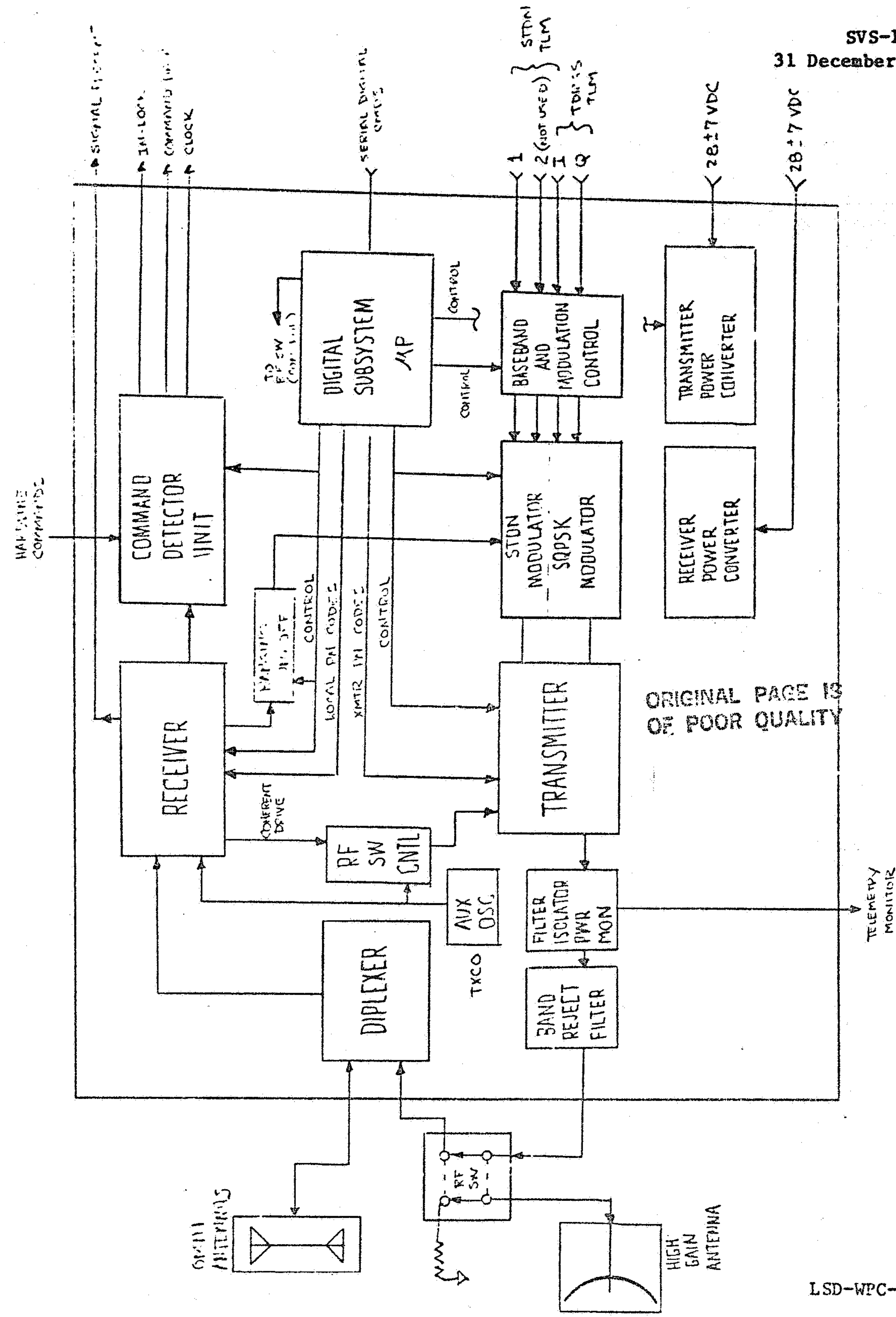

Figure 4.1-3. C&DH Transponder Functional Block Diagram

LSD-WPC-263

At baseband, for the return link transmission, signals can be obtained from either PMP-A or PMP-B to either the A or B transmitter. (See Figure 4.1-4.) A command controlled Normal-Reverse switch (S6), contained within the PMP, provides for this passive cross-strapping. The Normal position simultaneously connects PMP-A to transmitter A and PMP-B to transmitter B. The reverse position results in an A to B, and B to A configuration. The detected forward link command is supplied from each receiver to both CU-A and CU-B, simultaneously (active cross-strap). (See Figure 4.1-5.)

In addition to forward link commanding by RF, there is also available a baseband command mode. This is obtained via hardline to the command detectors in the transponders. The signal required is a 16 KHz subcarrier, PSK modulated, by the command, at 2 Kbps, NRZ-M coded.

4.1.1.2.1 Command Data Detection

In the TDRSS Mode, the command data is recovered from the Forward Link spreading code and is chopped with a 16 kHz square wave prior to delivery to the Command Detector Unit (CDU). In the GSTDN Mode, the 16 kHz subcarrier containing the command data is deliverd to the CDU.

Based on whether a TDRSS or a GSTDN signal was acquired, the CDU is automatically configured by the transponder's internal digital subsystem to accept either the TDRSS digital bit stream or the GSTDN 16 kHz biphase (± /2) modulated subcarrier. The CDU delivers to the CU the original command bit stream, a clock timing and an "in-lock" signal (Figure 4.1-6).

4.1.1.2.2 Transmit Return Link Telemetry

The transmitter in the Transponder has inputs for two digital telemetry data bit streams in the TDRSS Mode and two analog telemetry signals in the GSTDN Mode. The two TDRSS data bit streams modulo-2 added to internally-generated PN codes and transmitted independently on the In-phase (I) Channel and the Quadrature (Q) Channel as Staggered-Quadriphase-Phase-Shift-Keyed (SQPSK) modulation on the S-Band Return Link. Only one of the two GSTDN analog signals are summed in a linear network and transmitted as residual-carrier phase modulation on the S-Band Return Link.

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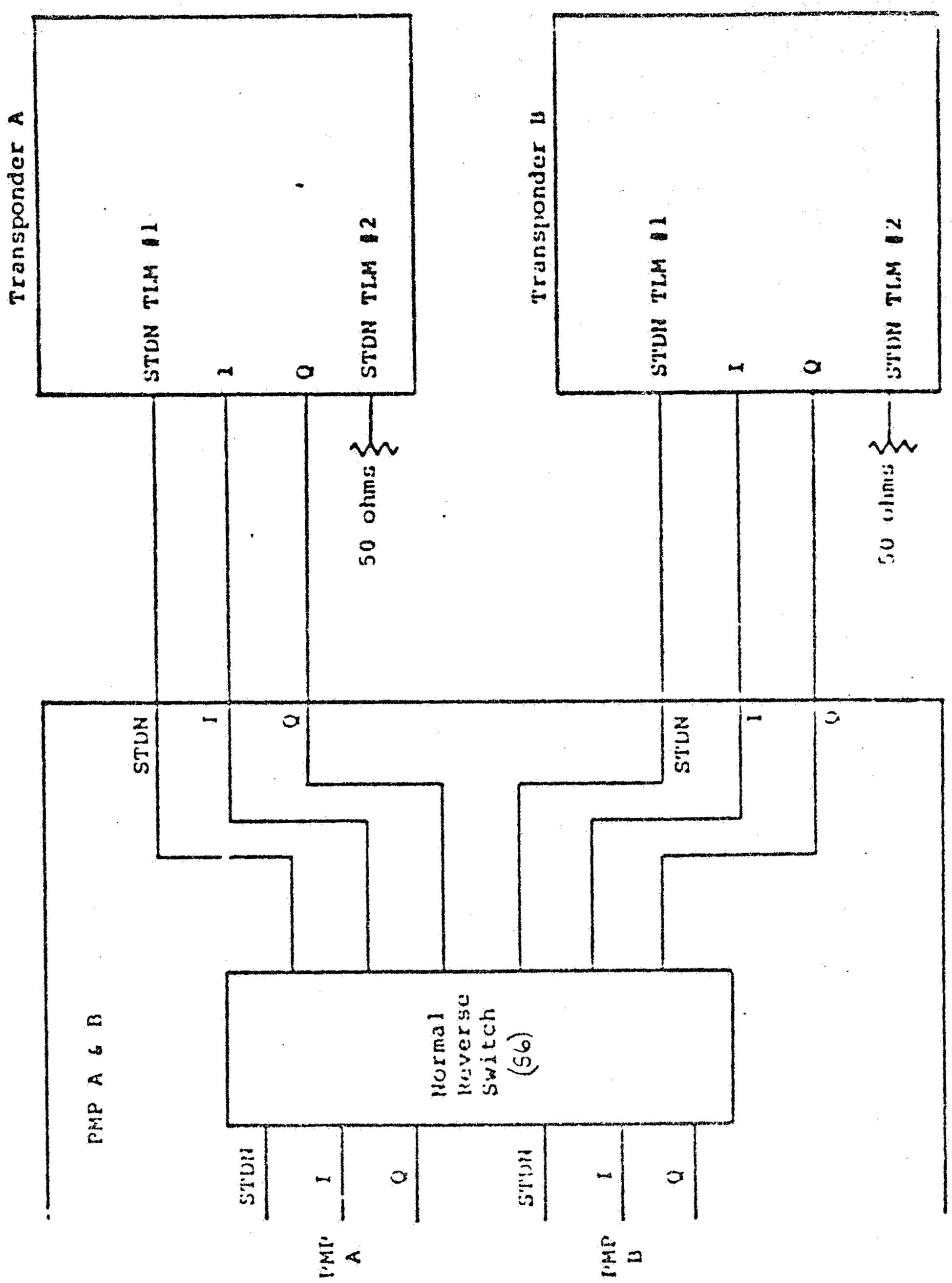

Figure 4.1-4. PMP-Transponder Interface Return Link

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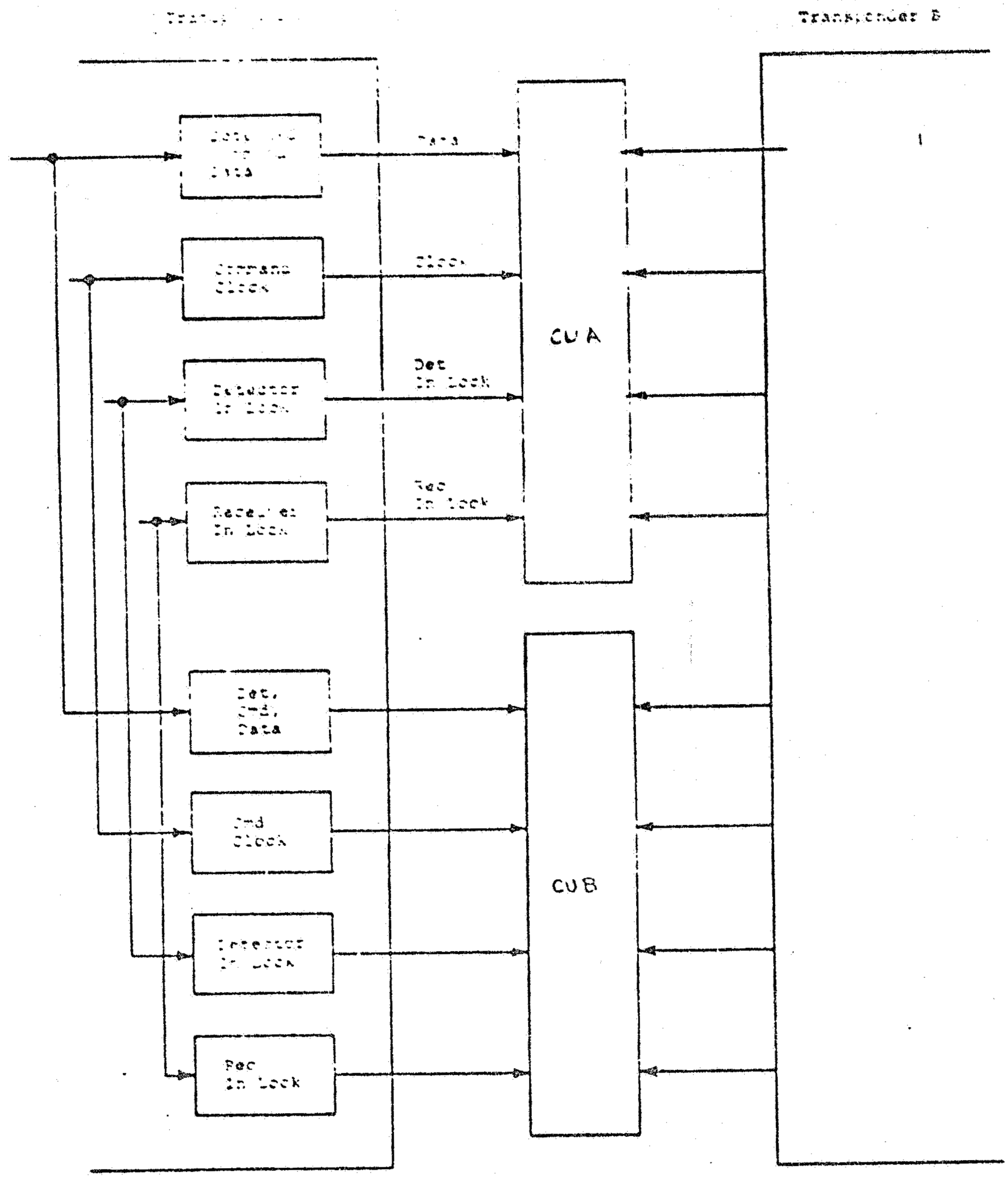

Figure 4.1-5 CU-Transponder Interface Foward Link

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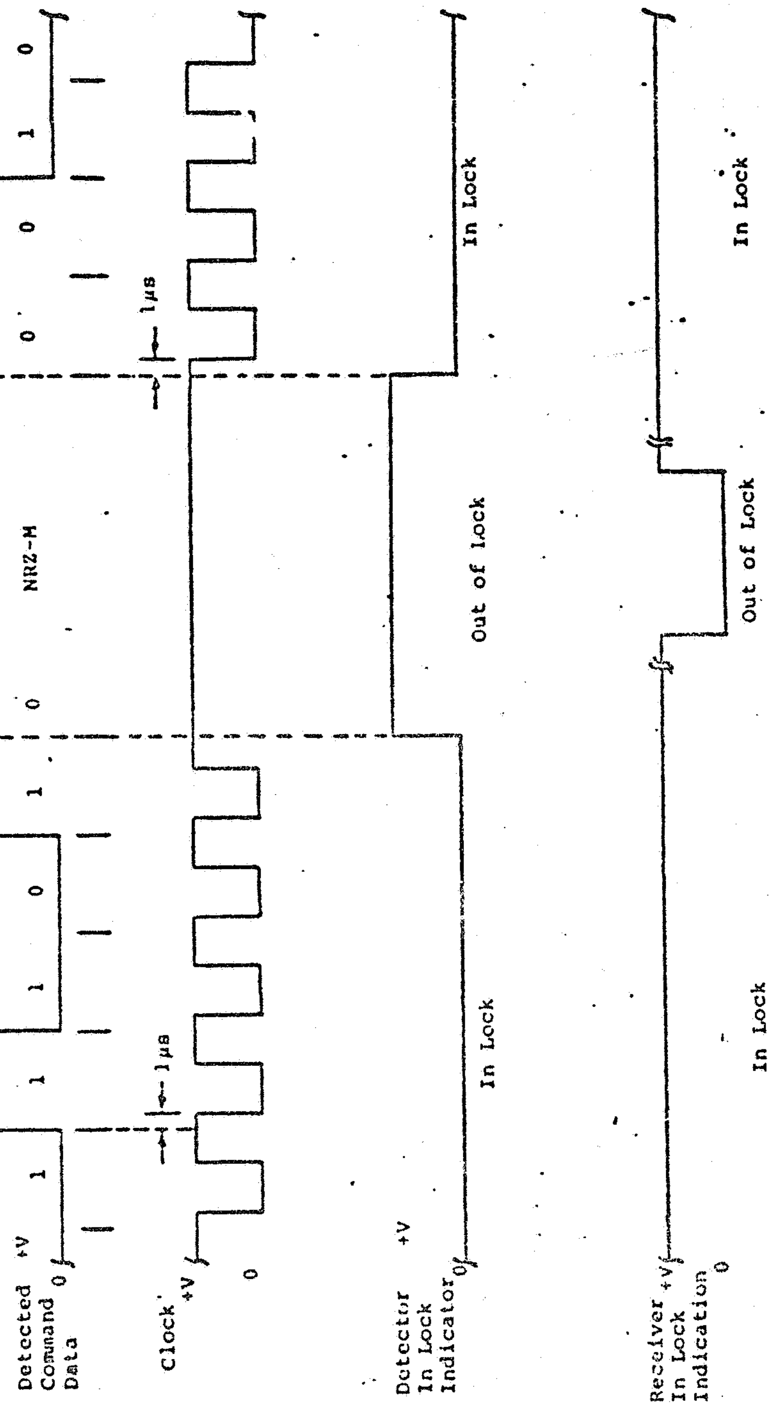

Figure 4.1-6 CU-Transponder Interface Foward Link

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The relative distribution modulation energy between Q Channel and the I Channel is a 4:1 ratio. The GSTDN phase modulation index can be commanded LOW or HIGH. Both the TDRSS and the STDN telemetry channels can be turned ON/OFF by external command, as well as the GSTDN Tone Ranging Channel, which is linearly summed with the GSTDN telemetry input.

The spreading code for the TDRSS Return Link is obtained from the transponder internal digital subsystem. Modulation mode control permits reconfiguration of the phase modulator network to deliver to the S-Band power amplifier stage any one of the following:

1. Residual carrier, linearly phase-modulated (GSTDN).
2. Suppressed-carrier SQPSK, PN internally-supplied (TDRSS).
3. Suppressed-carrier Biphase modulated bit stream or PN on the Q Channel and PN on the I Channel (TDRSS).

The configuration of the transmitter and the selection of the modulation sources and levels for TDRSS or GSTDN operation is automatically accomplished by the digital subsystem, based on the Forward Link mode being received by the transponder, external commands and fixed programming.

Following modulation, the S-Band signal is amplified to the desired output level. The output filter/isolator, which protects the transmitter from shorts or opens on the antenna line, also contains power monitors for telemetering the forward and reflected signal power. A band reject filter protects the receiver.

4.1.1.2.3 Turn-Around Ranging

The turn-around ranging function in the transponder is available only when the receiver is locked to a Forward Link signal. In the TDRSS mode, turn-around ranging is obtained by synchronizing the "all 1's" state in the locally-generated Return Link PN code. The "all 1's" state in the received Forward Link PN code. The received code itself is not turned around. With the transponder operating in the coherent carrier turn-around mode, this function is available in the MA and SSA services except when transmitting high data rate telemetry signals.

The GSTDN ground Tone Ranging Subsystem relies on the spacecraft transponder to detect sinewave tones in the range of 4 kHz to 500 kHz which have been phase-modulated on the Forward Link carrier by the ground station and to re-modulate them at a pre-determined phase modulation index on the Return Link carrier. In the phaselock receiver in the transponder, a separate intermediate frequency amplifier/phase detector channel is provided for the range tone signals. The amplitude of the output tones is maintained constant by an automatic gain control system so that a pre-determined phase modulation index for the ranging tones is on the Return Link. A commandable switch is provided in the ranging channel so that it can be commanded ON/OFF. The ranging tones may be transmitted alone or may be summed with Return link telemetry subcarriers from the PMP prior to applying the signals to the transmitter phase modulator.

4.1.1.2.4 Coherent Carrier Turn-Around

The ground Doppler Range Rate Tracking Subsystem relies on the spacecraft transponder to turn around the Forward Link carrier frequency in the precise ratio of 240/221 to generate the Return Link carrier. This is called the "coherent turn-around" mode.

In the suppressed-carrier TDRSS Mode, the "carrier" which is turned around is reconstructed in the receiver detector circuits from the sidebands of the Forward Link spread-spectrum signal. In the GSTDN Mode, the transmitter drive frequency is obtained from the phaselock tracking loop in the receiver, which is phase-locked to the Forward Link residual-carrier signal.

In both the TDRSS and GSTDN Modes, the phaselock receiver is a double-conversion superhetrodyne type in which the effect of the down-conversion is to cause the receiver voltage-controlled oscillator (VCO) to run at precisely (2/221) of the S-Band Forward Link input frequency. The transmitter contains frequency multiplier and up-converter circuits which provide an over-all frequency multiplication of precisely 120 times the input drive frequency. When the transmitter drive frequency is obtained from the Receiver VCO the transmitter S-Band Return Link frequency is precisely (240/221) times the received S-Band Forward Link frequency.

If the receiver is not locked to a Forward Link signal, an r-f switch in the transmitter automatically selects the transmitter drive frequency from a quartz crystal oscillator. This is called the "non-coherent" mode.

4.1.1.2.5 Operational States

4.1.1.2.5.1 Automatic States. Numerous states of the transponders are automatically re-configured by the self-contained Digital Subsystem. They are:

1. GSTDN Mode configuration

2. TDRSS Mode configuration

3. TDRSS Mode Acquisition States

4. Coherent/Non-coherent Return Link Carrier modes

4.1.1.2.5.2 Commandable States. As mentioned above, various functions of the Transponder can be controlled ON/OFF, or values of parameters can be set, by external command. Commands are contained in a 16 bit serial command word which is read into the transponder at a 256 kbps rate. See SVS-10124 in the Data Format Control Book, Vol. III (Command).

4.1.1.2.5.3 Command Processing. A single command or command sequence versus the telemetry indicators to accept reject and count commands are shown in Figure 4.1-7. The Reject bit is normally in the reject state. When the command is accepted it goes to the accept state for approximately three milliseconds. The ground software should look at the command counter after the command has been sent and not the reject bit, which may not be seen in the accept state via telemetry.

4.1.1.3 Pre-Modulation Processor

The central control for baseband signal data processing and application to the transponder for the return link transmission is the PMP. The Pre-Modulation Processor has redundant units (PMP A&B).

A simplified block diagram of the PMP is given in Figure 4.1-8. The input signals applied to PMP are command selectable for processing, coding and multiplexing. The resultant output signals are routed to the transponder for return link transmission. The PMP also supplies the tape output signals for recording by the NBTR.

The PMP is essentially divided into three essential functions. These functions are: the serial command decoders and drives, the serial telemetry encoders, and the signal processing circuits.

The PMP accepts input signals at seve ports. The sources of data are:

1. Realtime telemetry data from CU-A
2. Realtime telemetry data from CU-B
3. Memory Dump from STINT-A
4. Memory Dump from STINT-B
5. Payload Correction Data from PCD Formatter A
6. Payload Correction Data from PCD Formatter B
7. Narrowband Tape Recorder (NBTR) Playback

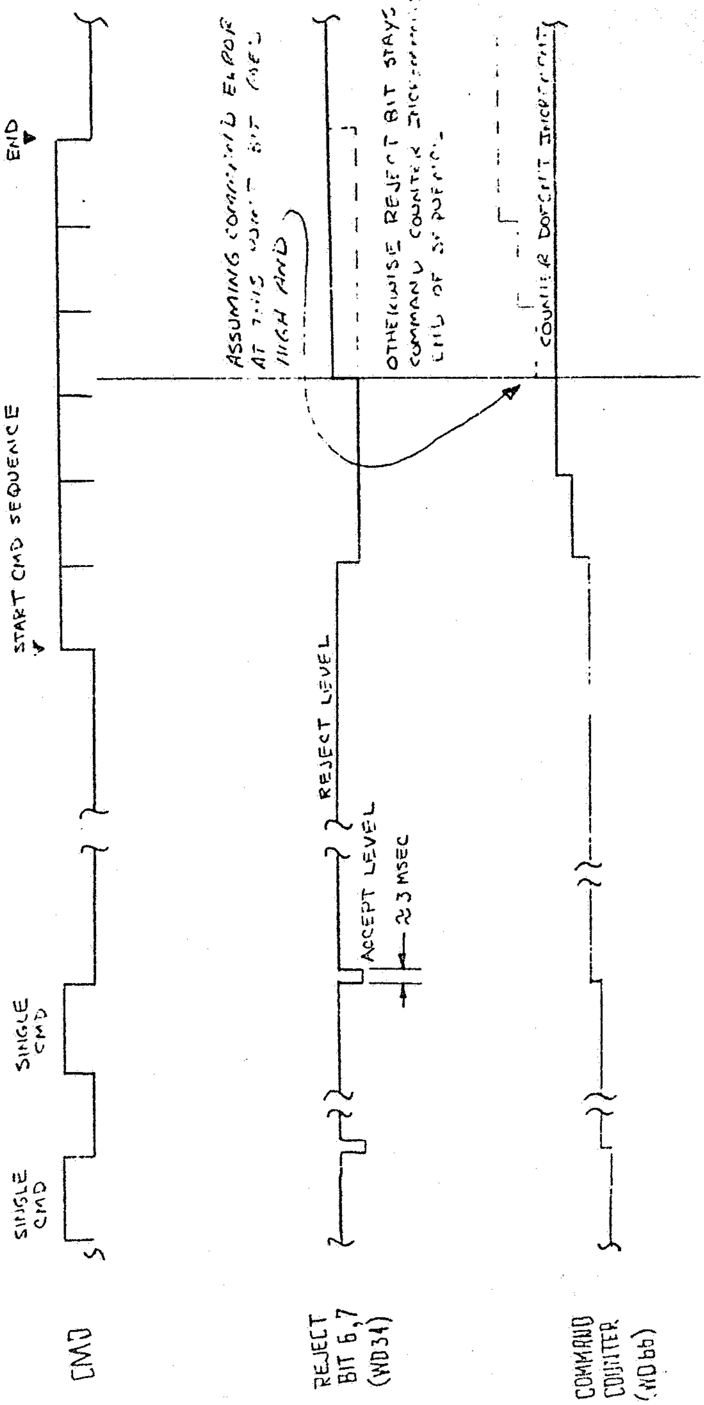

Figure 4.1-7. Commands VS Telemetry Indicators

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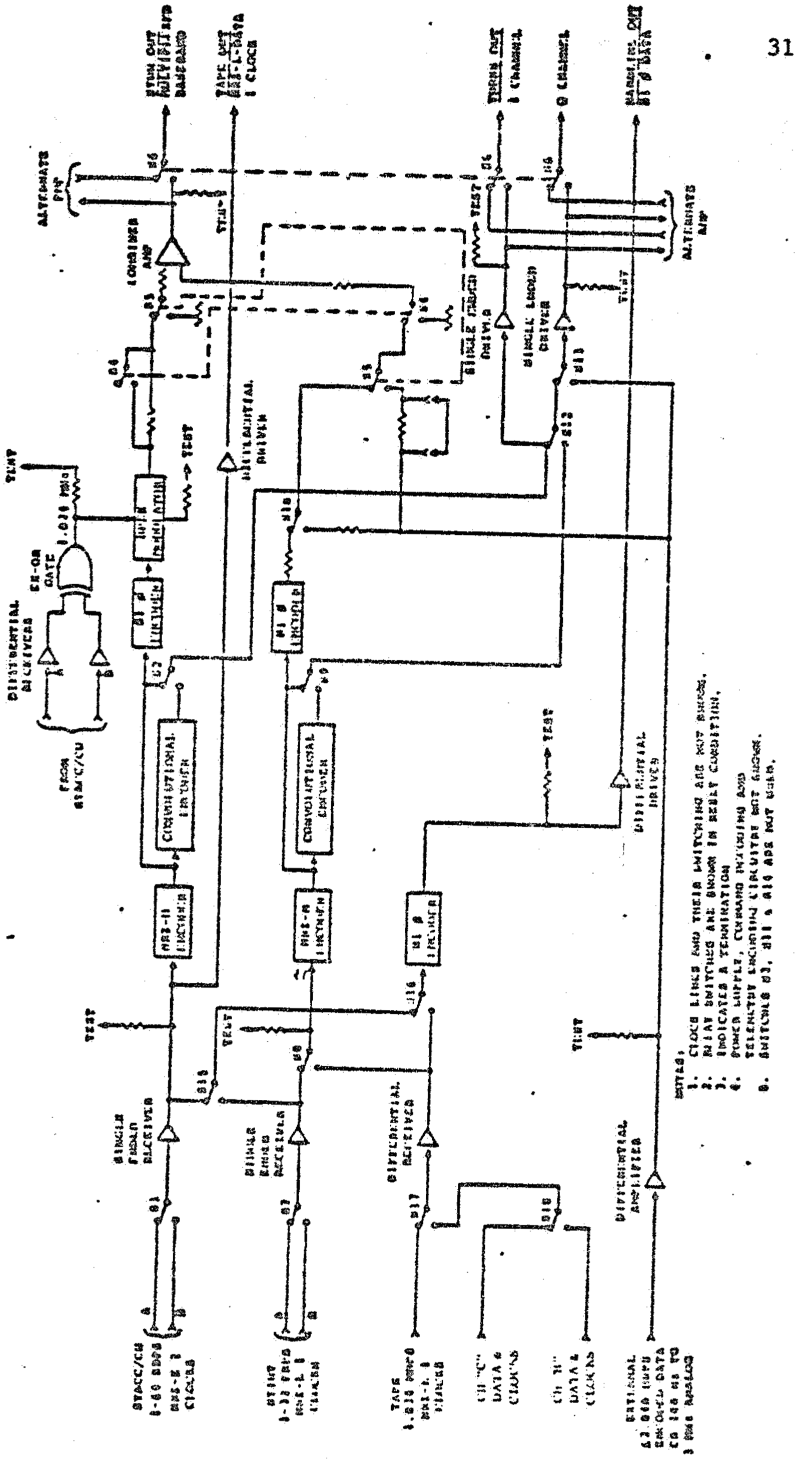

Figure 4.1-8. Simplified Diagram of PMP Components and Mode Switches

These data sources are selected in various combinations for routing to either a GSTDN or TDRSS transmitter output. In addition, real time telemetry data outputs can be supplied to hardline output. All input/output combinations are established by selecting the appropriate PMP mode.

All data to the GSTDN output is Bi-phase-S encoded to incorporate the clock signal into the data signal. The GSTDN output is a frequency division multiplexed signal formed by BPSK modulating the real time telemetry data onto a subcarrier at a frequency above the baseband spectral occupancy of the second data channel. Alternately, the modulated telemetry channel can be individually obtained. In the case of the TDRSS output, the simultaneous provision of 2 outputs for each of the PMP operating modes is handled through separate I and Q channel outputs to the transmitter. Here NRZ-M encoding is provided with selectable convolutional encoding to improve link bit error rates. The "Modes of Operations", and "Command" sections cover the switch settings for the PMP.

The PMP Tape output signal to the tape recorder's record amplifier is the real time telemetry data (8 Kbps only) from the selected CU (Tape Recorder A is assigned to PMP-A and Tape Recorder B to PMP-B). The PMP drive to the tape recorders is provided with ON/OFF command control. PMP R/T telemetry output to the tape recorder record amplifier consists of NRZ-L data and 1X clock.

The PMP hardline can, by command, supply the data from any input port. ON/OFF control of the hardline output is available by command.

Nine different PMP modes of operation (designated A to I) are command selectable for application to the return link transmission. These output either one or two of the input signals at a time. Modes A thru D are used in association with the GSTDN mode of the transponder, E is not used and F thru I with the TDRSS mode. For the GSTDN modes, dual input signals are frequency division multiplexed before application to the transponder. In the TDRSS mode, the two signals are provided separately on ports designated I and Q. Independent command selection of convolution encoding for the I and Q channels is also provided.

The input and output signal characteristics are summarized below. All input data signals are NRZ-L and include both 1X and 2X clocks.

In any of the GSTDN modes (A to D) R/T telemetry data is converted to BiPhase-S and PSK modulated on a 1.024 MHz subcarrier. The latter is supplied from the active CU. The other input signal source (High Rate Channel Data) is BiØ-S coded and summed with the subcarrier. Frequency spectrum occupancy for this second data channel lies below the subcarrier. Note that STDN mode A only outputs the R/T telemetry subcarrier signal. This clears the frequency spectrum below the subcarrier, and allows internal summing within the transponder of its ranging channel.

The GSTDN Modes (A to D) supply the drive signal to the transmitter's linear phase modulator. Output level from the PMP is automatically set, as each mode is selected, so that the resultant transmitter modulation index results in a nominal 20% residual carrier in the transmitted signal. Mode A requires that the transponder be in the high modulation index (1.6) state. Mode A, with ranging, utilizes the low modulation index (telemetry =0.8 and ranging =0.6). Mode B uses high modulation index (telemetry =0.8 and High Rate Channel data =1.0.

In the TDRSS modes (F to I), the R/T telemetry data is NRZ-M coded and applied to the I channel. The second data source (High Rate Channel Data) also NRZ-M coded, is applied to the Q channel. A 1/2 rate, length 7, convolutional encoder, can be applied to both the I and Q channels independently. Output signal level to the transponder is constant for all TDRSS modes.

The redundant PMP output signals are applied to the two transponders in a cross strap arrangement so that, by proper command, the simultaneous connection of PMP-A to Transponder A and PMP-B to Transponder B are obtained (Normal); or the reverse is obtained (A to B and B to A). (See Figure 4.1-2, Switch 6).

4.1.1.4 STACC Central Unit (CU)

The CU interfaces with most of the C&DH components and its functions include:

1. Central command distribution of the forward link data.

2. Central control of telemetry acquisition for the return link.

3. Operation with the OBC in conjunction with the above and other command and telemetry functions.

4. Provisions of a stable spacecraft clock for accurate indication of relative spacecraft time and for distribution to the DPU.

The STACC CU, summarized in Table 4.1-1, accomplishes the above for the C&DH Subsystem by communication via the Multiplex Data Bus for all subsystems of the Landsat D spacecraft.

The CU interfaces are described below along with the general functional characteristics.

Table 4.1-1. Central Unit (CU) Functions

I Command Decoding & Verification

- Active Redundant Cross-Strapped Channels
- Selectable S/C Address & Unit ID
- Selectable NRZ-M or L Command Coding

II Telemetry Format Generation & Control

- 8 Bits x 128 Word Minor Frame
- 16 Fixed Words per Minor Frame
- 128 x 128 Word Major Frame
- 6 x 128 Channel Subcoms
- Commandable

  Telemetry Rate 1, 8 and/or 32 Kbps
  Dwell Mode
  Formats

    Format I & Format II
    Flexible Formats (OBC Option)

III Multiplex Data Bus Control

IV S/C Clock & Timing Signals

V NSSC Communications Control

VI External Ultra Stable Oscillator

VII Special Command Outputs

VIII Spacecraft Telemetry to DPU (to Thematic Mapper)

4.1.1.4.1 Forward Link Commands to CU

The forward link signal is detected in the transponder and each CU receives input signals from both transponders. The signals include NRZ-M data, clock, detector in-lock, and receiver in-lock. All signals must be present for the CU to process the command. See the Data Format Control Book, Volume II (Telemetry) and Volume III (Command) for data formats described. Figure 4.1-9 is a simplified block diagram of the CU and the interface (commands, telemetry, control and timing) signals included in the CU.

Both transponder receivers are continuously operational and reception is through dedicated omni and S-Band High Gain Antennas. Forward link signals will generally be recovered by both transponder receivers and simultaneously applied to the CU. Redundant decoders in the CU accept these signals, and after verification, the CU selects one of these for distribution. The verification and selection process is implemented in the CU to: prevent distribution of erroneous commands, prevent failure of one transponder receiver from disabling both inputs to the CU, terminate command processing if errors are detected, and prevent distribution of commands out of sequence. To accomplish this the CU decoders operate in snarp selection dual-diversity (i.e., one of the two input channels is selected for distribution), with initial preferential selection of the transponder A input signal, and the CU only allows selection sequence transfer from the transponder receiver A to B (not B to A). The latter strategies prevent out of sequence commands.

The verification and selection logic in the CU performs as follows. Two decoders (A and B) in the CU continually process the input signals from transponder A and B, respectively. Subsequent to the command word introduction, verification of each 48 bit command word is accomplished by checking the seven bit spacecraft address, one bit CU designation, and seven bit polynomial (error) check code. If verification is obtained for the transponder A signal, it will be selected and distributed by the CU, independently of whether or not the B signal was satisfactory. The issuance of the command from transponder A is indicated in the return link telemetry by an advance of the command counter work and by the CU-A Decoder Channel A Reject-No (word 3, bit 7) indication.

If a special command is sent to the alternate CU, which is always in STANDBY during normal subsystem operation, the standby CU command count, located on a different return link telemetry word, will indicate the command count advance. No downlink telemetry of the CU decoder channel is provided for the CU that is in STANDBY.

The redundant CU should never be in the ON state along with the prime CU. It should always be left in STANDBY in case the external oscillator fails.

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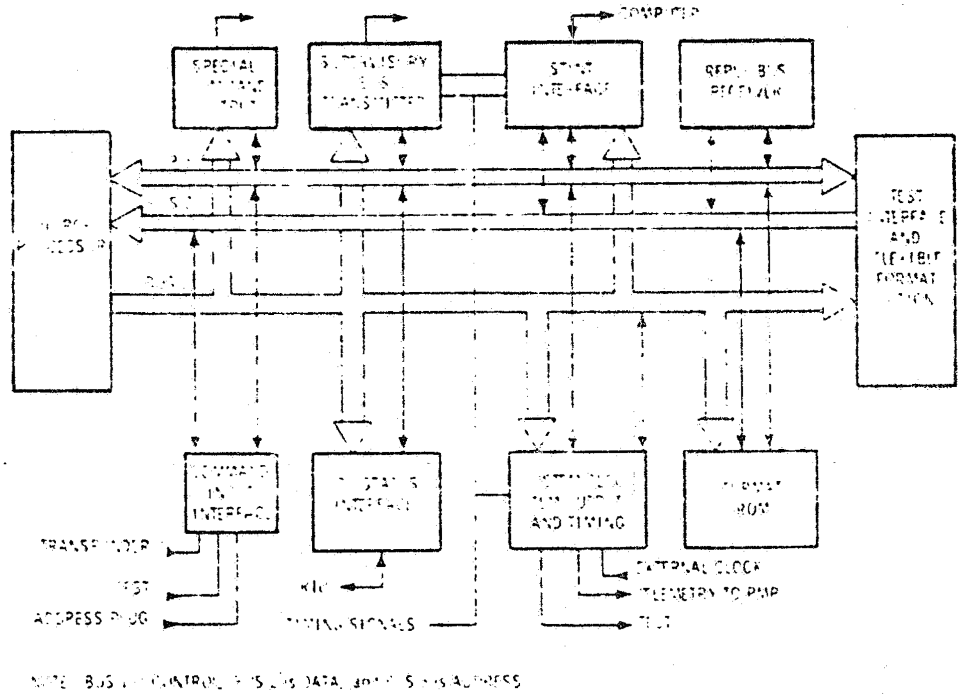

Figure 4.1-9. STACC Central Unit Block Diagram (C&DH)

Processing of the transponder A signal will continue until the transponder A RF received signal quality degrades to the point at which the transponder detector or receiver loses lock; or bit error causes the CU to detect an error during the verification check. Upon detection of an error the downlink CU-A decoder channel monitor (word 3, bit 7) will change state to indicate CU-A Decoder Channel A Reject-Yes. If during the course of the command sequence, starting from the Introduction, the transponder B CU decoder had verified all words, including that for which the A side had just determined an error, the CU will select the B side for distribution, starting at the latter word. The command counter will advance as before. In the event that all words on the B side had not been verified, or in the even that the transponder B signal subsequently degrades to the point at which errors are detected, the CU will halt the forward link command distribution. This action is reflected in the downlink telemetry by a halt in the command counter and a CU Command Reject-Yes flag indication (the reject flag is in the NO state at all times during successful verification from either the A or B sides).

Under very rapid forward link signal fading conditions which may occur during prelaunch test, the CU Command Reject-No telemetry indication could be maintained, until signal strength increased to the point at which the transponder clock signal to the CU was reestablished. If that situation did occur, the command counter halt is used as an indication of command reject.

Subsequent to the B side rejection, and halt of forward link command distribution, the command word introduction must again be included in the forward link transmission before further commands can be successfully processed by the CU. At this point the CU will again proceed to process commands as previously described with the preferential selection of the A side.

In summary, a command is accepted if the five following are true:

1. Receiver is in lock.
2. Command detector in lock.
3. Barker code is good.
4. Presence signal is available.
5. Poly Code check is good.

The full introduction sequence of 128 bits plus 8 bit Barker code is not mandatory, but is preferred in order to assure satisfactory reacquisition of the forward link signal by the transponder. Only the 8 bit barker code is mandatory.

4.1.1.4.2 Return Link Telemetry From CU

The return link telemetry format generation and telemetry data acquisition is established through the CU. The telemetry format is fixed at a minor frame length of 128-8 bit words, and a major frame length of 128 minor frames. Six words in the minor frame are available for subcommutation to 128 words (each). Data rate is command selectable 1, 2, 4, 8, 16, 32, 64, and 32 Kbps. Aside from 8 fixed telemetry words, words 0 to 3 and 64 to 67), generated and applied internally from the CU, 120 minor frame words are assignable to the telemtry acquired from the RIUs. Assignment of the data obtained from the spacecraft's RIUs into the minor frame word location can be achieved by any one or three (commandable) alternates. Two of these, termed Format I (Engineering) and Format II (Mission) provide (different) fixed format assignments by the use of PROMS located in the CU. The third format is achieved in conjunction with the OBC. This provides a flexible format since the format, stored in the OBC memories, can be altered via the forward link. When the OBC format is used the telemetry address information is routed through the STINT and to the CU which provides the control.

There are sixteen positions in the minor frame that have fixed word assignments. Except for these, it is possible, by command, to select the dwell mode for any minor frame word. The selected word will appear in all of the remaining locations (112), with the 16 fixed locations returning the normally assigned telemetry data.

The CU assembles the telemetry data into an NRZ-L serial data stream and supplies it to the redundant PMPs. The active CU also applies redundant 1.024 MHz clock signals directly to the PMPs, which is used within the PMP in the GSTDN mode as the subcarrier for the return link telemetry. The downlink telemetry data is also applied to the redundant STINTS for use by the OBC.

4.1.1.4.3 CU To/From STINT-OBC

Each CU interfaces with the redundant STINTS which supply the access to the redundant OBCs. The forward link stored commands and OBC data are supplied directly from the CU to the STINT/OBC. The OBC also performs a number of spacecraft functions that are routed through the CU to the supervisory BUS then distributed by the RIU to the Landsat-D Subsystems. Referring to the Supervisory Line Activity shown in the DFCB Volume III, the latter functions are allocated in 31.25 microsecond slots as follows:

1. RIU Channel Address TM/Computer-used when telemetry control by OBC is in effect.

2. Computer Commands-for issuing stored commands

3. RIU Channel Address Computer-data request by the OBC flex format for use in internal computation

4. Ground commands slot

As a result of the above, return data is supplied on the Reply Line, as shown in the DFCB Volume II and returned to the OBC via the CU/STINT.

The maximum stored command rate is 1000 commands per second, including approximately 60 discrete commands per second. This maximum rate will require one command for every 8 of the 125 microsecond groups as shown in the DFCB Volume III (Command).

The maximum Reply Line data rate is 64 Kbps for downlink telemetry and 64 Kbps for computer requested data. Reply line activity for these maximum rates require its total capacity, i.e., both channels every 125 microseconds as shown in the DFCB Volume II (Telemetry).

Both the Supervisory and Reply Lines transfer the information at 1.024 Mbps.

The dump data is obtained from the STINT and applied directly to the PMP.

4.1.1.4.4 CU Interface to MDB and BCU

The CU interfaces with the Multiplex Data Bus (MDB) which is routed to other spacecraft subsystems. Within the C&DH Module the MDB also interfaces with the Bus Control Unit (BCU) for application to the redundant RIUs.

The active CU supplies the Supervisory Line Message on one of the redundant lines (A or B) which is selectable by special command. Similarly it receives the Reply Line Message on either line A or B.

The DFCB provides the format definitions for the Supervisory Line Message types and the MDB interface characteristics.

4.1.1.4.5 CU-to-CU

The interconnections between CU-A and B provide for ON/STANDBY control. To activate a given CU, special commands sent by the forward link are addressed to it. Three commands are generally required. These are Mate CU OFF 1, Mate CU OFF 2, and Self-ON. The first two commands place the alternate CU (assumed initially ON) in the STANDBY mode. Dual mate off commands are implemented in order to reduce the probability of inadvertent CU turn-off.

4.1.1.4.6 CU to/from RIU

The RIU provides command and telemetry interfaces to the CU, which are described later. Additionally both RIU A and B supply Standby voltages to each CU. These provide failure protection by steering serial magnitude commands from the redundant RIUs. They are also used to energize the CU hardline telemetry monitor output.

4.1.1.4.7 Hardline-to-CU

A capability is included in the C&DH subsystem to obtain hardline commands to CU-A. Three signals are supplied NRZ-M data at either 125; 1000 or 2000 bps; a 1X clock; and command presence.

4.1.1.4.8 CU-S/C Clock

The CU S/C clock is controlled by a 4 MHz oscillator with stability of 2 parts in 10^8 at constant temperature and a slope of 2 parts in 10^8 per degree C. Spacecraft time is included as 24 bits in the return link telemetry. Maximum count is 200 days with 1.024 seconds update. Spacecraft time is set to zero when the CU is in Standby. The CU contains all signal, telemetry and command provisions for application of an external ultra-stable oscillator which is the primary spacecraft clock for Landsat-D . The internal CU S/C clock will be selected on initial power up of the CU.*

4.1.1.4.8.1 CU-Ultrastable Oscillator. A 4.096 MHz Ultra Stable Oscillator will provide the precision master frequency source to be used for timing operations, including the operation of the clock in the Instrument Module. This Ultra-Stable Oscillator will provide to the STACC CU two buffered square wave output signals of 4.09600 MHz and telemetry status. The oscillator frequency stability will be less than 1 x 10^{-10} per day after the first 30 days of operation and not exceed 5 x 10^{-12} per degree celsius over a range of $-20^{o}C$ to $+50^{o}C$. After initial CU power up the CU will be commanded to accept this Ultra-Stable Oscillator signal and turn off the internal S/C clock.

4.1.1.4.9 CU Command Control

The CU has provisions for control by special command (see 4.6) and RIU commands.

The assignment of CU special command is indicated in Table 4.6-1. The CU is also controlled by RIU serial magnitude command zero, given in Table 4.6-2. Both CU A and CU B share the same command. The CU must be ON in order to execute the command. RIU A and B provide redundant commands to each CU. There are no RIU discrete commands.

*See the constraints on commanding both CU's to the external oscillator.

4.1.1.4.10 CU Telemetry Monitors

All control commands (special and RIU) to the CUs are provided with telemetry status monitors on the return link telemetry (see 4.7).

4.1.1.4.11 CU From PCU

Each CU is supplied from continuous DC power on the primary voltage bus from the PCU. The inactive CU is in the standby state.

When the primary bus voltage is first applied to the module, both CU's will go to the Standby state. This will also occur if there is a temporary interruption of the bus voltage to an active CU. Only one CU should be ON at a time. To turn a CU ON from this initial state (both in STANDBY), a special command, Self-On, is required, addressed to the CU (see DFCB Volume III, Command for CU address bit A_8) that is to be turned ON. If activation of the alternate CU is desired, the SELF-ON command, addressed to the Standby CU, must be preceeded by the Special Commands Mate CU OFF 1 and Mate CU OFF 2. This sequence is required so that both CUs are not powered ON simultaneously. The latter situation is undesirable since there is probability (very low) of inducing a sequence (both CUs OFF) will result in an interruption of all telemetry and command functions, including those to the OBC. It is desirable to halt the computer, before the switchover. After CU turn-on, is achieved, the CU will be under Format II control at the 1 Kbps return link telemetry rate, using the internal oscillator. Special and/or RIU commands are then used to select the desired CU operating mode and external clock oscillator ON.

4.1.1.5 Remote Interface Unit (RIU)

The C&DH subsystem components derive their telemetry and command functions from RIU's. Telemetry capability is doubled by use of redundant Expander Units (EU's). RIU telemetry capability can be increased by addition of EU's as shown in Figure 4.1-10 and explained in 4.1.1.6.

There are multiple RIU's located in the various Landsat-D subsystems, the RIU functions are summarized in Figure 4.1-11.

In its function as a remote unit, the RIU receives telemetry and command instructions from the CU, and returns telemetry data to the CU, on the Supervisory and Reply lines, respectively. The C&DH RIU/EUs are assigned address #1 so that the CU can uniquely address instructions destined for the C&DH components. The RIU/EU address assignment is accomplished by external wiring of an RIU.

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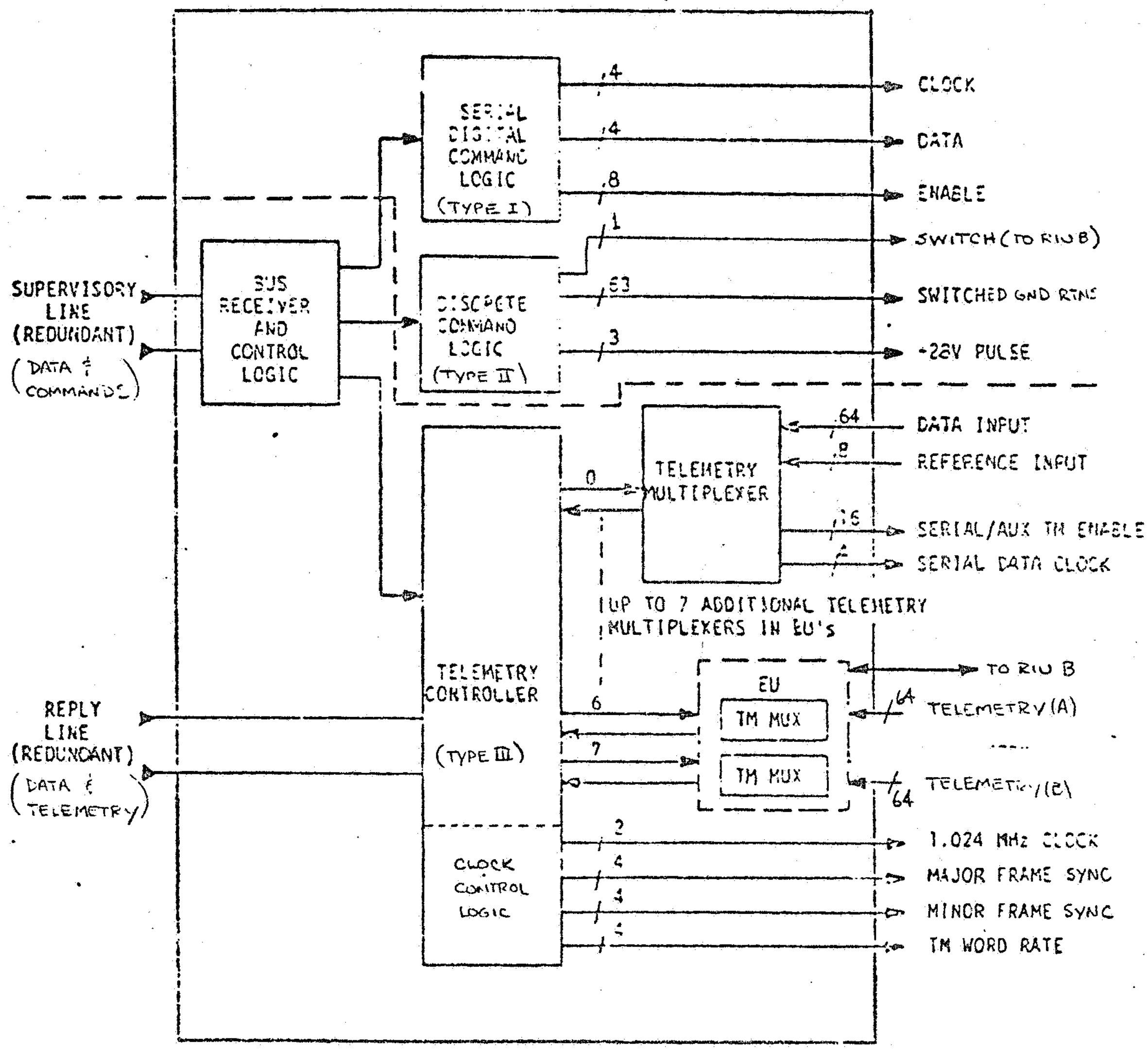

Figure 4.1-10. RIU Simplified Block Diagram

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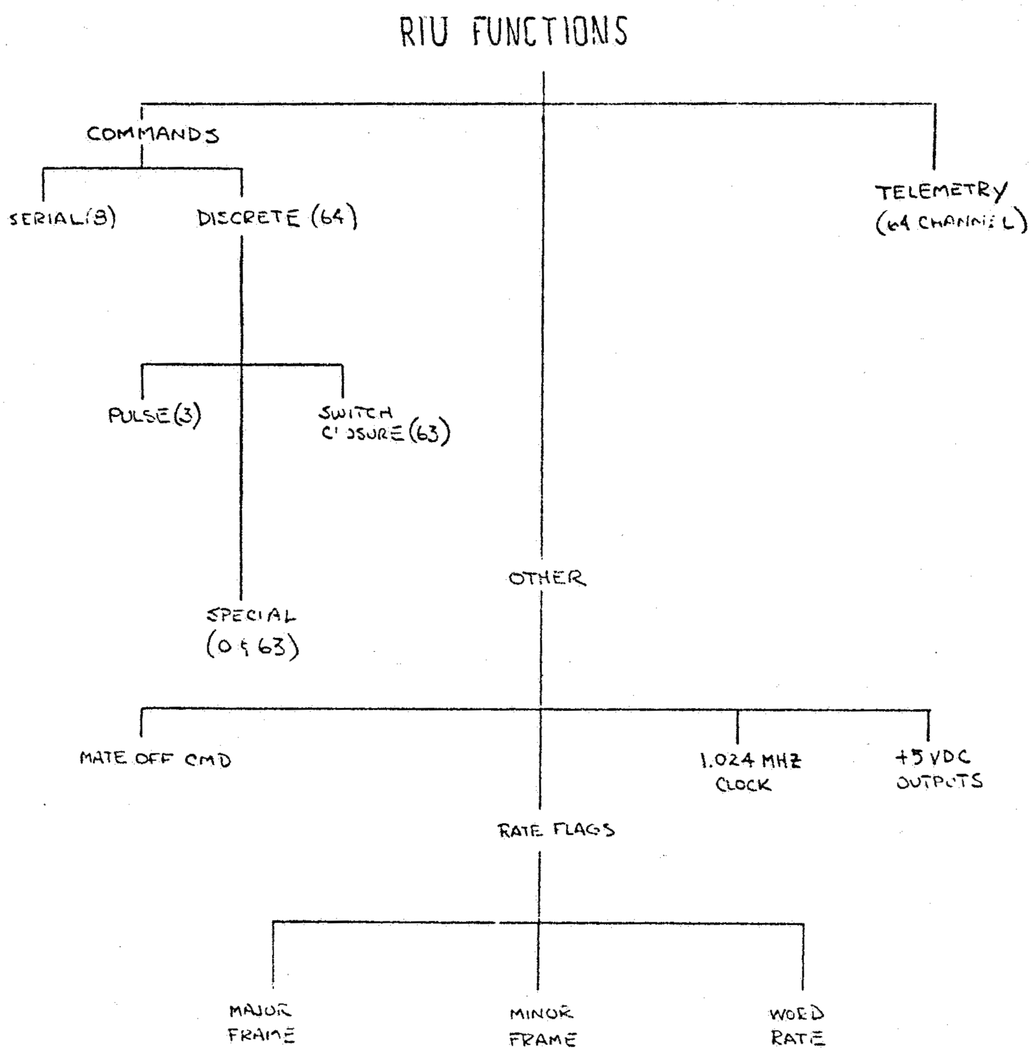

Figure 4.1-11. RIU Functions

The RIU total redundant command capability allows for 64 discrete commands (includes RIU SELF ON, MATE OFF and REDUNDANT OFF) and 8 serial magnitude commands. The total RIU/EU telemetry capability is up to 512 channels. The telemetry provides for four different types of monitors; bi-level (single bit), analog, conditioned analog (passive source), and serial digital. See Section 4.7 for the telemetry assignments and Section 4.6 for Command assignments.

In addition to the above, the RIU outputs various sync (word, minor frame and major frame) pulses, a 1.024 MHz clock and DC voltages. In Landsat-D the DC voltages are used by the PCU, STINT, CU and alternate RIU for various circuit functions.

4.1.1.5.1 RIU Communication To/From CU

The command and telemetry control message Formats between the RIU and CU are described in the DFCB Volume II and III. As shown in Figure 4.1-12 the redundant RIUs are paralleled across the BCU, which in turn interfaces with the redundant supervisory and reply lines from the CU. All Landsat-D Subsystem versus RIU number are shown.

4.1.1.5.2 RIU Command Distribution

Command messages directed to RIU address #1 are accepted by the C&DH RIUs and distributed to the various C&DH components. Both of the redundant Supervisory Lines (A and B) are continuously monitored by the RIUs.

In the case of discrete commands, requiring a +28 volt pulse output, and a ground closure addressed to the subsystem component, maximum use is made in assignment of 3 isolated 28 volt sources contained in each RIU. All of the prime C&DH components are assigned to BUS #1 and the remaining subsystems to BUS #2 through #9. The 28 volt discrete commands are rated for 200 milliamps drive. Command duration is nominally 7 milliseconds, with timing of switch closure (ground return) and 28 volt pulse as shown in the DFCB Volume III (Command).

Serial magnitude commands are distributed on three lines (enable, clock and command data) with timing as shown in the DFCB. Command length is 16 bits at a rate of 256 Kbps, NRZ-L. The command clock is distributed in common to all RIU's. The command data is similarly distributed.

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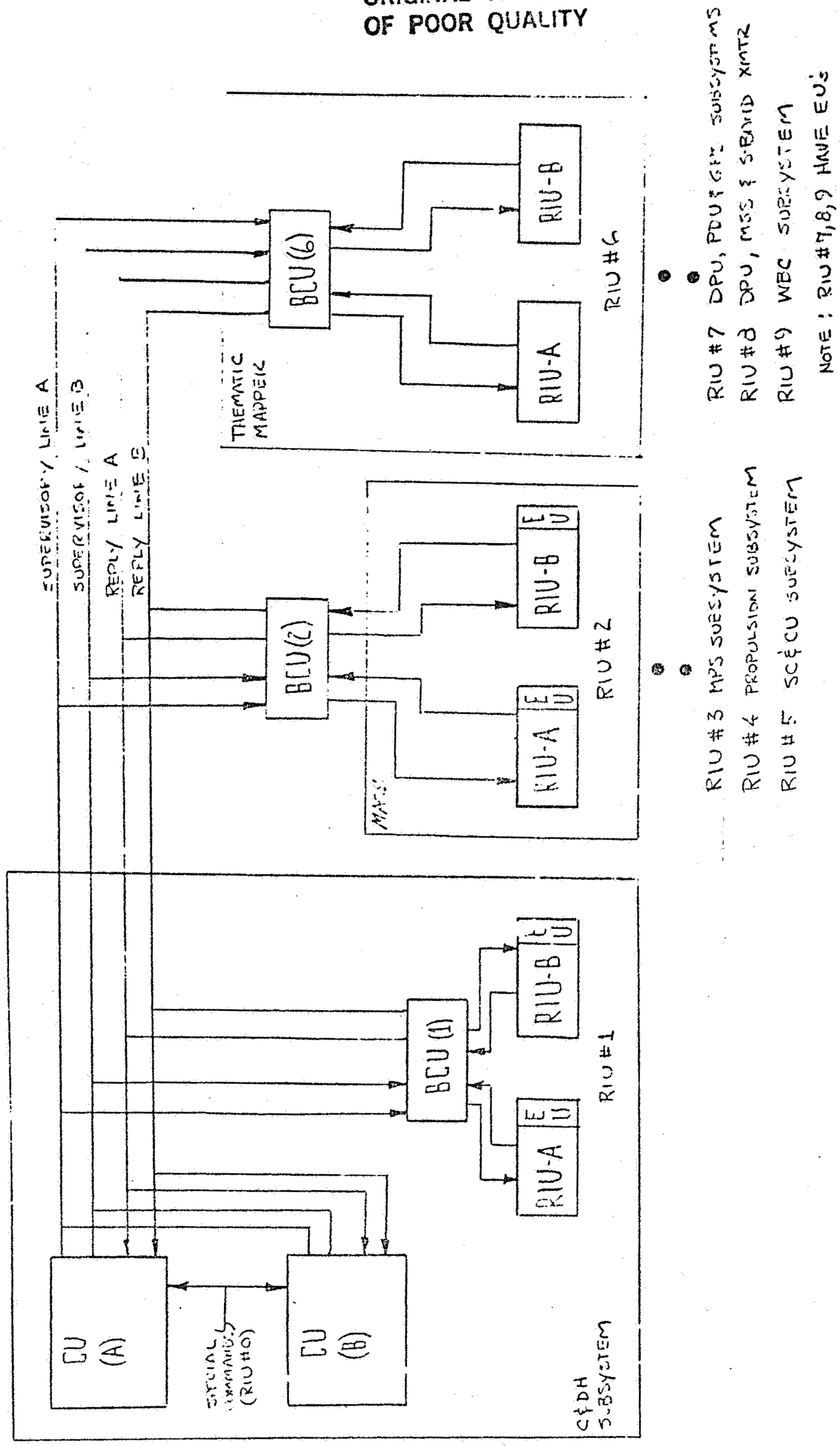

Figure 4.1-12. Functional Block Diagram MDB Interfaces

4.1.1.5.3 RIU Telemetry Acquisition

The RIU/EU accomodates 4 types of telemetry; bi-level, analog, conditioned analog and serial digital (8-bit words). Telemetry assignments for the C&DH components are given in Section 4.7, Telemetry. The conditioned analog monitors interface with passive thermistor, temperature monitoring circuits, to which they apply a constant 1 milliamp current during the sampling interval. The RIU-ADC converts the resultant voltage level to an 8-bit word for return on the reply line. Timing is shown in DFCB Volume II (Telemetry) Analog signal samples are also converted to 8-bit words. Acquisition of the serial digital telemetry is accomplished with a 256 Kbps, 8 bit clock, distributed to the subsystem component for an 8-bit subsystem component output via the reply line. Accompanying the serial digital clock signal is an enable pulse addressed to the particular subsystem component. The bi-level monitors are readout as 8-bit words.

In all of the above cases, a telemetry request to the RIU results in the return on the redundant reply lines (A and B) of an 8 bit data word preceeded by a leading bit, logic zero, sync signal. Reply line rate is 1.024 Mbps, BIØ-L.

4.1.1.5.4 RIU Sync and Clock Outputs

The RIUs utilize the signalling information on the Supervisory Line to produce coherent sync and signals. Synchronization with the Supervisory Line is maintained at all times, independent of whether or not the RIU is addressed. Outputs are available from each of the following sync signals; major frame rate, minor frame rate, and word rate. Each sync signal has a pulse duration of 47 microseconds. A 1.024 MHz clock signal is also provided.

4.1.1.5.5 RIU to EU Interfaces

Each RIU interfaces with an associated EU multiplexer (2 EU multiplexers are contained in an EU). An EU multiplexer is identical to an RIU multiplexer. The RIU provides the EU with supply voltages and transfers telemetry requests received on the Supervisory Line - directed to the EU - by means of clock, address and enabling signals. Messages for the EU are identified by 3 bits (bits 22 to 24, see DFCB Volume III) in the Supervisory Line message. The EU is identified by $(1)_8$, while the RIU is identified by $(0)_8$. The remaining allocations $(2)_8$ to $(7)_8$ are available when the telemetry system is expanded up to an additional 6 EUs. The EU outputs either an 8 bit word or an analog sample to the RIU in response to a telemetry request. The RIU-ADC is used to convert the analog samples to an 8 bit word. The RIU then sends the response down the Reply Line.

4.1.1.5.6 RIU DC Power

The two C&DH RIUs are supplied continuous DC power from the PCU. In normal operation one RIU is OFF (STANDBY), while the second unit is operating at a rate determined by the CU format in effect. Normally the ON (STANDBY 2) RIU in the C&DH is expected to operate at a low duty cycle, about 1%.

4.1.1.5.7 RIU Data Flow and Operational Description

The RIU data flow was described in the previous paragraphs.

When the primary bus voltage is first applied to the RIUs, or when it is restored after interruption, the RIUs will assume their prior states. In normal C&DH operation, one RIU will be in the active state (ON/Standby 2), and the other will be in the OFF (STANDBY) state. In order to activate the alternate RIU, it is necessary to send two commands to the OFF unit. The first is the Self RIU Enable (STANDBY 1) (Command 0).

In this mode it can issue discrete commands. Command 63 is then sent, which activates the unit (Standby 2) and simultaneously disables the (alternate) mate RIU (OFF), Command 58 provides a backup OFF command to the mate RIU. Once put in operation, the RIU is controlled by CU direction.

4.1.1.6 Expander Unit (EU)

Each RIU contains a single telemetry multiplexer capable of retrieving four types of signals from a total of 64 inputs, reference Figure 4.1-10. A total of eight multiplexers may be used with any given RIU providing a maximum input capability of 512 channels. The additional telemetry multipliers are housed in Expander Units.

4.1.1.7 Bus Coupling Unit (BCU)

The coupling between the MDB and the RIUs is accomplished by Bus Coupling Units. These suffice to provide correct impedance matching and reliability characteristics. The coupling provides both isolation (transformer-coupling) and fail-safe (resistors) features in its design. Each BCU accommodates a maximum of four RIU's with the total length of the stub up to 20 ft. An RIU is coupled to each line of the bus by means of a transformer coupled stub. The transmission medium for the stub is identical to that of the bus lines. Two 56-ohm resistors are connected between the coupling transformer and the bus. The transformer separates the coupling resistors from the stub, and has a turns ratio of 3:1 as measured from the bus side to the stub. The input impedance of the RIU is not less than 2000 ohms at a frequency of 1.024 MHz. The RIU couples to the stub through an internal transformer with a turns ratio of 1:3 as measured from the stub side to the RIU. The two stub coupling transformers are identical. The transformer design is such that the bus signal waveshapes are maintained on the output side of the RIU transformer for the supervisory lines and on the bus side of the bus transformer for the reply lines.

4.1.1.8 Power Conditioning Unit (PCU)

C&DH Subsystem module power is derived from two voltage sources: the first is dedicated to the resupply heaters only. The second (the primary voltage bus) is routed to the PCU for distribution to C&DH Subsystem components. Distribution by the PCU, plus a description of other functions performed by the PCU follows:

A block diagram of the power distribution is shown in Figure 4.1-13. The PCU in addition to providing the primary voltage bus distribution includes the following:

1. +28 Volt power bus protection
2. +28 Volt power bus distribution
3. Computer power conditioning and control
    a. +5V $\pm$ 5% at 1.0 to 3.5A
    b. +12VV $\pm$ 5% at 0 to 1.5A
    c. -5V $\pm$ 5% at 0 to 0.5A
    d. Switching for memories
4. Redundant power clear circuits to STINT/OBC.
5. Redundant oscillators for OBC.
6. Generation and distribution of +28 volt, long duration drive signals to the RF antenna switching relays.
7. Pulse stretchers for high current relays.
8. Signal conditioning for the RF switches, telemetry monitors.

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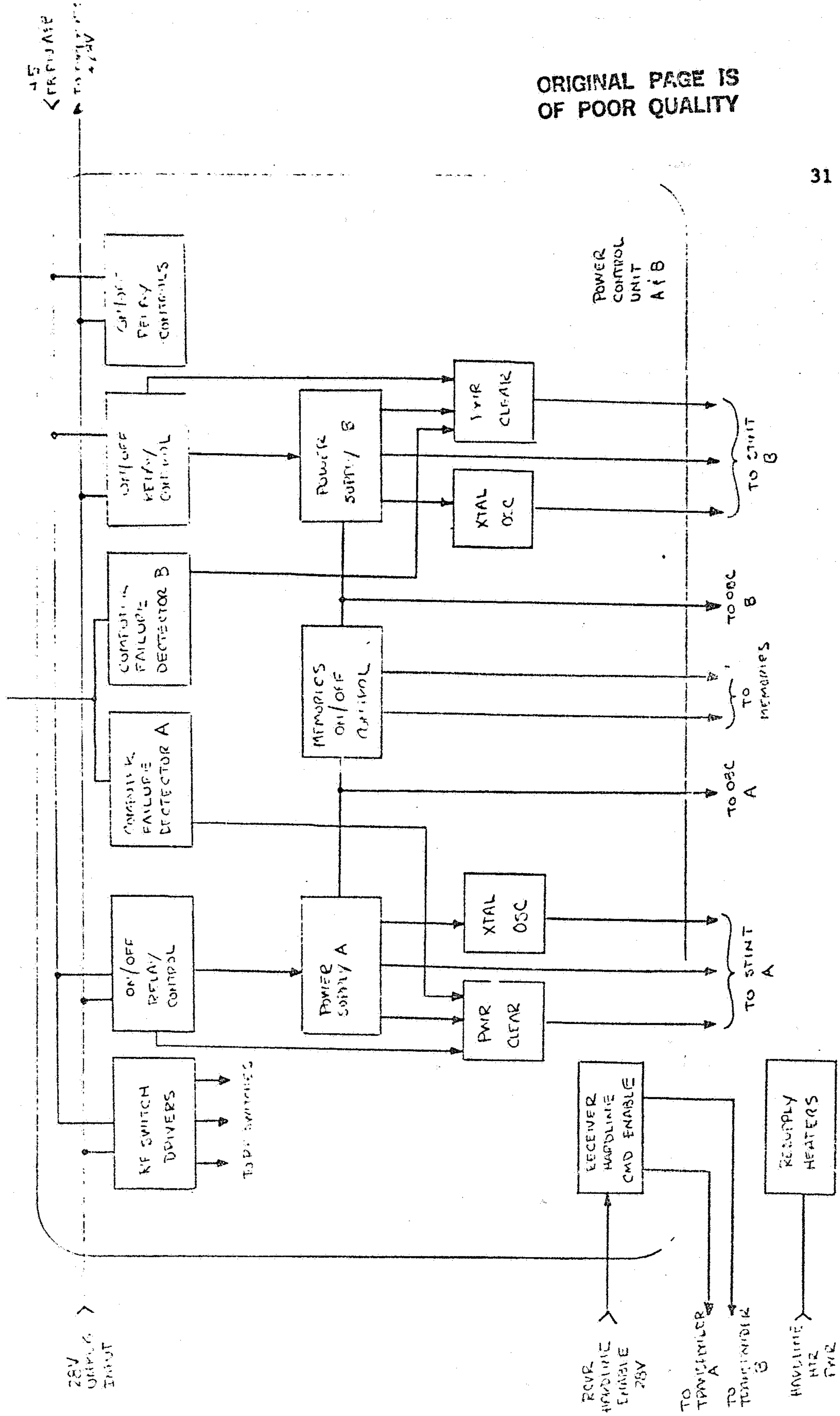

Figure 4.1-13. Power Conditioning Unit Block Diagram

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9. Redundant computer failure detection circuits.

10. Implement redundant ON/OFF controls for mission peculiar loads of 2 amps at +28 volts.

11. Provide two (2) non-latching relays for hardline CMD Enable.

4.1.1.8.1 PCU DC Power

4.1.1.8.1.1 OBC Power Supplies. Redundant power supplies A and B for the OBC/STINT, derive their ON/OFF control by latching relays. Each supply is protected by redundant fuses, and a trip circuit, which is activated by undervoltage, overvoltage or over current.

Two of the fault conditions; overcurrent and undervoltage, result in latching of the trip circuit, i.e., when the trip circuit is activated, the DC/DC converter output voltages are turned off and remain off whether or not the fault conditions are subsequently cleared. To restore operation, the primary bus voltage to the power supply must first be disconnected by sending the Power Supply OFF command. This is followed by the Power Supply ON command. Assuming that the fault conditions are cleared, the power supply operation is now restored.

An overvoltage fault does not produce latching of the trip circuit. When the fault is removed, the power supply DC/DC converters operation is restored without the necessity of sending any commands.

Each power supply energizes an OBC oscillator circuit, a computer protection circuit (the Computer Failure Detector portion), and produces regulated secondary voltages of +5, -5 and 12V for distribution to the OBC/STINT. Each power supply is dedicated (i.e., A to A and B to B) to an associated oscillator circuit, and computer protection circuit. Each is also dedicated in the distribution of +5 Volts to the STINT and OBC. The distribution of OBC memory voltages (+5, -5 and +12 VDC) is configured so that by command control either of the supplies can energize all memories up to the maximum of eight.

4.1.1.8.1.2 DC Power Distribution. The primary voltage bus input is distributed by the PCU. The DC voltage is in the range of 21.6 to 35VDC, under normal conditions. ON/OFF switching is provided internally in the PCU for a number of these lines, other lines provide continuous power. These are divided into three categories: input voltage, output voltage (28 VDC) and conditioned secondary output voltage from the PCU power supplies.

The input DC voltage includes the 28 VDC (low power) transponder receiver hardline command enable. There are also redundant +5 VDC inputs (from RIU A and B) which are used to provide for signal conditioning of all telemetry monitors in the PCU, as well as for OBC protection circuit operation. The sources are not fused within the C&DH Module. The RIUs' are fused on the primary line side (28V).

Resupply heaters are directly wired via hardline. No fuses are used.

The +28 VDC output lines are categorized as continuous and switched (within the PCU). All lines are redundantly fused. The conditioned secondary voltage outputs are dedicated to the respective STINT-OBC. Switching employed for the memories is discussed in Section 6.0.

4.1.1.8.2 PCU Data Flow

Aside from the Telemetry and Commands and DC voltage distribution, there are three PCU outputs delivering either signal or control to external components. These are given in Table 4.1-2 and operationally described in Paragraph 4.1.1.2 and Section 6.0.

Referring to Table 4.1-2 a digital oscillator ouptut signal is applied to the STINT (dedicated-oscillator A to STINT A, and B to B). It is also applied to the OBC (also dedicated).

The OBC (protection) clear signal is also dedicated. It is applied to the STINT, which routes it to the OBC.

The transponder receiver hardline command enable output circuit in the PCU is a straight wire that is shorted during enable (open otherwise). Both receivers A and B are enabled simultaneously from redundant feeds, by 28V application to a single control relay in the PCU.

Table 4.1-2. PCU Outputs

Designation	Destination	Remarks
Oscillator (1.8 MHz for LSD)	STINT	The STINT conditions this signal and transmits it to the OBC.
OBC Clear	STINT	The STINT provides a straight wire feed to the OBC.
Transponder Receiver Hardline Command Enable	Transponder Receiver	Controls both A&B Recievers simultaneously

4.2 PERFORMANCE CAPABILITIES

The C&DH performance characteristics are summarized in Table 4.2-1.

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Table 4.2-1. C&DH Subsystem Summary

Function	Capability	Landsat-D Implementation
Receive Frequency Band	2025-2120 MHz	2106.40625 MHz
Transmit Frequency Band	2200-2300 MHz	2287.50 MHz
RF Power	1, 2.5 or 5 Watts	5 Watts
TDRSS Q/I RF Power Ratio	1:1 to 4:1	4:1
Noise Figure	6.0 dB, Nominal	SAME
Coherent Turn Around Ratio (F_T/F_R)	240/221	SAME
S-Band Transponder	Near Earth or GSTDN/TDRSS	GSTDN/TDRSS
Transmitter Modulation	FDM/PM (STDN) SQPSK (TDRSS)	SAME
Ranging Modulation	Side Tone (GSTDN) PRN (TDRSS)	SAME
Mission Unique (Fused) Continuous Prime Power	Dual Redundant Sets of 7 lines	TBD
Primary Power Source Line Voltage	22-35 VDC	SAME
Prime DC Power Distribution (PCU)	Redundant Fused Lines	SAME
PCU Oscillator Frequency for OBC	1.4 to 1.8 MHz	1.8 MHz
STACC/CU External Oscillator	Accommodates Ultrastable Oscillator	4.096 MHz
Mission Unique Equipment Location	6 Sq. Ft. Available	1 S/C Ext. Oscillator 2 Tape Recorders and 4 Memories

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Table 4.2-1. C&DH Subsystem Summary

Function	Capability	Landsat-D Implementation
OBC Memories (8K words each)	4 to 8	8
PMP Data Handling	Provides FDM of 2 Selected Data Streams	SAME
	Conversion NRZ-L Data to NRZ-M, BiØ-M, BiØ-L	
	1/2 Rate Convolutional Encoding (TDRSS)	
TDRSS Ground Command Bit Rates	Two of following: 1,000, 500, 250, 125 bps	125 and 1,000 bps
GSTDN Ground Command Bit Rate	2,000 bps	SAME
Command Format	NRZ-M 16 KHz subcarrier (GSTDN) PRN at 3 MCPS (TDRSS)	SAME
	PN Codes 1 to 85	PN Code 2 (LSD) and 3 (LSD Prime)
Command Word Length	48 bits (includes 7 bit polynominal check	SAME
Real Time Command Rate	41 per sec max. (at 2 KBps)	SAME
Stored Command Rate	1000 per sec max (Combined ser. Mag and Discrete)	SAME
Serial Magnitude	1.000 per sec max.	
Discrete	60 per second max.	
Stored Commands (Data Dependent or Time Tagged)	Via NSSC-1 OBC	SAME

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Table 4.2-1. C&DH Subsystem Summary

Function	Capability	Landsat-D Implementation
STACC RIU Commands	64 Discrete 8 (16 Bit) Serial Digital	SAME
STACC CU Special Command	16 (Ground Closures)	SAME
Telemetry Rates	1 to 64 Kbps (Commandable in binary steps)	8 Kbps (Commandable) 1 kbps
Telemetry Format	-Word Length 8 bits -Minor Frame 128 words -Major Frame 128 Minor Frames -Sync Word 24 Bits -Subcommutation 6 Words x 128	SAME
Telemetry Format Control	-Fixed Format I -Fixed Format II -Via OBC (Flexible) -Via STACC CU (Flexible)	 SAME NOT USED NOT USED
STACC RIU/EU Telemetry	-64 Telemetry Channels Apportioned to: -16 Serial Digital Max. -16 Conditioned Analog Max. -64 Bilevel Max. -64 Analog Max. For each RIU or EU	SAME
NSSC-1 Computer Dump Downlink Telemetry Rates	1 Kbps or 32 Kbps by Command	SAME
Data Multiplex Bus	-Redundant Supervisory and Reply Lines -Isolated From RIU/EU By STACC BCU -Accommodates up to 62 RIU's	SAME

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Table 4.2-1. C&DH Subsystem Summary

Function	Capability	Landsat-D Implementation
STACC RIU Output Signals Other Than Commands	-1.024 MHz Clock -Major Frame Sync -Minor Frame SYnc -Word Rate	SAME
External Telemetry	Analog or Biphase Digital Up to 2.048 Mbps	Digital Feed Available at Module Interface Connector
Hardline Monitors	-STACC CU Telemetry -STACC STINT (OBC)	SAME
Spacecraft Address	Various (7 bits)	LSD CDH S/N 2 = $(156)_8$ LSD PRIME CDH S/N 4 = $(073)_8$ Spare CDH S/N 3 = $(103)_8$
STACC/CU Frame Synch Code	Various (24 bits)	$76547144 0_8$

4.3 MODES OF OPERATION

4.3.1 RF ANTENNA AND SWITCH MODES

4.3.1.1 RF Switch Operating Modes

The feed circuits, resulting from the three RF configurations (I, II and III) are shown respectively in the block diagrams of Figures 4.3-1 through 4.3-3. The receive and transmit paths for each transponder are obvious from the diagrams. The diplexer is terminated in 50 ohms through the relays when the associated transmitter is applied to the high gain port. Note that when both transmitters are in the Omni position, the high gain port is terminated with 50 ohms, as shown in Figure 4.3-4.

With a transmitter RF power rating of 5 watts ±1 dB, output power levels are greater than 3.2 and 3.5 watts for the omni and high gain ports, respectively. The RF switches are rated to allow switching with the transmitter ON. However, the operational procedure should turn-off the transmitter before switching to assure that arcing does not occur or subsequent damage to the switch may occur.

4.3.2 TRANSPONDER OPERATING MODES

This section is organized into subsections which reflect the two basic operating modes of the transponder:

1. GSTDN MODE
   Receiver (Forward Link)
   Transmit (Return Link)

2. TDRSS MODE
   Receiver (Forward Link)
   Trasmit (Return Link)

When the transponder is first powered up, or where there is a interruption of power, the forward and return links involve data rates and modulation indices which are a function of the configuration which the transponder automatically assumes. Interruption of the transmitter prime power does not change the configuration.

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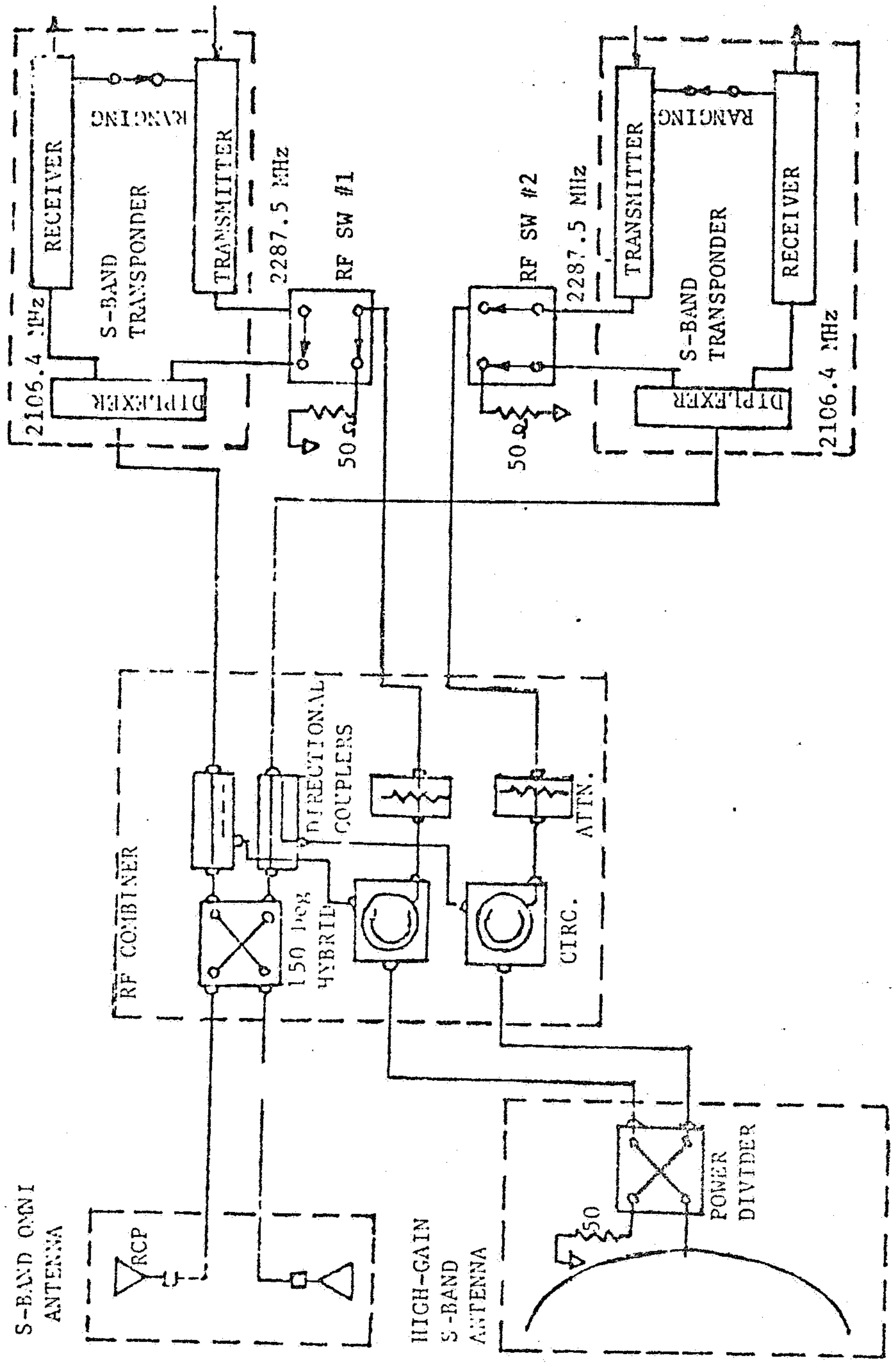

Figure 4.3-1. RF Switch Configuration I

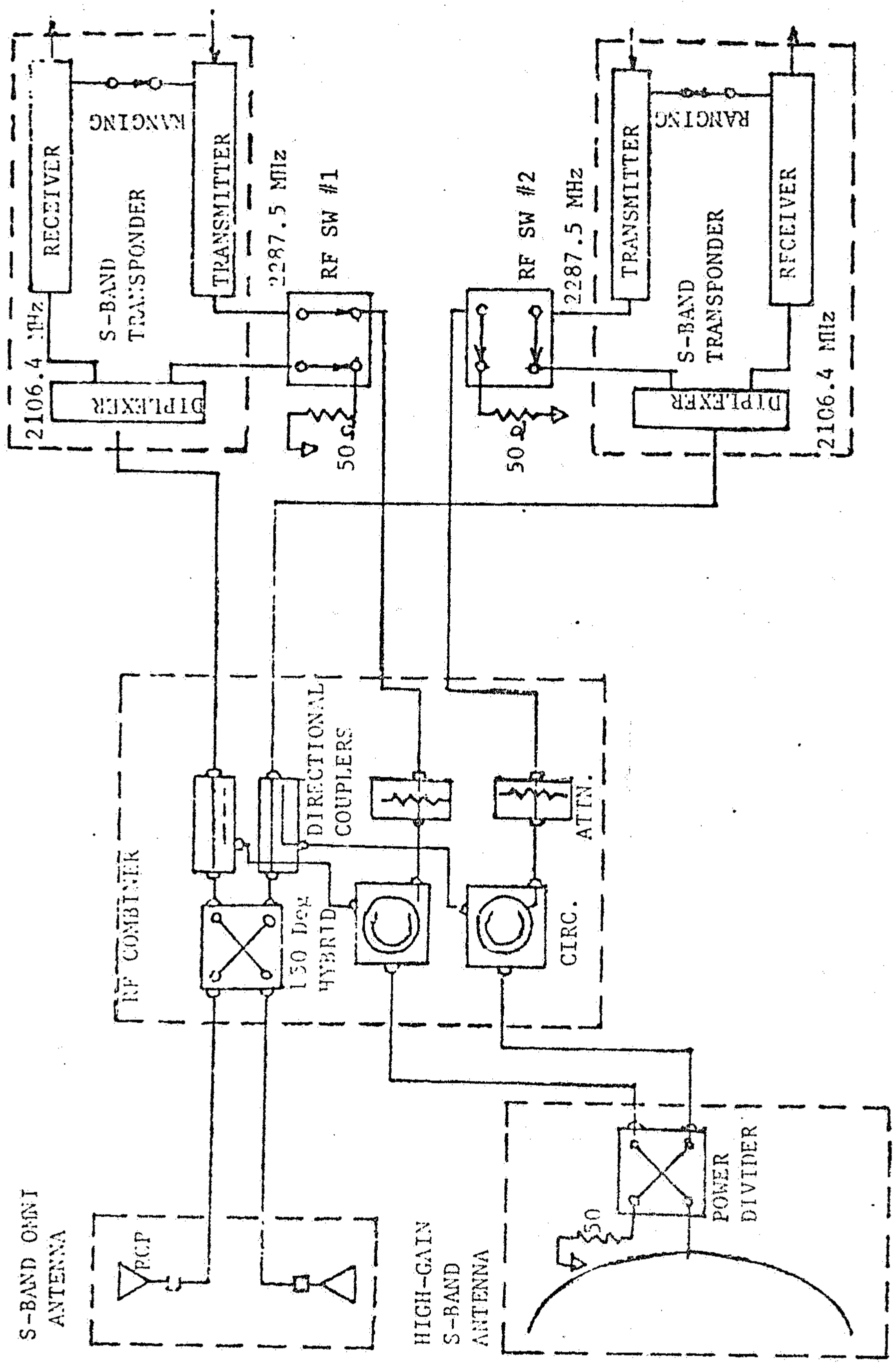

Figure 4.3-2. RF Switch Configuration II

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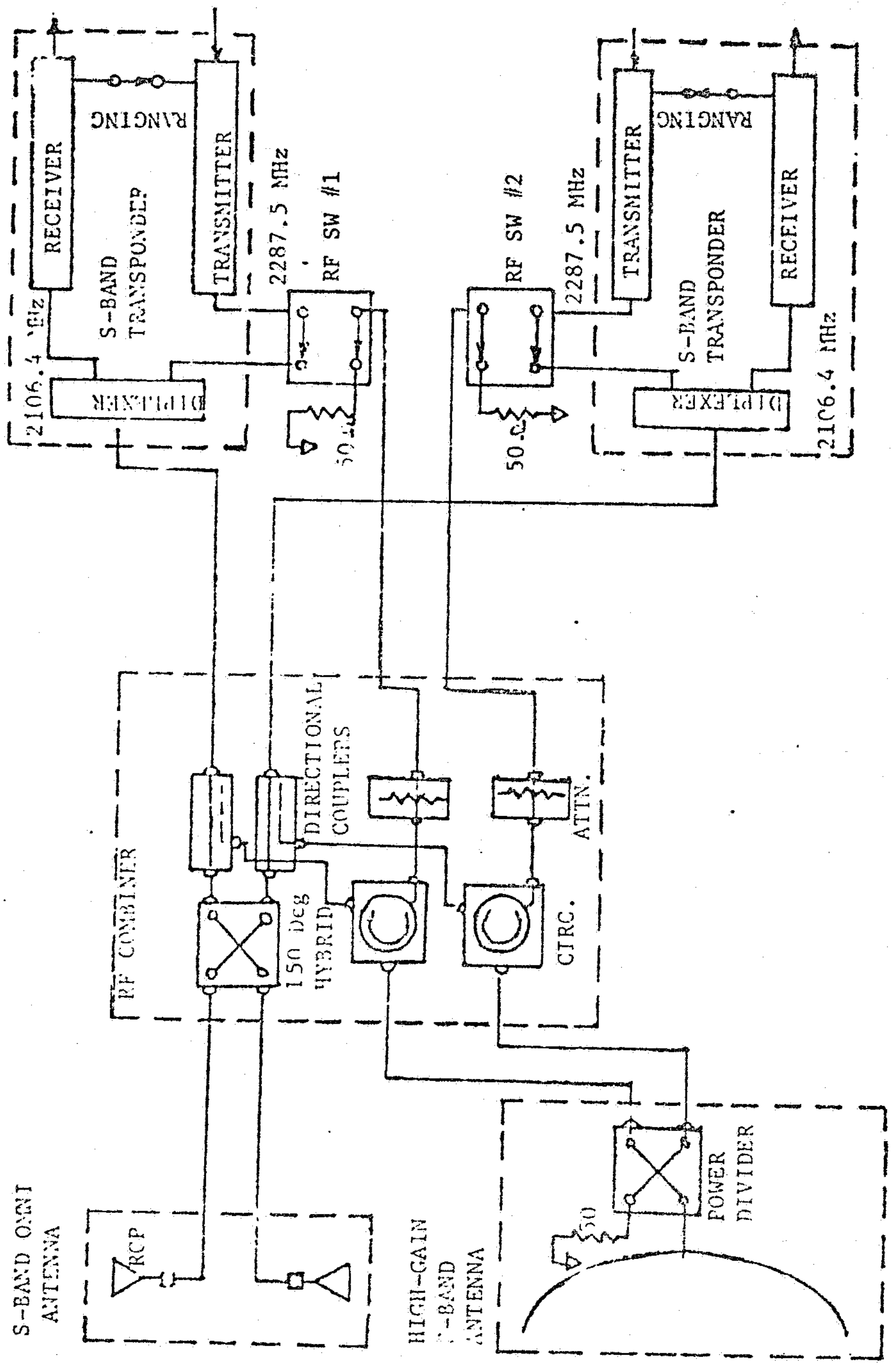

Figure 4.3-3. RF Switch Configuration III

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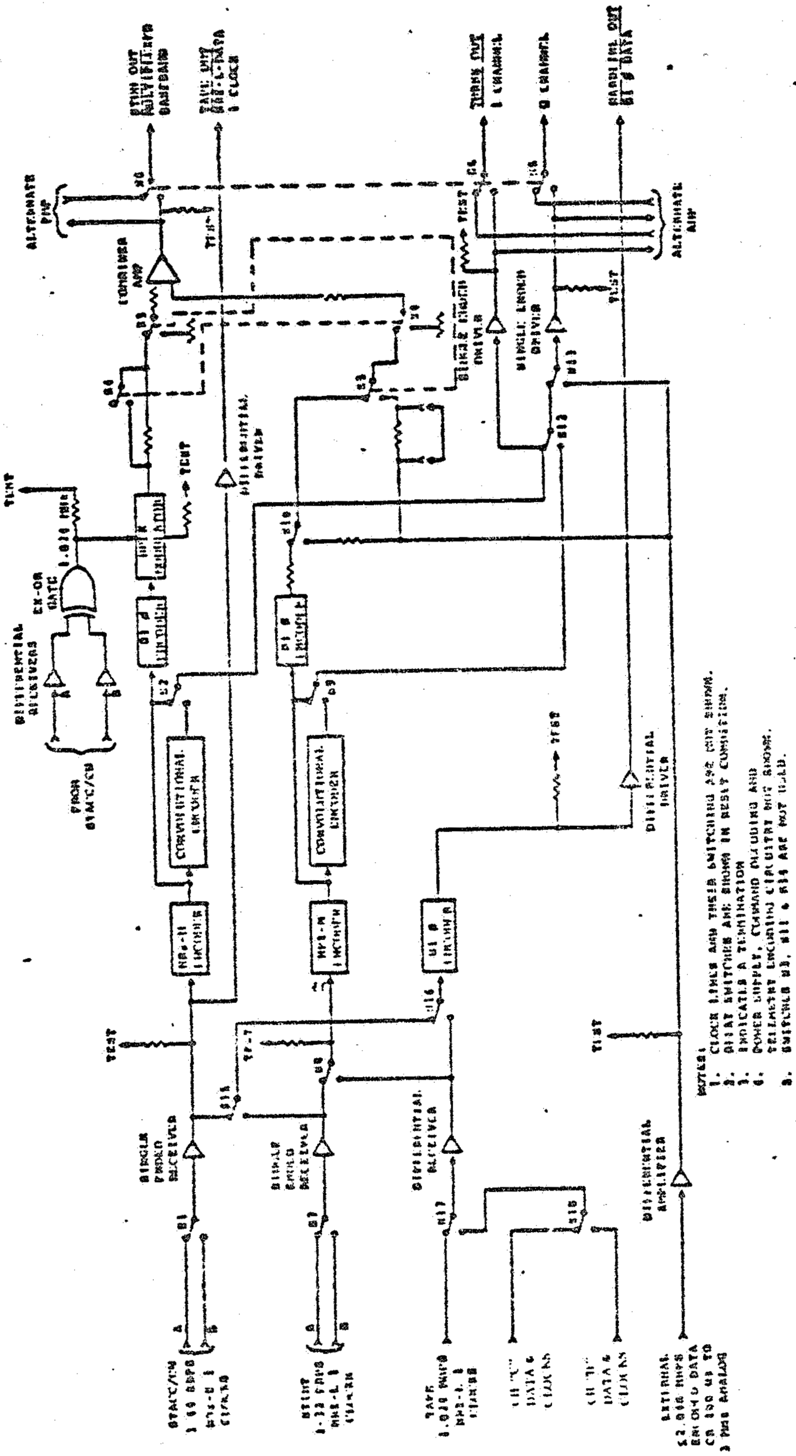

Figure 4.3-4. Simplified Diagram of PMP Components and Mode Switches

Upon initial DC application or after temporary disruption, the receiver will be in the dual mode and low TDRSS command rate, i.e., forward link GSTDN reception at 2 Kbps or TDRSS at 125 bps. The transmitter will be OFF with the mode states indicated below.

Mode	-	STDN
Modulation Index	-	LOW
<u>Telemetry Inputs:</u>		
STDN 1 and 2	-	OFF
Ranging Channel	-	Disabled
<u>Automatic Transmitter ON:</u>	-	Inhibited
Override	-	Allowed
<u>Automatic AUX OSC to VCO</u>	-	Allowed

The transponder can be commanded into either the TDRSS or GSTDN mode as required. Only one transmitter should be powered at a time. In the GSTDN mode, a low modulation index is used when the R/T telemetry data is accompanied by ranging (mode A of the PMP). All other PMP GSTDN modes require high modulation index.

4.3.2.1 <u>GSTDN Mode</u>

There are two commandable states of the transponder which result in the use of two different acquisition threshold values. The states are:

1. Dual GSTDN/TDRSS Acquisition

2. Commanded GSTDN only

In the dual GSTDN/TDRSS Acquisition state, the receiver looks for the appropriate signal in two dynamic ranges.

	-50 dBm to -95 dBm	GSTDN signal
and	-110 dBm to -135 dBm	TDRSS signal

In other words, the first criteria for locking onto the appropriate GSTDN or TDRSS signal is based upon power level only. Note that the area between -95 to -110 dBm (15 dBm range) is a non-useable area i.e. the receiver does not lock up to either mode. After lock up in a given mode (TDRSS or GSTDN), the mode remains unchanged even down to -130 dBm.

The GSTDN ground station signal is swept in frequency about the nominal rest frequency of the transponder receiver which acquires and tracks the ground station signal.

It should be noted that there is no TDRSS only mode as is the case for GSTDN.

The inputs to the transponder are command controllable. The ON/OFF control of the telemetry channels and modulation index are accomplished by bit configuration within a 16 bit serial digital command word. The receivers are always powered. The transmitter prime power is controlled by a discrete command to the PCU, however, the ON/OFF state should be controlled by transponder serial digital commands. Command states are covered in Section 4.6.

In the GSTDN Mode, the forward link is detected by the command detector unit at the 2 KBps Command data rate which is delivered along with clock timing, and a "inlock" signal to the Central Unit (CU) for processing. GSTDN 2 Kbps command rate is fixed and is not command selectable.

The return link can contain either the spacecraft R/T telemetry only, or both the R/T Telemetry and High Rate Channel Data. Both, if present, and selected by the PMP Serial Magnitude (digital) command, are summed together in the PMP and are relayed over a line (STDN #1) to the transponder.

Note that STDN #2 telemetry output from the PMP is not used.

The TDRSS functions of the Modulator are completely disabled automatically in the GSTDN Mode.

4.3.2.2 TDRSS Mode

The reception of the TDRSS signal is initiated in the range of -110 dBm to -135 dBm to the receiver. In order to begin commanding or ranging, the PN or Gold Code acquisition must be completed.

The receiver must first complete the short PN code acquisition, then the long PN code acquisition can begin.

4.3.2.2.1 TDRSS Mode Acquisition States

As shown in Figure 4.3-5, there are 1,023 chips to the short PN code and 261,888 (1023 x 256) chips to the long PN code. The PN code rate received is 3.07 megachips per second (MCPS).

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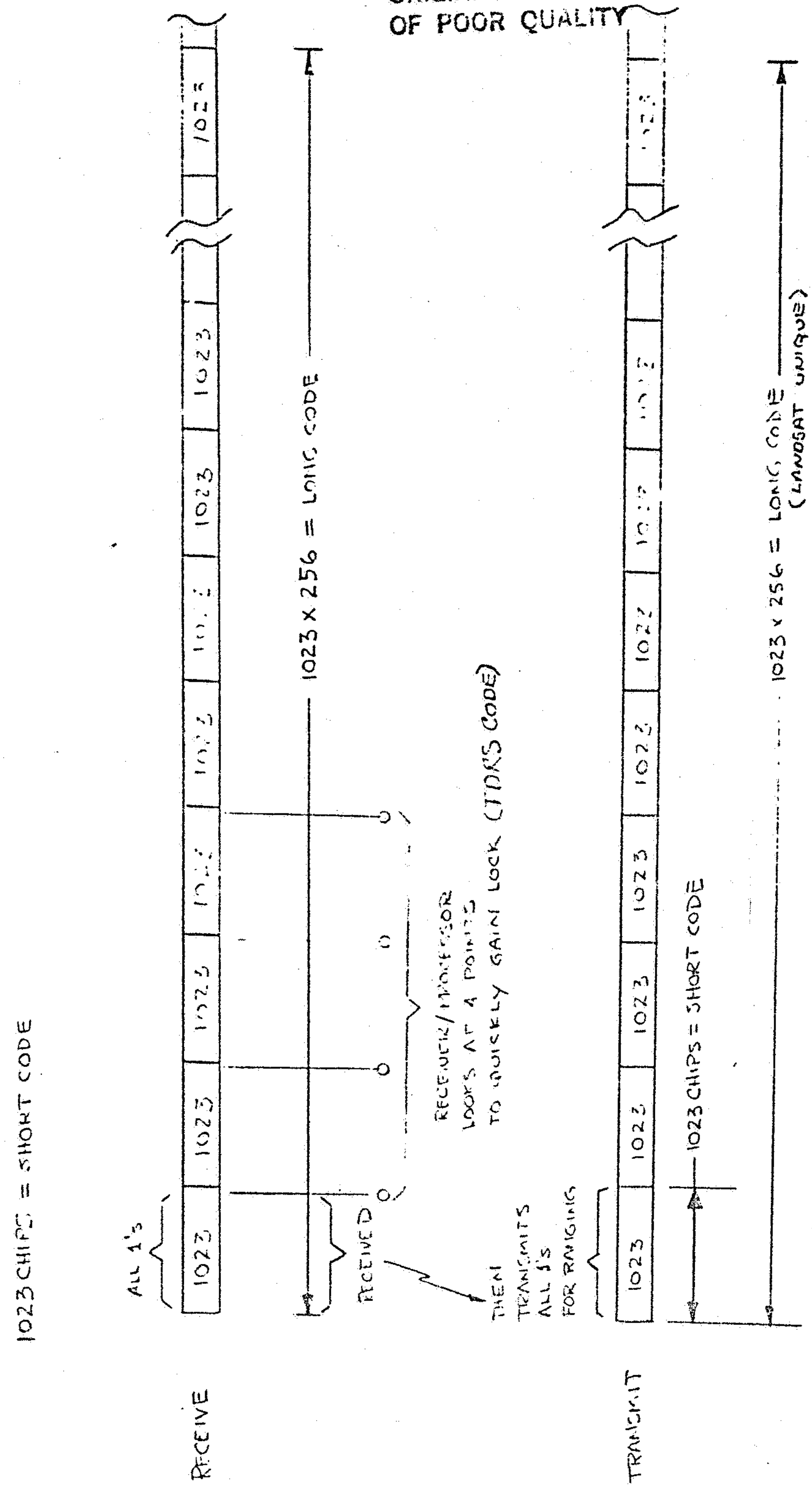

Figure 4.3-5. PN Code via TDRSS

To acquire the short PN code it takes approximately 20-25 seconds to receive and lock onto the entire code with about 90% confidence. On the average the acquisition time is shorter. It takes about 5 seconds to acquire the carrier signal level and 10 seconds to acquire the PN code for a total of 15 seconds. Once the short PN code is recognized, commanding can begin.

The long PN code will be locked onto using the short PN code which takes approximately 10 seconds. Hence, it takes a total of approximately 25-30 seconds to acquire the TDRSS signal before ranging can begin.

After the receiver acquired a long code, and it can acquire a shifted long code, which is 2 chips away from current chip, then the receiver breaks lock and starts over. A multi path is present by definition, multi paths are possible especially when the line of sight between the TDRSS and Landsat-D spacecrafts is near the earths horizon over water.

The Command Detector in the TDRSS Transponder is commanded to operate in either the 125 Bps or 1 Kbps bit rate. The command bit rates are controlled by bits C_{12} and C_{13} of the Transponder 16-bit serial digital command. There is no commandable command bit rate for the GSTDN.

The most likely arrangement for command bit rates is to have receiver A in the 125 BPS configuration and receiver B in the 1 KBPS configuration or vice versa. This assures that the command signal via TDRSS will be received regardless of either command rate.

It should also be noted that the Command Detector Unit will automatically switch to the 2 KBPS Command bit rate when the GSTDN Signal has been selected. Therefore, the 2 KBPS command bit rate is not a controlled item via ground command.

In the TDRSS Mode, the return link telemetry channels for the Multiple Access (MA) and the S-Band Single Access (SSA) transmitters are identical except for the bandwidth of the modulator filter:

Access Method	Bandwidth
MA	8 MHZ
SSA	12 MHZ

Two input channels from the PMP to the transmitter are provided as:

Channel	Description
I	I Channel (In-Phase)
Q	Q Channel (Quadrtaure)

The relative power ratio of Q channel to the I Channel is preset (See Data Format Control Book Volume II Telemetry). By serial digital command (Bits C_{17}, C_{18} and C_{19}), the two channels to the modulators can be disabled/enabled in either or both I and Q channels independently.

The GSTDN functions of the modulator are completely disabled automatically in the TDRSS Mode.

For a detailed definition of the TDRSS signal structure and operating modes, refer to "Tracking and Data Relay Satellite System User's Guide", STDN No. 101.2, Revision 3, dated January 1978.

The Transmitter(s) can also be controlled to come ON automatically (Bits C_{20} and B_{21}) by serial digital command once an uplink signal is detected (GSTDN or TDRSS). It should be noted that once the transmitter comes ON, it stays ON even in the absence of an uplink signal. It must be commanded OFF.

4.3.3 PMP OPERATING MODES

The basic modes available and the configuration of the PMP switches necessary for mode selection are shown in Figure 4.3-4 and listed in Table 4.3-1. The mode switching includes automatic level setting for the two STDN output signals to ensure the proper phase modulation indexes for each signal in the STDN transponder. Options are provided off the basic modes to allow convolutional encoding of real time data (switch S2), convolutional encoding of OBC Dump, NBTR Playback, PCD (switch S9), selection of real time telemetry input A or B (switch S1), selection of STINT input A or B (switch S7), and selection of transponder output A or B (switch S6). Additional, real time output to tape can be selected, and a real time, STINT, or TAPE Hardline Output can be selected (switches S15 and S16). The TAPE and Hardline Outputs shall be turned on/off through control of power to the output amplifiers. The mode outputs shall be turned ON/OFF through control of power to the STDN and TDRSS output amplifiers. This method shall allow the provision of TAPE and Hardline Outputs simultaneously with the selection of a transponder outputting mode.

Table 4.3-1. PMP-Transponder Modes of Operation

	MODE	DATA SOURCE	DATA RATE	DATA MODULATION FORMAT
GSTDN	A	Realtime Telemetry	1 or 8 Kbps	PSK on 1.024 MHz Sinsuoidal Subcarrier (PSK/PM)
	B	Realtime Telemetry Plus	1 or 8 Kbps	Same as A
		OBC Dump	32 Kbps	PM or Carrier
	C	Realtime Telemetry Plus	1 or 8 Kbps	Same As A
		NBTR Playback	256 Kbps	PM on Carrier
	D	Realtime Telemetry Plus	1 or 8 Kbps	Same As A
		Payload Correction Data	32 Kbps	PM on Carrier
TDRSS	F	Realtime Telemetry	1 or 8 Kbps	SQPN/QPSK Data PN Encoded
	G	Realtime Telemetry Plus	1 or 8 Kbps	Same as F
		OBC Dump	32 Kbps	
	H	Realtime Telemetry Plus	1 or 8 Kbps	Same as F
		NBTR Playback	128 Kbps	
	I	Realtime Telemetry Plus	1 or 8 Kbps	Same as F
		Payload Correction Data	32 Kbps	

NOTE: Mode E & J not used.

4.3.3.1 PMP Input Signals

Signal inputs to each PMP are:

1. Real time NRZ-L data and required clocks from either of two STACC CU's with rates command selectable from 1 to 64 Kbps.

2. 32 Kbps computer memory NRZ-L data and required clocks from either of two STACC STINTS.

3. NRZ-L playback from an NTBR dedicated to the PMP. Recorders will be capable of providing NRZ-L data, bit rate clock and two times bit rate clocks in playback mode.

4. 32 Kbps NRZ-L Payload Correction data from the PCD Mux in PCU.

4.3.3.2 PMP Selectable Modes

The Landsat-D PMP is capable of operating in any one of 8 possible command selectable data modes to the transmitter portion of redundant transponders. Data via GSTDN is realtime PSK data on a subcarrier alone or summed with selected high rate channel data directly on the carrier. The composite signal will be phase modulated on the S-band carrier within the transponder. The four GSTDN data modes are:

Mode A. Realtime biphase-S data phase shift keyed on a 1.024×10^6 Hz subcarrier.

Mode B. Same as Mode A with addition of biphase-S On-Board computer memory dump.

Mode C. Same as Mode A with NRZ-L NBTR Playback data. Playback data will be 256 Kbps.

Mode D. Same as Mode A with NRZ-L Payload correction data.

Data via TDRSS is real time alone or combined with selected high rate channel data in the appropriate TDRSS quadri-phase digital data mode. The four TDRSS data modes are:

Mode F. Realtime NRZ-M data on parallel output lines for the I and Q channels of the TDRSS transponder. Data can be one-half encoded.

Mode G. Realtime NRZ-M data on the I channel and NRZ-M on board computer memory dump on the Q channel. Both data streams can be rate one half encoded.

Mode H. Same as Mode G except NBTR playback data on the Q channel.

Mode I. Same as Mode G except payload correction data on the Q channel.

The output modes are mutually exclusive. To conserve power, interface circuits are turned OFf when not in use. Mode selection will be via serial magnitude command.

4.3.3.3 PMP Hardline and NBTR Output

Data on these lines is command selectable real time telemetry or High Rate Channel Data. The hardline output is available simultaneously with either the TDRSS or STDN mode. Output to the tape recorder's record amplifier consists of NRZ-L data and 1X clock.

4.3.4 STACC CU MODES OF OPERATION

The modes of Operation for the STACC Central Unit are summarized as follows:

1. OFF/Standby
2. Self On
3. Format I (Engineering)
4. Format II (Mission)
5. OBC Controlled Format
6. Dwell
7. Computer Dump

4.3.4.1 STACC CU Off/Standby Mode

The CU OFF/Standby mode is only entered or exited by the special commands sent from the Ground. The CU can process special commands in the OFF/STANDBY Mode.

4.3.4.2 SELF-ON Mode

This mode of the CU is entered and exited only by the ground initiated special commands. The Initial Power ON condition selects the internal oscillator (external ultra-stable must be commanded ON) and engineering format PROM at 1 KBPS rate. To go back to the internal oscillator, command CU OFF.

4.3.4.3 Format I Mode (Engineering)

In this mode of operation, the CU is constructing the format of the return link telemetry from PROM One. The format is independent of the telemetry rate, however, it is transmitted at the 8 KBPS on-orbit normal telemetry rate (see the DFCB, Volume II, (Telemetry). The format is initiated by a STACC CU Serial magnitude command zero to RIU #1 in the C&DH Subsystem (bits 13 and 14).

4.3.4.4 STACC CU Format II Mode (Mission)

In this mode of operation, the CU is constructing the format of the return link telemetry from PROM two. Format II is independent of telemetry rate, however, it is normally transmitted at 8 kbps. (See the DFCB Volume II, (Telemetry). This format is initiated in the same manner as format I above.

4.3.4.6 STACC CU OBC Controlled Format Mode

The OBC controlled format provides a flexible means to control telemetry from the OBC memory which is updateable by ground command. (See the DFCB, Volume II, Telemetry.) This format is initiated in the same manner as Format I above.

4.3.4.7 STACC CU Dwell Mode

In the Dwell Mode, the minor frame word, identified by ground command (RIU #1, Command Ø) bits 5 through 11, defines the Minor Frame word to be repeated in the telemtry format except for the 16 fixed words. This mode is entered by STACC CU serial magnitude command.

4.3.4.8 STACC CU Computer Dump Mode

During this mode, the CU receives the data (memory) via the STINT and passes it to the Pre-Modulator Processor (PMP). A unique format is transmitted over the extra channel from the PMP to the transponders. (See the DFCB, Volume II Telemetry for the format.) The dump is set up by a Special Command to RIU #Ø for a data rate of 1 or 32 KBPS. Subsequently, a pair of OBC Executive Request Commands (Software Controlled dump) or hardware commands (CLEAR, SELECT FIXED BANK, DUMP FIXED BANK) as words for the computer will initiate the OBC Dump. Four copies of the dump are sent. This mode of operation can work concurrently with the dwell, Format I/II or OBC controlled format modes.

4.3.5 RIU MODES OF OPERATION

An RIU has three modes of operation:

1. OFF
2. STANDBY 1
3. STANDBY 2

4.3.5.1 Off

In this mode of operation, the RIU will not provide telemetry, Frame and Word Rate Sync, clock (1.024 MHZ) nor process serial magnitude commands and Discrete Commands (1-63). It will however process discrete command zero (activation of STANDBY 1 or SELF ON).

4.3.5.2 STANDBY 1

In STANDBY 1 mode, the RIU can process discrete commands 1 through 63 but cannot process serial magnitude commands. 1+ is essentially identical to OFF (above) except that discrete commands (1-63) will be processed when received.

4.3.5.3 STANDBY 2

To initiate this mode, RIU A or B will process discrete command 63 which places it in STANDBY 2 and turns the MATE OFF.

If there is a power failure, the unit remains the same as prior to the failure.

4.3.6 PCU MODES OF OPERATION

Essentially the PCU provides continuous, dedicated or switched output power to the C&DH subsystem as summarized as follows:

	Destination	Type
Unregulated	Transponder Receiver A	- Continuous
	Transponder Receiver B	- Continuous
	R.F. Switch #1	- Continuous
	R.F. Switch #2	- Continuous
	PMP-A	- Continuous
	PMP-B	- Continuous
	STACC CU-A	- Continuous
	STACC CU-B	- Continuous
	STACC RIU-A	- Continuous
	STACC RIU-B	- Continuous
	Transponder Transmitter-A	- Switched
	Transponder Transmitter-B	- Switched
	R.F. Switch BUS-A	- Switched
	R.F. Switch BUS-B	- Switched
	Module Heater #1	- Switched
	Module Heater #2	- Switched
Conditioned	NBTR A	- Continuous
	NBTR B	- Continuous
	STINT A	- Dedicated
	STINT B	- Dedicated
	Memories	- Switched

The four areas of PCU operation are as follows: Switched primary voltage distribution, transponder receiver hardline command enable, power supply, OBC functions, and retsoration of computer operation subsequent to an overvoltage, overcurrent or undervoltage fault.

4.3.6.1 Switched Distribution

Switched (enable/disable) power lines are provided to the transponder transmitters and Module Heaters. In the case of transmitters, power on-off is controlled by commands directly to the individual transmitters. Power to the Module Heaters is controlled by thermostat located in the heater vicinity.

The RF Switches can be operated either from the Bus Select A or the Bus Select B position. The Bus Select A position must be used when operating with RIU-A, and the B position with RIU-B.

4.3.6.2 Transponder Receiver Hardline Command Enable

The Transponder Receiver Hardline Command Enable function is obtained for both A and B units by application of a single 28 volt source (Figure 4.1-13). Since relays in the PCU are non-latching, the 28V control must be maintained during the entire command time duration.

4.3.6.3 OBC Power Supplies

In operating the OBC-power supplies, caution must be exercised to prevent damage to the memories or relays, by verifying that the power supplies are off before any switching of memories is attempted. Additionally only one (either A or B) of the power supplies should be ON at a time.

In configuring the memories to the ON state there are two initial conditions to be set prior to power supply turn-on. After deciding which memories will be activated and which power supply will be used, proceed by sending the Memory Power Supply Select Commands, e.g., in Table 4.6-1 send commands 42 and 37 for all memories to Power Supply A. Depending on which memories are to be powered send the appropriate Memory Enable commands. Note that for the full complement of eight Memories they are disabled four at a time and enabled two at a time.

When it is desired that only certain memories be energized, depending on the previous configuration, it might be necessary to first send the disable commands (commands 40 and 35).

After the memories are configured, the selected power supply can be turned ON.

With the power supply ON, conditioned secondary voltages are available to the dedicated STINT and CPM. The OBC oscillator and computer protection circuit are also operational. For the latter, there are two functions that must be satisfied before the computer is allowed to operate. The first function involves an internal measurement of the +5V secondary voltage and verification that it is within prescribed limits. This function is represented by the Power Clear box in Figure 4.1-13 and is always powered by +5 Volts obtained from the RIU. The second is the reception of an RIU (either A or B) supplied one second check signal (at least every three seconds) indicating proper computer operation. The latter is supplied to the Computer Failure Detector of Figure 4.1-13 which is powered by the power supply. Computer Failure Detector Disable commands are provided to allow initial turn-on of the system (i.e., there is no one second computer signal when the computer is OFF).

With the Computer Failure Detector Enabled, if either of the above two functions are not satisfied, the output circuit is clamped to ground. This causes the computer operation to halt after approximately 3 seconds of no continuous pulses with RIU #1. This will cause a safe hold.

4.3.6.4 Power Supply Fault

The above output circuit is also grounded, and computer operation halted when either of the power supply faults occur, i.e., overvoltage, overcurrent or undervoltage. As previously indicated the power supply DC/DC converter is turned OFF when the fault occurs, which causes the +5 $\pm$5% Volt secondary voltage to be exceeded. This in-turn results in grounding of the open collector output to the OBC. For the overvoltage fault, the power supply secondary voltages are automatically restored subsequent to clearing of the fault. The overcurrent and undervoltage faults require the command sequence of Power Supply OFF then Power Supply ON to restore the DC voltages. In all three cases, overvoltage, overcurrent and undervoltage, the OBC commands, preceeded by the CFD Disable Command, are required to start the computer.

4.4 C&DH Subsystem Constraints

4.4.1 R.F. SWITCH CONSTRAINTS

When reconfiguring the RF Switch the transmitter must be off to prevent possible switch damage.

4.4.2 TRANSPONDER CONSTRAINTS

1. Transmitter turn ON/OFF should be accomplished with the transponder serial magnitude command, not the PCU Enable/Disable discrete commands.

2. If the transponder is receiving a strong signal it may not be possible to command via TDRSS mode due to lower level of signal required (-110 to -135 dBm) since the transponder will be looking for a GSTDN type signal.

3. When the transponder is operating in the coherent turn around mode and ranging is being conducted via GSTDN, the high rate channel (OBC Dump, PCD NBTR Playback) must not be commanded ON. That is, ranging and high rate data are mutually exclusive.

4. Coherent Mode can cause noise on the return link bit stream when switching PMP modes. Use the non-coherent mode to avoid this problem by inhibiting the automatic transfer from "Auxiliary Oscillator to VCO" by Transponder serial magnitude command.

4.4.3 PMP CONSTRAINTS

1. PMP Mode A should not be used except for an emergency, where the high mod index (1.6) might be useful e.g., transmitter, PMP or antenna problems might warrant a high index for telemetry to GSTDN. Otherwise use PMP mode B (Realtime Telemetry and High Rate data to STDN) where both can be transmitted simultaneously.

2. The PMP may be turned OFF when not transmitting, to save power, however it should be left in the ON state since no additional power is used.

4.4.4 STACC CU CONSTRAINTS

1. Only one CU should be commanded ON at any time. If both are ON, the MDB (bus) data will be worthless and therefore not meaningful to the RIU's nor CU's, but no damage occurs. The recovery is to turn both CU's OFF then CU (A or B) ON by special commands (RIU #Ø).

2. R.F. Commands override hardline commands.

4.4.5 RIU CONSTRAINTS

The RIU's in the C&DH Subsystem have no operational constraints except that in normal C&DH operations, one RIU is active and the alternate is OFF. Once in operation, the CU controls the RIU.

4.4.6 PCU CONSTRAINTS

The PCU constraints are summarized below:

1. Power supplies must be powered OFF when configuring the memories (Power Supply Select and Memory ENABLE/DISABLE).

2. Only one Power Supply should be ON at a time.

3. The Transponder transmitter ON/OFF control should be obtained directly by commands to the Transponder. The ENABLE/DISABLE Transmitter command at the PCU is for back-up only.

4.5 REDUNDANCY/CROSS STRAPPING

A general description of the redundancy and cross strapping of the C&DH subsystem is given below. A simplified block diagram of the C&DH Subsystem, including redundancies, is given in Figure 4.1-1.

The discussion of redundancies can be simplified by classifying the types of redundancies employed in the subsystem. These are shown in Figure 4.5-1 and include:

1. Active Cross-Strapping

2. Passive Cross-Strapping

3. Dedicated Assignment (i.e., no cross-strapping)

An example of the active type is the forward link signals from the transponders receivers to the CU's. Here, both receivers A and B are continuously powered and supply signals to both CU's simultaneously. A given CU, when powered, can select either of these two receiver signals for distribution to the subsystem (without any overt command control).

The passive cross-strapping also permits signal feed from the A & B components to the interfacing A & B components, as shown in Figure 4.5-1 for the downlink telemetry signal from the CU to the PMP. However, here command control is required to reconfigure the standby component, e.g., PMP-A selection of CU-B and turn-on of CU-B (and turn-off of CU-A).

Dedicated assignments of redundant components, e.g., CPM to STINT, does not include cross-strapping. Either both A units or both B units are powered simultaneously.

For convenience, the redundancy classifications, and ON/OFF component status, described below, are summarized in Table 4.5-1.

By convention, prime and redundant components are designated by the letters A and B, respectively. Other letter (or number) designation signifies either no redundancy or that components may be used in various combinations (e.g., the OBC memories).

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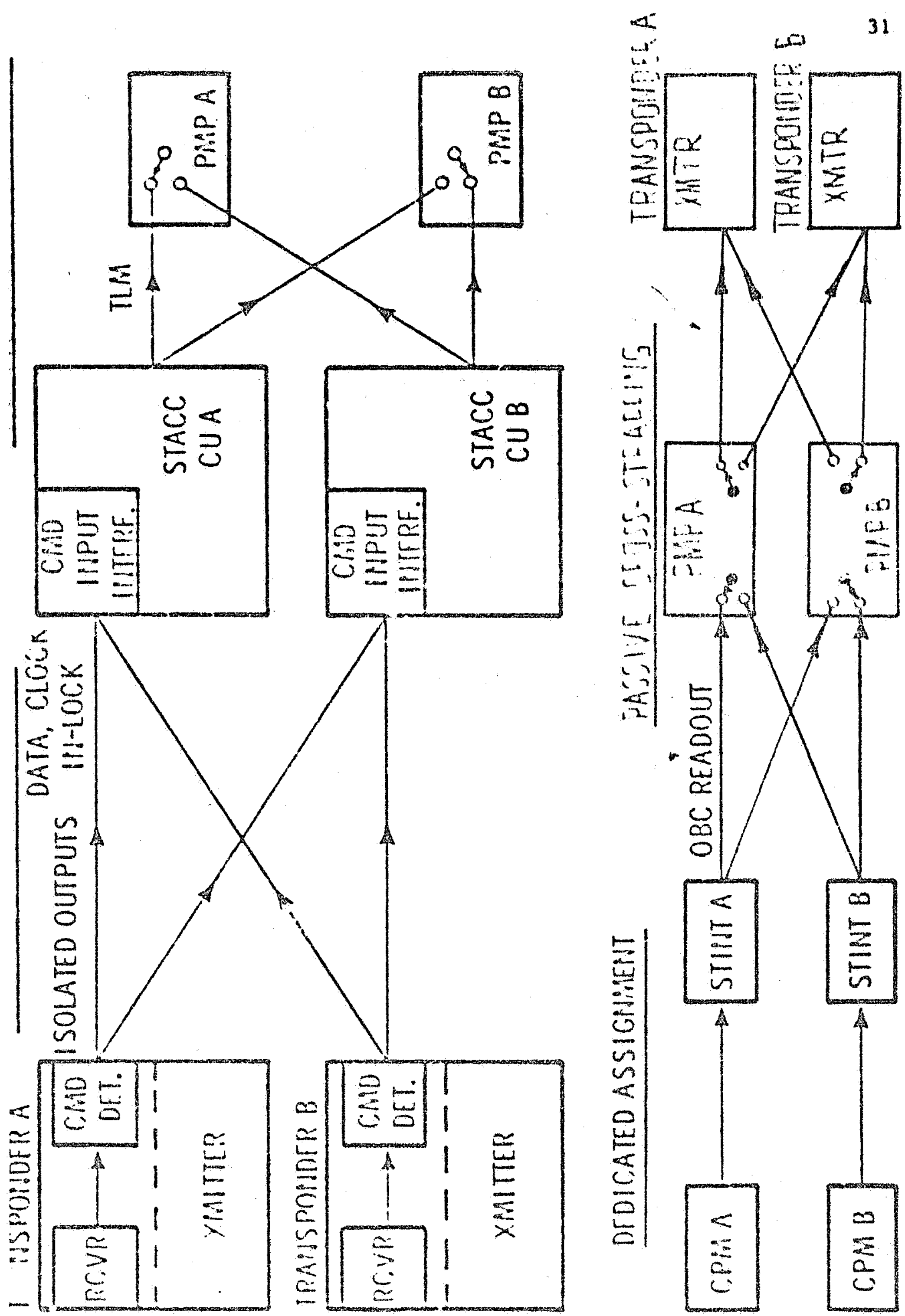

Figure 4.5-1. Redundancy Classification

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Table 4.5-1. Component Redundancy Classification and On/Off Status

Component/Funtion	Redundancy*	On/Off Status
Omni Antenna to Transponder Receiver A	D	Both receivers are continuously powered
Omni Antenna to Transponder Receiver B	D	
Transponder Transmitter A to Omni 1 or High Gain Ant.	P	Only one transmitter powered
Transponder Transmitter B to Omni 2 or High Gain Ant.		
Hardline (Baseband Commands to Receiver A	D	-
Hardline (Baseband) Commands to Receiver B	D	-
Baseband Commands from the Module Interface Connector or Module Test Connector to CU A&B, respectively	D	Only one CU is ON,
Receivers A&B to each CU	A	Only one CU is ON, the alternate unit is in Standby
CU Special Commands	D	-
CU to Supervisory Line (Telemetry & Command)	P	-
MDB Supervisory Line Command Message to RIU´s	P	Only one RIU is ON (Standby 2), the alternate unit is in Standby (DFF)
RIU Commands and Telemetry to/from Users	P	
CU A and B to STINT A and B (telemtry) data and stored commands)	P	Only one STINT powered
STINT A to/from CPM A	D	Only one CPM powered
STINT B to/from CPM B	D	
CPM to Memories	P	Memories can all be simultaneously powered

*A - Active Cross-Strap
P - Passive Cross-Strap
D - Dedicated Assignment

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Table 4.5-1. Component Redundancy Classification and On/Off Status

Component/Funtion	Redundancy*	On/Off Status
		Memories address recognition circuitry are simultaneously powered
MDB Supervisory Line Telemetry Request to RIUs	P	-
RIU Telemetry to MDB Reply Lines	A	-
MDB Reply Lines to CU	P	-
CU A and B R/T TLM to PMP A&B	P	-
STINT A and B Memory Dump to PMP A&B	P	-
Tape Recorder A TLM Playback and Record to/from PMP-A	D	-
Tape Recorder B TLM Playback and Record to/from PMP-B	D	-
External Data - MIC to PMP-A		
External Data - MIC to PMP-B	D	-
PMP A&B to Transmitters A&B	P	Mission requires that both PMPs be powered simultaneously for some operational modes
PCU Power Supply A Secondary Voltage to STINT A and CPM-A PCU Power Supply B Secondary Voltage to STINT B and CPM-B	D	Only one power supply powered
PCU Power Supply A and B Secondary Voltage to Memories	P	-
PCU (OBC) Oscillator and Failure Detector to OBC	D	-

4.5.1 RF SWITCH REDUNDANCY

All RF Switch and Antenna feed functions are provided redundantly as previously described in paragraph 4.1.1.1.

Starting with the RF signal flow, there are four antenna ports. These interface with transponders A and B through the RF switches and diplexers producing three commandable transmit configurations:

RF Configuration	Transponder A Transmit Antenna	Transponder B Transmit Antenna
I	Omni 1	High Gain
II	High Gain	Omni 2
III	Omni 1	Omni 2

Forward link reception is non-switchable. Transponder receiver A and B signal reception is from either the OMNI´s or the High Gain Antenna.

Commands to the subsystem can be obtained from signals applied directly to the receiver´s detectors (Hardline Commands) or via RF. Both the A and B receivers are powered continuously, and during RF operation will both provide baseband signals to CU-A and B simultaneously. Only one CU is ON at a time, the alternate unit is maintained in a standby mode.

4.5.2 TRANSPONDER REDUNDANCY

The Landsat-D employs redundant transponders. The transponders can be configured by ground command, for either the TDRSS or GSTDN mode. The return (telemetry) link transmission signals are obtained from either the PMP-A or PMP-B to either the A or B transmitter (see Figure 4.1-4).

4.5.3 PMP REDUNDANCY

The PMP is a completely redundant unit, with capability of operating the A or B side. There is a dedicated assignment of tape recorder input and output signals to each PMP. Hardline monitors are also dedicated. The PMP-A Hardline monitor is applied to hardline output A and PMP-B hardline monitor is applied to hardline output B. Each PMP can operate with either transponder for forward or return links. The PMP´s are cross-strapped to the STACC CU´s to also operate with either CU.

4.5.4 STACC CU REDUNDANCY

The A and B STACC CU´s provide baseband signals from both the A and B receivers simultaneously. Only one CU is ON at a time. The alternate unit is maintained in the standby mode. A form of dual-diversity (sharp selection, with priority given to reception from receiver A and transfer inhibit to prevent message gaps) is contained within each CU, which in effect gives an active cross-strap redundancy from the receivers to each CU. The signal, after processing by the CU, can be routed to three areas. It can be sent to either STINT A or B, or sent via the redundant supervisory lines A/B to the BCU´s and on to the RIU´s. The RIU´s send data to either CU A/B via redundant reply lines A/B.

4.5.5 RIU REDUNDANCY

Commands are routed to the RIU´s via redundant supervisory lines. This can be the RIU (A or B) within the C&DH module, or one of the other subsystem RIU´s. Within the C&DH both RIU A&B monitor the Supervisory Line message (active cross-strapping). Upon receipt of a properly addressed message, the RIU distributes the message to the C&DH components. Either RIU A or B can be used to issue any command assigned to the C&DH subsystem.

The telemetry signals are gathered by the RIUs. Either RIU A or B in the C&DH can be used to provide all C&DH assigned telemetry. Reply lines are redundant and telemetry return from RIU is carried on both reply lines simultaneously.

4.5.6 PCU REDUNDANCY

The PCU obtains primary bus voltage (28 volts, nominal) and distributes it to most components. The exceptions are the OBC (CPM and Memories) and STINT. The latter are supplied with conditioned secondary voltages from redundant power supplies in the PCU. The memories, however, by command selection can be powered from either the A or B supply, whichever unit is ON.

The PCU also contains redundant oscillators and computer failure detector circuitry for the OBC, that are similarly dedicated to the A and B units, respectively. Note that only one power supply should be energized.

4.6 C&DH COMMANDS

Operation of the C&DH Subsystem is controlled using 5 serial magnitude commands, 46 discrete commands, and 13 special commands. Special commands are discrete commands addressed directly to the central unit (CU) for execution, and do not require operation of the CU clock oscillator.

Discrete commands, including special commands, are listed in Table 4.6-1, which contains the command address (RIU and channel) and the unique acronym assigned to each command function. Table 4.6-2 presents the bit structure for the magnitude data in each serial command, and Table 4.6-3 contains the command address (ADD) and the unique acronyms assigned to specific serial command bit patterns and functions. In the ADD column, the first character identifies the RIU, the second character (7) indicates a serial magnitude command, and the third character designates the serial command enable line.

Command descriptions are provided in Section 4.6.1, command sequences in Section 4.6.2, command restraints in Section 4.6.3, and functional diagrams in Section 4.6.4.

Table 4.6-1. Discrete Commands

RIU	CHAN	ACRONYM	COMMAND NAME
0	00	CUNOOP	CENTRAL UNIT NO OPERATION
0	01	CUSLFN	SELF CU ON (INT OSC SELECTED & POWERED ON)
0	02	CUMAF1	MATE CU OFF 1
0	03	CUMAF2	MATE CU OFF 2
0	04	CUEXON	SELECT EXTERNAL OSC
0	05	SUPRAN	SELECT SUPERVISORY LINE A ON/B OFF
0	06	SUPRBN	SELECT SUPERVISORY LINE B ON/A OFF
0	07	RPLYAN	SELECT REPLY LINE A ON/B OFF
0	08	RPLYBN	SELECT REPLY LINE B ON/A OFF
0	09	TLMHDN	CU HARDLINE TELEMETRY ON
0	10	TLMHDF	CU HARDLINE TELEMETRY OFF
0	12	OBCD1K	SELECT 1 KBPS OBC DUMP
0	13	OBCD32	SELECT 32 KBPS OBC DUMP
1	00	SRIUEN	RIU 1 SELF ENABLE (STANDBY 1)
1	63	RIUSB2	RIU 1 SELF STANDBY 2 (MATE RIU DISABLE)
1	58	MRIUDI	RIU 1 MATE DISABLE (BACKUP)
1	20	STNSAN	STINT A AND NSSC A ON
1	22	STNSAO	STINT A AND NSSC A OFF
1	19	STNSBN	STINT B AND NSSC B ON
1	21	STNSBO	STINT B AND NSSC B OFF
1	26	CPFDEA	ENABLE COMPUTER FAILURE DETECTOR A
1	28	CPFDDA	DISABLE COMPUTER FAILURE DETECTOR A
1	23	CPFDEB	ENABLE COMPUTER FAILURE DETECTOR B
1	25	CPFDDB	DISABLE COMPUTER FAILURE DETECTOR B
1	24	CA1SEC	COMPUTER A 1-SECOND TEST
1	51	CB1SEC	COMPUTER B 1-SECOND TEST
1	31	MEM0EN	ENABLE MEMORY 0 (0 AND 4)
1	33	MEM2EN	ENABLE MEMORY 2 (2 AND 6)
1	37	SPAM02	SELECT POWER SUPPLY A FOR MEMORY 0 AND 2 (0,2,4,6)
1	39	SPBM02	SELECT POWER SUPPLY B FOR MEMORY 0 AND 2 (0,2,4,6)
1	35	MEM02D	DISABLE MEMORY 0 AND 2 (0,2,4,6)
1	36	MEM1EN	ENABLE MEMORY 1 (1 AND 5)
1	38	MEM3EN	ENABLE MEMORY 3 (3 AND 7)
1	42	SPAM13	SELECT POWER SUPPLY A FOR MEMORY 1 AND 3 (1,3,5,7)
1	44	SPBM13	SELECT POWER SUPPLY B FOR MEMORY 1 AND 3 (1,3,5,7)
1	40	MEM13D	DISABLE MEMORY 1 AND 3 (1,3,5,7)
1	16	PMPAON	PMP A ON
1	04	PMPATA	PMP A SELECT NBTR 1 PLAYBACK
1	06	PAMUXA	PMP A SELECT PCD A

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Table 4.6-1. Discrete Commands

RIU	CHAN	ACRONYM	COMMAND NAME
1	08	PAMUXB	PMP A SELECT PCD B
1	18	PMPAOF	PMP A OFF
1	15	PMPBON	PMP B ON
1	03	PMPBTB	PMP B SELECT NBTR 2 PLAYBACK
1	05	PBMUXA	PMP B SELECT PCD A
1	07	PBMUXB	PMP B SELECT PCD B
1	17	PMPBOF	PMP B OFF
1	34	S28ARF	SELECT 28V BUS A FOR RF SWITCH (RIU A ONLY)
1	53	S28BRF	SELECT 28V BUS B FOR RF SWITCH (RIU B ONLY)
1	02	RFCON1	SELECT RF CONFIGURATION 1
1	01	RFCON2	SELECT RF CONFIGURATION 2
1	49	RFCON3	SELECT RF CONFIGURATION 3
1	46	XMTRAE	TRANSPONDER A XMTR PRIMARY POWER ENABLE
1	48	XMTRAD	TRANSPONDER A XMTR PRIMARY POWER DISABLE
1	41	XMTRBE	TRANSPONDER B XMTR PRIMARY POWER ENABLE
1	43	XMTRBD	TRANSPONDER B XMTR PRIMARY POWER DISABLE
1	50	HTR1EN	ENABLE HEATER 1
1	52	HTR1DI	DISABLE HEATER 1
1	55	HTR2EN	ENABLE HEATER 2
1	57	HTR2DI	DISABLE HEATER 2
1	59		NBTR 2 POWER ON
1	60		NBTR 1 POWER ON
1	61		NBTR 2 POWER OFF
1	62		NBTR 1 POWER OFF

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Table 4.6-2. Magnitude Data Bit Structure

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
01-70	CENTRAL UNIT CONTROL	SELECT BIT RATE (1 OF 7) 000 1 KBPS 001 2 KBPS 010 4 KBPS 011 8 KBPS 100 16 KBPS 101 32 KBPS 110 64 KBPS 111 128 KBPS* *. NOT USED ON NMS	
		CONTROL OF BITS 0-2 *	
		DWELL 0=NO 1=YES	
		DWELL CHANNEL ID (BINARY NUMBER OF CHANNEL TO BE DWELLED ON (0-127))	LSB
		CONTROL OF BITS 4-11 *	
		FORMAT SOURCE SELECT (1 OF 3) 00 NOT USED 01 ENGINEERING ROM FORMAT 10 MISSION ROM FORMAT 11 OBC FLEXIBLE FORMAT	
		CONTROL OF BITS 13 & 14 *	

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* 1 = ENABLE
0 = DISABLE

Table 4.6-2. Magnitude Data Bit Structure

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25)															
			00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
01-71	OBC SELF TEST	OBC SELF TEST THIS COMMAND IS SENT ONLY FROM THE OBC & IS COMPLEMENTED EACH TIME IT IS SENT	0	1	0	1	0	1	0	1	0	0	0	0	1	1	1	1

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Table 4.6-2. Magnitude Data Bit Structure

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
1-72	PMP CONTROL																	
		PMP ADDRESS 0=A 1=B	□															
		R/T TO TAPE RECORDER 0=OFF 1=ON		□														
		NOT USED			□													
		CONTROL OF BITS 1-2 *				□												
		ENCODE R/T DATA TO XMTR 0=OFF 1=ON					□											
		ENCODE OBC/WBTR TO XMTR 0=OFF 1=ON						□										
		CONTROL OF BITS 4-5 *							□									
		SELECT TRANSPONDER A/B - PMF A/B 0=A TO A AND B TO B 1=B TO A AND A TO B								□								

* 1 = ENABLE
0 = DISABLE

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Table 4.6-2. Magnitude Data Bit Structure

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
1-72	PKP CONTROL (CONT)	TRANSMIT MODE SELECT (1 OF 9) 0000=OUTPUTS OFF 1000=A R/T TO STDN 0100=B R/T & DBC TO STDN 1100=C R/T & NBTR TO STDN 0010=D R/T & EXT TO STDN 1010=E EXT TO STDN 0110=F R/T TO TDRSS 1110=G R/T & DBC TO TDRSS 0001=H R/T & NBTR TO TDRSS 1001=I R/T & EXT TO TDRSS 0101=SELECT CU A 1101=SELECT CU B 0011=SELECT STINT A 1011=SELECT STINT B 0111=NOT USED 1111=NOT USED CONTROL OF BITS 7-11 * HARDLINE MODE SELECT (1 OF 4) 00=OFF 01=DBC DUMP TO HARDLINE 10=R/T TO HARDLINE 11=NBTR DUMP TO HARDLINE CONTROL OF BITS 13-14 * SEE PULSE CMD FOR PROPER PCD OR NBTR SELECTION	

* 1 = ENABLE
0 = DISABLE

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Table 4.6-2. Magnitude Data Bit Structure

COMMAND ADDRESS	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
1-73	TRANSPONDER A CONTROL		
		TRANSPONDER ADDRESS A/B 0=A 1=B	C *
		TDRSS/STDN XMTR CONTROL 000=IGNORE COMMAND 001=STDN XMTR ON HI MOD INDX 010=STDN XMTR ON LO MOD INDX 011=NOT USED 100=TDRSS XMTR ON 101= XMTR OFF 110=RCVR IN DUAL MODE 111=RCVR IN STDN MODE ONLY	
		RANGING & TLM CONTROL 000=IGNORE COMMAND 001=TLM I/P 1 ON 010=TLM I/P 2 ON 011=DISB RANGING 100=ENABLE RANGING 101=NOT USED 110=TLM I/P 1 OFF 111=TLM I/F 2 OFF	
		ENABLE/DISABLE PN CODE ON Q CH 0=ENAB 1=DSAB	
		ENABLE/DISABLE PN CODE ON I CH 0=ENAB 1=DSAB	

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* TRANSPONDERS A & B USE SAME ADDRESS (0)

Table 4.6-2. Magnitude Data Bit Structure

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
1-73	TRANSPONDER A CONTROL(CONT)	CONTROL OF BITS 7 & 8 *										□						
		ALLOW/INHIB AUTO XMTR ON/OFF 0=INHIBIT 1=ALLOW											□					
		CONTROL OF BIT 10 *												□				
		SELECT MED/LOW CMD RATE 0=LOW 1=MED													□			
		CONTROL OF BIT 12 *														□		
		ALLOW/INHIB AUTO AUX OSC TRANSFER TO VCO 0=ALLOW 1=INHIBIT															□	
		CONTROL OF BIT 14 *																□

* 1 = ENABLE
0 = DISABLE

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Table 4.6-2. Magnitude Data Bit Structure

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
1-74	TRANSPONDER B CONTROL	TRANSPONDER ADDRESS A/C 0=A 1=B	0 *															
		TDRSS/STDN XMTR CONTROL 000=IGNORE COMMAND 001=STDN XMTR ON HI MOD INDX 010=STDN XMTR ON LO MOD INDX 011=NOT USED 100=TDRSS XMTR ON 101= XMTR OFF 110=RCVR IN DUAL MODE 111=RCVR IN STDN MODE ONLY																
		RANGING & TLM CONTROL 000=IGNORE COMMAND 001=TLM I/P 1 ON 010=TLM I/P 2 ON 011=DISB RANGING 100=ENABLE RANGING 101=NOT USED 110=TLM I/P 1 OFF 111=TLM I/P 2 OFF																
		ENABLE/DISABLE PN CODE ON Q CH 0=ENABLE 1=DISABLE																
		ENABLE/DISABLE PN CODE ON I CH 0=ENABLE 1=DISABLE																

* TRANSPONDERS A & B USE SAME ADDRESS (C)

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Table 4.6-2. Magnitude Data Bit Structure

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
1-74	TRANSPONDER B CONTROL(CONT)																	
		CONTROL OF BITS 7 & 8 *										☐						
		ALLOW/INHIB AUTO XMTR ON/OFF 0=INHIBIT 1=ALLOW											☐					
		CONTROL OF BIT 10 *												☐				
		SELECT MED/LOW CMD RATE 0=LOW 1=MED													☐			
		CONTROL OF BIT 12 *														☐		
		ALLOW/INHIB AUTO AUX OSC TRANSFER TO VCO 0=ALLOW 1=INHIBIT															☐	
		CONTROL OF BIT 14 *																☐

* 1 = ENABLE
0 = DISABLE

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Table 4.6-3. Serial Command Acronyms

ADD	16-BIT MAGNITUDE	ACRONYM	COMMAND NAME
170			CENTRAL UNIT CONTROL:
170	0001000000000000	BR1KB	SELECT 1 KBPS BITRATE
170	0011000000000000	BR2KB	SELECT 2 KBPS BITRATE
170	0101000000000000	BR4KB	SELECT 4 KBPS BITRATE
170	0111000000000000	BR8KB	SELECT 8 KBPS BITRATE
170	1001000000000000	BR16KB	SELECT 16 KBPS BITRATE
170	1011000000000000	BR32KB	SELECT 32 KBPS BITRATE
170	1101000000000000	BR64KB	SELECT 64 KBPS BITRATE
170	0000000000000001	CUFLXF	SELECT CU FLEX FORMAT
170	0000000000000011	CUENGF	SELECT ENGINEERING ROM FORMAT
170	0000000000000101	CUMISF	SELECT MISSION ROM FORMAT
170	0000000000000111	CPMFLX	SELECT OBC FLEX FORMAT
170	00001VVVVVVV1000	DWELL,V	SWELL ON CHANNEL V (0-127)
170	0000000000001000	NODWLL	DWELL MODE OFF
171			OBC SELF TEST
172			PMP CONTROL:
172	0101000000000000	PARTTN	PMP A R/T DATA TO TAPE ON
172	0001000000000000	PARTTF	PMP A R/T DATA TO TAPE OFF
172	0000111000000000	PACXNN	PMP A ENC R/T ON AND OBC/NBTR 1 ON
172	0000001000000000	FACXFF	PMP A ENG R/T OFF AND OBC/NBTR 1 OFF
172	0000011000000000	PACXFN	PMP A ENC R/T OFF AND OBC/NBTR 1 ON
172	0000101000000000	PACXNF	PMP A ENC R/T ON AND OBC/NBTR 1 OFF
172	0000000010001000	PANMOA	PMP A SELECT MODE A XPNDR A
172	0000000001001000	PANMOB	PMP A SELECT MODE B XPNDR A
172	0000000011001000	PANMOC	PMP A SELECT MODE C XPNDR A
172	0000000000101000	PANMOO	PMP A SELECT MODE D XPNDR A
172	0000000010101000	PANMOE	PMP A SELECT MODE E XPNDR A
172	0000000001101000	PANMOF	PMP A SELECT MODE F XPNDR A
172	0000000011101000	PANMOG	PMP A SELECT MODE G XPNDR A
172	0000000000011000	PANMOH	PMP A SELECT MODE H XPNDR A
172	0000000010011000	PANMOI	PMP A SELECT MODE I XPNDR A
172	0000000110001000	PARMOA	PMP A SELECT MODE A XPNDR B
172	0000000101001000	PARMOB	PMP A SELECT MODE B XPNDR B
172	0000000111001000	PARMOC	PMP A SELECT MODE C XPNDR B
172	0000000100101000	PARMOD	PMP A SELECT MODE D XPNDR B
172	0000000110101000	PARMOE	PMP A SELECT MODE E XPNDR B
172	0000000101101000	PARMOF	PMP A SELECT MODE F XPNDR B
172	0000000111101000	PARMOG	PMP A SELECT MODE G XPNDR B

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Table 4.6-3. Serial Command Acronyms

ADD	16-BIT MAGNITUDE	ACRONYM	COMMAND NAME
172	0000000100011000	PARMOH	PMP A SELECT MODE H XPNDR B
172	0000000110011000	PARMOI	PMP A SELECT MODE I XPNDR B
172	0000000000001000	PANMOO	PMP A XPNDR A MODE SELECT OFF
172	0000000100001000	PARMOO	PMP A XPNDR B MODE SELECT OFF
172	0000000001011000	PANCUA	PMP A XPNDR A CU A
172	0000000011011000	PANCUB	PMP A XPNDR A CU B
172	0000000000111000	PANSTA	PMP A XPNDR A STINT A
172	0000000010111000	PANSTB	PMP A XPNDR A STINT B
172	0000000101011000	PARCUA	PMP A XPNDR B CU A
172	0000000111011000	PARCUB	PMP A XPNDR B CU B
172	0000000100111000	PARSTA	PMP A XPNDR B STINT A
172	0000000110111000	PARSTB	PMP A XPNDR B STINT B
172	0000000000000001	PAHDOF	PMP A HARDLINE OUTPUTS OFF
172	0000000000000101	PARTHN	PMP A REAL TIME DATA TO HARDLINE ON
172	0000000000000011	PAMDHN	PMP A OBC MEM DUMP TO HARDLINE ON
172	0000000000000111	PATDHN	PMP A NBTR 1/PCD TO HARDLINE ON
172	1101000000000000	PBRTTN	PMP B R/T DATA TO TAPE ON
172	1001000000000000	PBRTTF	PMP B R/T DATA TO TAPE OFF
172	1000111000000000	PBCXNN	PMP B ENC R/T ON AND OBC/NBTR 2 ON
172	1000001000000000	PBCXFF	PMP B ENC R/T OFF AND OBC/NBTR 2 OFF
172	1000011000000000	PBCXFN	PMP B ENC R/T OFF AND OBC/NBTR 2 ON
172	1000101000000000	PBCXNF	PMP B ENC R/T ON AND OBC/NBTR 2 OFF
172	1000000000001000	PBNMOO	PMP B XPNDR B MODE SELECT OFF
172	1000000100001000	PBRMOO	PMP B XPNDR A MODE SELECT OFF
172	1000000110001000	PBRMOA	PMP B SELECT MODE A XPNDR A
172	1000000101001000	PBRMOB	PMP B SELECT MODE B XPNDR A
172	1000000111001000	PBRMOC	PMP B SELECT MODE C XPNDR A
172	1000000100101000	PBRMOD	PMP B SELECT MODE D XPNDR A
172	1000000110101000	PBRMOE	PMP B SELECT MODE E XPNDR A
172	1000000101101000	PBRMOF	PMP B SELECT MODE F XPNDR A
172	1000000111101000	PBRMOG	PMP B SELECT MODE G XPNDR A
172	1000000100011000	PBRMOH	PMP B SELECT MODE H XPNDR A
172	1000000110011000	PBRMOI	PMP B SELECT MODE I XPNDR A
172	1000000010001000	PBNMOA	PMP B SELECT MODE A XPNDR B
172	1000000001001000	PBNMOB	PMP B SELECT MODE B XPNDR B
172	1000000011001000	PBNMOC	PMP B SELECT MODE C XPNDR B
172	1000000000101000	PBNMOD	PMP B SELECT MODE D XPNDR B
172	1000000010101000	PBNMOE	PMP B SELECT MODE E XPNDR B
172	1000000001101000	PBNMOF	PMP B SELECT MODE F XPNDR B
172	1000000011101000	PBNMOG	PMP B SELECT MODE G XPNDR B

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Table 4.6-3. Serial Command Acronyms

ADD	16-BIT MAGNITUDE	ACRONYM	COMMAND NAME
172	1000000000011000	PBNMOH	PMP B SELECT MODE H XPNDR B
172	1000000010011000	PBNMOI	PMP B SELECT MODE I XPNDR B
172	1000000101011000	PBRCUA	PMP B XPNDR A CU A
172	1000000111011000	PBRCUB	PMP B XPNDR A CU B
172	1000000100111000	PBRSTA	PMP B XPNDR A STINT A
172	1000000110111000	PBRSTB	PMP B XPNDR A STINT B
172	1000000001011000	PBNCUA	PMP B XPNDR B CU A
172	1000000011011000	PBNCUB	PMP B XPNDR B CU B
172	1000000000111000	PBNSTA	PMP B XPNDR B STINT A
172	1000000010111000	PBNSTB	PMP B XPNDR B STINT B
172	1000000000000001	PBHDOF	PMP B HARDLINE OUTPUTS OFF
172	1000000000000101	PBRTHN	PMP B REAL TIME DATA TO HARDLINE ON
172	1000000000000011	PBMDHN	PMP B OBC MEM DUMP TO HARDLINE ON
172	1000000000000111	PBTDHN	PMP B NBTR 2/PCD TO HARDLINE ON
173			TRANSPONDER A CONTROL;
173	0001001000000000	TAXSHM	STDN XMTR ON HI MOD INDEX TLM 1 ON
173	0010001000000000	TAXSLM	STDN XMTR ON LO MOD INDEX TLM 1 ON
173	0100000000000000	TAXTON	TDRSS XMTR ON
173	0101000000000000	TAXOFF	TRANSMITTER OFF
173	0110000000000000	TARSTM	RECEIVER IN DUAL MODE
173	0111000000000000	TARSMO	RECEIVER IN STDN MODE ONLY
173	0000001000000000	TATL1N	TELEMETRY LINE 1 ON
173	0000110000000000	TATL1F	TELEMETRY LINE 1 OFF
173	0000010000000000	TATL2N	TELEMETRY LINE 2 ON
173	0000111000000000	TATL2F	TELEMETRY LINE 2 OFF
173	0000100000000000	TAERNG	ENABLE STDN RANGING
173	0000011000000000	TADRNG	DISABLE STDN RANGING
173	0000000001000000	TAINQN	PN CODE I & Q CHANNELS ENABLE
173	0000000011000000	TAIFQN	PN CODE I CHAN DISAB, Q CHAN ENAB
173	0000000101000000	TAINQF	PN CODE I CHAN ENAB, Q CHAN DISAB
173	0000000111000000	TAIFQF	PN CODE I & Q CHANNELS DISABLE
173	0000000000110000	TAAXIF	ALLOW AUTO XMTR TURN-ON
173	0000000000010000	TAAXIN	INHIBIT AUTO XMTR TURN-ON
173	0000000000000001	TAAOVN	ALLOW AUTO TRANSFER TO VCO
173	0000000000000011	TAAOVF	INHIBIT AUTO TRANSFER TO VCO
173	0000000000001100	TACMRM	SELECT MEDIUM COMMAND RATE
173	0000000000000100	TACMRL	SELECT LOW COMMAND RATE

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Table 4.6-3. Serial Command Acronyms

ADD	16-BIT MAGNITUDE	ACRONYM	COMMAND NAME
174			TRANSPONDER B CONTROL;
174	0001001000000000	TBXSHM	STDN XMTR ON HI MOD INDEX TLM 1 ON
174	0010001000000000	TBXSLM	STDN XMTR ON LO MOD INDEX TLM 1 ON
174	0100000000000000	TBXTON	TDRSS XMTR ON
174	0101000000000000	TBXOFF	TRANSMITTER OFF
174	0110000000000000	TBRSTM	RECEIVER IN DUAL MODE
174	0111000000000000	TBRSMO	RECEIVER IN STDN MODE ONLY
174	0000001000000000	TBTL1N	TELEMETRY LINE 1 ON
174	0000110000000000	TBTL1F	TELEMETRY LINE 1 OFF
174	0000010000000000	TBTL2N	TELEMETRY LINE 2 ON
174	0000111000000000	TBTL2F	TELEMETRY LINE 2 OFF
174	0000100000000000	TBERNG	ENABLE STDN RANGING
174	0000011000000000	TBDRNG	DISABLE STDN RANGING
174	0000000001000000	TBINQN	PN CODE I&Q CHANNELS ENABLE
174	0000000011000000	TBIFQN	PN CODE I CHAN DISAB, Q CHAN ENAB
174	0000000101000000	TBINQF	PN CODE I CHAN ENAB, Q CHAN DISAB
174	0000000111000000	TBIFQF	PN CODE I&Q CHANNELS DISABLE
174	0000000000110000	TBAXIF	ALLOW AUTO XMTR TURN-ON
174	0000000000010000	TBAXIN	INHIBIT AUTO XMTR TURN-ON
174	0000000000000001	TBAOVN	ALLOW AUTO TRANSFER TO VCO
174	0000000000000011	TBAOVF	INHIBIT AUTO TRANSFER TO VCO
174	0000000000001100	TBCMRM	SELECT MEDIUM COMMAND RATE
174	0000000000000100	TBCMRL	SELECT LOW COMMAND RATE

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Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
CUNOOP	4.6.1.1.1			CCMDCNT	INCREMENT
CUSLFN	4.6.1.1.2	CUMAF1		CCUANF=1	CU A ON
		CUMAF2		CCUBNF=1	CU B ON
CUMAF1	4.6.1.1.2			CCUANF=0	CU A OFF
				CCUBNF=0	CU B OFF
CUMAF2	4.6.1.1.2	CUMAF1		CCUANF=0	CU A OFF
				CCUBNF=0	CU B OFF
CUEXON	4.6.1.1.2			COSCINX=0	
SUPRAN	4.6.1.1.3		SUPRBN	CSUPVBA=0	
SUPRBN	4.6.1.1.3		SUPRAN	CSUPVBA=1	
RPLYAN	4.6.1.1.3		RPLYBN	CRPLYBA=0	
RPLYBN	4.6.1.1.3		RPLYAN	CRPLYBA=1	
TLMHDN	4.6.1.1.4		TLMHDF	CCUAHFN=0	CU A
				CCUBHFN=0	CU B
TLMHDF	4.6.1.1.4		TLMHDN	CCUAHFN=1	CU A
				CCUBHFN=1	CU B
OBCD1K	4.6.1.1.5		OBCD32	CCUADMP=0	CU A
				CCUBDMP=0	CU B
OBCD32	4.6.1.1.5		OBCD1K	CCUADMP=1	CU A
				CCUBDMP=1	CU B
SRIUEN	4.6.1.7			CRIUSBA=0	RIU A
				CRIUSBA=1	RIU B
RIUSB2	4.6.1.7	SRIUEN		CMATENF=0	
MRIUDI	4.6.1.7			CMATENF=0	
STNSAN	4.6.1.6.1	CPFDDA	STNSAO	CSTOBCA=1	
STNSAO	4.6.1.6.1		STNSAN	CSTOBCA=0	
STNSBN	4.6.1.6.1	CPFDDB	STNSBO	CSTOBCB=1	
STNSBO	4.6.1.6.1		STNSBN	CSTOBCB=0	
CPFDEA	4.6.1.6.3	OBC RUNNING	CPFDDA	CCFDAED=1	
CPFDDA	4.6.1.6.3		CPFDEA	CCFDAED=0	
CPFDEB	4.6.1.6.3	OBC RUNNING	CPFDDB	CCFDBED=1	
CPFDDB	4.6.1.6.3		CPFDEB	CCFDBED=0	
CA1SEC	4.6.1.6.3			NO DIR VER	OBC COMMAND
CB1SEC	4.6.1.6.3			NO DIR VER	OBC COMMAND
MEMOEN	4.6.1.6.2	OBC PWR OFF	MEMO2D	CMEMOED=1	
MEM2EN	4.6.1.6.2	OBC PWR OFF	MEMO2D	CMEM2ED=1	
SPAMO2	4.6.1.6.1	OBC PWR OFF	SPBMO2	CPWRMO2=0	
SPBMO2	4.6.1.6.1	OBC PWR OFF	SPAMO2	CPWRMO2=1	
MEMO2D	4.6.1.6.2	OBC PWR OFF	MEMOEN	CMEMOED=0	

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Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
			MEM2EN	CMEM2ED=0	
MEM1EN	4.6.1.6.2	OBC PWR OFF	MEM13D	CMEM1ED=1	
MEM3EN	4.6.1.6.2	OBC PWR OFF	MEM13D	CMEM3ED=1	
SPAM13	4.6.1.6.1	OBC PWR OFF	SPBM13	CPWRM13=0	
SPBM13	4.6.1.6.1	OBC PWR OFF	SPAM13	CPWRM13=1	
MEM13D	4.6.1.6.2	OBC PWR OFF	MEM1EN	CMEM1ED=0	
			MEM3EN	CMEM3ED=0	
PMPAON	4.6.1.3.1		PMPAOF	CPMPANF=1	
PMPATA	4.6.1.3.2		PAMUXA	CPAN1MX=1	
			PAMUXB		
PAMUXA	4.6.1.3.2		PMPATA	CPAN1MX=0	
			PAMUXB	CPAMXAB=0	
PAMUXB	4.6.1.3.2		PMPATA	CPAN1MX=0	
			PAMUXA	CPAMXAB=1	
PMPAOF	4.6.1.3.1		PMPAON	CPMPANF=0	
PMPBON	4.6.1.3.1		PMPBOF	CPMPBNF=1	
PMPBTB	4.6.1.3.2		PBMUXA	CPBN2MX=1	
			PBMUXB		
PBMUXA	4.6.1.3.2		PMPBTB	CPBN2MX=0	
			PBMUXB	CPBMXAB=0	
PBMUXB	4.6.1.3.2		PMPBTB	CPBN2MX=0	
			PBMUXA	CPBMXAB=1	
PMPBOF	4.6.1.3.1		PMPBON	CPMPBNF=0	
S28ARF	4.6.1.5	RIU A ON	S28BRF	C28VRFS=0	
S28BRF	4.6.1.5	RIU B ON	S28ARF	C28VRFS=1	
RFCON1	4.6.1.5		RFCON2	CRFSWC=10	
			RFCON3		
RFCON2	4.6.1.5		RFCON1	CRFSWC=01	
			RFCON3		
RFCON3	4.6.1.5		RFCON1	CRFSWC=11	
			RFCON2		
XMTRAE	4.6.1.4.4		XMTRAD	CXMTAED=1	
XMTRAD	4.6.1.4.4		XMTRAE	CXMTAED=0	
XMTRBE	4.6.1.4.4		XMTRBD	CXMTBED=1	
XMTRBD	4.6.1.4.4		XMTRBE	CSMTBED=0	
HTR1EN	4.6.1.8		HTR1DI	CHTR1ED=1	
HTR1DI	4.6.1.8		HTR1EN	CHTR1ED=0	
HTR2EN	4.6.1.8		HTR2DI	CHTR2ED=1	
HTR2DI	4.6.1.8		HTR2EN	CHTR2ED=0	

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Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
BR1KB	4.6.1.2.1			CBITRAT=000	
BR2KB	4.6.1.2.1			CBITRAT=001	
BR4KB	4.6.1.2.1			CBITRAT=010	
BR8KB	4.6.1.2.1			CBITRAT=011	
BR16KB	4.6.1.2.1			CBITRAT=100	
BR32KB	4.6.1.2.1			CBITRAT=101	
BR64KB	4.6.1.2.1			CBITRAT=110	
CUFLXF	4.6.1.2.2			CFORMAT=00	NOT USED
CUENGF	4.6.1.2.2			CFORMAT=01	
CUMISF	4.6.1.2.2			CFORMAT=10	
CPMFLX	4.6.1.2.2			CFORMAT=11	
DWELL,V	4.6.1.2.3		NODWLL	CDWLMOD=1 CDWLCHN=V	V=4-127
NODWLL	4.6.1.2.3			CDWLMOD=0	
PARTTN	4.6.1.3.2	PMPAON	PARTTF	CPARTTR=10	
PARTTF	4.6.1.3.2	PMPAON	PARTTN	CPARTTR=00	
PACXNN	4.6.1.3.5	PMPAON	PACXFF	CPARTENC=1 CPASTENC=1	
PACXFF	4.6.1.3.5	PMPAON	PACXNN	CPARTENC=0 CPASTENC=0	
PACXFN	4.6.1.3.5	PMPAON		CPARTENC=0 CPASTENC=1	
PACXNF	4.6.1.3.5	PMPAON		CPARTENC=1 CPASTENC=0	
PANMOA	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=1000 CPABXP=0	
PANMOB	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=0100 CPABXP=0	
PANMOC	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=1100 CPABXP=0	
PANMOD	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=0010 CPABXP=0	
PANMOE	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=1010 CPABXP=0	
PANMOF	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=0110 CPABXP=0	
PANMOG	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=1110 CPABXP=0	
PANMOH	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=0001 CPABXP=0	

Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
PANMOI	4.6.1.3.3	PMPAON	PANMOO	CPAMODE=1001 CPABXP=0	
PANMOO	4.6.1.3.3	PMPAON		CPAMODE=0000 CPABXP=0	
PARMOA	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=1000 CPABXP=1	
PARMOB	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=0100 CPABXP=1	
PARMOC	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=1100 CPABXP=1	
PARMOD	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=0010 CPABXP=1	
PARMOE	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=1010 CPABXP=1	
PARMOF	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=0110 CPABXP=1	
PARMOG	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=1110 CPABXP=1	
PARMOH	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=0001 CPABXP=1	
PARMOI	4.6.1.3.3	PMPAON	PARMOO	CPAMODE=1001 CPABXP=1	
PARMOO	4.6.1.3.3	PMPAON		CPAMODE=0000 CPABXP=1	
PANCUA	4.6.1.3.2	PMPAON	PANCUB	CPACUBA=0 CPABXP=0	
PANCUB	4.6.1.3.2	PMPAON	PANCUA	CPACUBA=1 CPABXP=0	
PARCUA	4.6.1.3.2	PMPAON	PARCUB	CPACUBA=0 CPABXP=1	
PARCUB	4.6.1.3.2	PMPAON	PARCUA	CPACUBA=1 CPABXP=1	
PANSTA	4.6.1.3.2	PMPAON	PANSTB	CPASTBA=0 CPABXP=0	
PANSTB	4.6.1.3.2	PMPAON	PANSTA	CPASTBA=1 CPABXP=0	
PARSTA	4.6.1.3.2	PMPAON	PARSTB	CPASTBA=0 CPABXP=1	

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Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
PARSTB	4.6.1.3.2	PMPAON	PARSTA	CPASTBA=1 CPABXP=1	
PAHDOF	4.6.1.3.4	PMPAON		CPAHDLN=00	
PARTHN	4.6.1.3.4	PMPAON	PAHDOF	CPAHDLN=10	
PAMDHN	4.6.1.3.4	PMPAON	PAHDOF	CPAHDLN=01	
PATDHN	4.6.1.3.4	PMPAON	PAHDOF	CPAHDLN=11	
PBRTTN	4.6.1.3.2	PMPBON	PBRTTF	CPBRTTR=10	
PBRTTF	4.6.1.3.2	PMPBON	PBRTTN	CPBRTTR=00	
PBCXNN	4.6.1.3.5	PMPBON	PBCXFF	CPBRTENC=1 CPBSTENC=1	
PBCXFF	4.6.1.3.5	PMPBON	PBCXNN	CPBRTENC=0 CPBSTENC=0	
PBCXFN	4.6.1.3.5	PMPBON		CPBRTENC=0 CPBSTENC=1	
PBCXNF	4.6.1.3.5	PMPBON		CPBRTENC=1 CPBSTENC=0	
PBRMOA	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=1000 CPABXP=1	
PBRMOB	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=0100 CPABXP=1	
PBRMOC	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=1100 CPABXP=1	
PBRMOD	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=0010 CPABXP=1	
PBRMOE	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=1010 CPABP=1	
PBRMOF	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=0110 CPABXP=1	
PBRMOG	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=1110 CPABXP=1	
PBRMOH	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=0001 CPABXP=1	
PBRMOI	4.6.1.3.3	PMPBON	PBRMOO	CPBMODE=1001 CPABXP=1	
PBRMOO	4.6.1.3.3	PMPBON		CPBMODE=0000 CPABXP=1	
PBNMOA	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=1000 CPABXP=0	
PBNMOB	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=0100 CPABXP=0	

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Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
PBNMOC	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=1100 CPABXP=0	
PBNMOD	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=0010 CPABXP=0	
PBNMOE	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=1010 CPABXP=0	
PBNMOF	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=0110 CPABXP=0	
PBNMOG	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=1110 CPABXP=0	
PBNMOH	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=0001 CPABXP=0	
PBNMOI	4.6.1.3.3	PMPBON	PBNMOO	CPBMODE=1001 CPABXP=0	
PBNMOO	4.6.1.3.3	PMPBON		CPBMODE=0000 CPABXP=0	
PBRCUA	4.6.1.3.2	PMPBON	PBRCUB	CPBCUBA=0 CPABXP=1	
PBRCUB	4.6.1.3.2	PMPBON	PBRCUA	CPBCUBA=1 CPABXP=1	
PBNCUA	4.6.1.3.2	PMPBON	PBNCUB	CPBCUBA=0 CPABXP=0	
PBNCUB	4.6.1.3.2	PMPBON	PBNCUA	CPBCUBA=1 CPABXP=0	
PBRSTA	4.6.1.3.2	PMPBON	PBRSTB	CPBSTBA=0 CPABXP=1	
PBRSTB	4.6.1.3.2	PMPBON	PBRSTA	CPBSTBA=1 CPABXP=1	
PBNSTA	4.6.1.3.2	PMPBON	PBNSTB	CPBSTBA=0 CPABXP=0	
PBNSTB	4.6.1.3.2	PMPBON	PBNSTA	CPBSTBA=1 CPABXP=0	
PBHDOF	4.6.1.3.4	PMPBON		CPBHDLN=00	
PBRTHN	4.6.1.3.4	PMPBON	PBHDOF	CPBHDLN=10	
PBMDHN	4.6.1.3.4	PMPBON	PBHDOF	CPBHDLN=01	
PLTDHN	4.6.1.3.4	PMPBON	PBHDOF	CPBHDLN=11	
TAXSHM	4.6.1.4.4	XMTRAE	TAXOFF	CXMTANF=1 CXPAMOD=1	TLM I/P 1 ON

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Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
TAXSLM	4.6.1.4.4	XMTRAE	TAXOFF	CXPAXMT=1 CXMTANF=1 CXPAMOD=0	TLM I/F 1 ON
TAXTON	4.6.1.4.4	XMTRAE	TAXOFF	CXPAXMT=1 CXMTANF=1 CXPAXMT=0	
TARSTM	4.6.1.4.1		TARSMO	CXPASTD=0	
TARSMO	4.6.1.4.1		TARSTM	CXPASTD=1	
TAXOFF	4.6.1.4.4			CXMTANF=0	
TATL1N	4.6.1.4.2		TATL1F	NO DIR VER	
TATL1F	4.6.1.4.2		TATL1N	NO DIR VER	NO TLM OUT
TATL2N	4.6.1.4.2		TATL2F	NO DIR VER	
TATL2F	4.6.1.4.2		TATL2N	NO DIR VER	
TAERNG	4.6.1.4.2		TADRNG	CXPARNG=1	
TADRNG	4.6.1.4.2		TAERNG	CXPARNG=0	
TAINQN	4.6.1.4.5		AIFQF	CXPAPNI=0 CXPAPNQ=0	
TAIFQN	4.6.1.4.5			CXPAPNI=1 CXPAPNQ=0	
TAINQF	4.6.1.4.5			CXPAPNI=0 CXPAPNQ=1	
TAIFQF	4.6.1.4.5			CXPAPNI=1 CXPAPNQ=1	
TAAXIF	4.6.1.4.4	XMTRAE	TAAXIN	CAUTXMA=1	
TAAXIN	4.6.1.4.4		TAAXIF	CAUTXMA=0	
TAAOVN	4.6.1.4.3		TAAOVF	CXPAOSC=0	
TAAOVF	4.6.1.4.3		TAAOVN	CXPAOSC=1	
TACMRM	4.6.1.4.1		TACMRL	CXPADET=1	
TACMRL	4.6.1.4.1		TACMRM	CXPADET=0	
TBXSHM	4.6.1.4.4	XMTRBE	TBXOFF	CXMTBNF=1 CXPBMOD=1 CXPBXMT=1	TLM I/P 1 ON
TBXSHL	4.6.1.4.4	XMTRBE	TBXOFF	CXMTBNF=1 CXPBMOD=0 CXPBXMT=1	TLM I/P 1 ON
TBXTON	4.6.1.4.4	XMTRBE	TBXOFF	CXMTBNF=1 CXPBXMT=0	
TBXOFF	4.6.1.4.4			CXMTBNF=0	
TBRSTM	4.6.1.4.1		TBRSMO	CXPBSTD=0	

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Table 4.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
TBRSM)	4.6.1.4.1		TBRSTM	CXPBSTD=1	
TBTL1N	4.6.1.4.2		TBTL1F	NO DIR VER	
TBTL1F	4.6.1.4.2		TBTL1N	NO DIR VER	NO TLM OUT
TBTL2N	4.6.1.4.2		TBTL2F	NO DIR VER	
TBTL2F	4.6.1.4.2		TBTL2N	NO DIR VER	
TBERNG	4.6.1.4.2		TBDRNG	CXPbRNG=1	
TBDRNG	4.6.1.4.2		TBERNG	CXPBRNG=0	
TBINQN	4.6.1.4.5		TBIFQF	CXPBPNI=0 CXPBPNQ=0	
TBIFQN	4.6.1.4.5			CXPBPNI=1 CXPBPNQ=0	
TBINQF	4.6.1.4.5			CXPBPNI=0 CXPBPNQ=1	
TBIFQF	4.6.1.4.5			CXPBPNI=1 CXPBPNQ=1	
TBAXIF	4.6.1.4.4	XMTRBE	TBAXIN	CAUTXMB=1	
TBAXIN	4.6.1.4.4		TBAXIF	CAUTXMB=0	
TBAOVN	4.6.1.4.3		TBAOVF	CXPBOSC=0	
TBAOVF	4.6.1.4.3		TBAOVN	CXPBOSC=1	
TBCMRM	4.6.1.4.1		TBCMRL	CXPBDET=1	
TBCMRL	4.6.1.4.1		TBCMRM	CXPBDET=0	

4.6.1 COMMAND DESCRIPTIONS

This section provides descriptions of the command functions using the acronyms in Table 4.6-1 and 4.6-3. All C&DH commands are addressed to RIU 1 (A or B) except special commands to the central unit which are addressed to RIU 0. All RIU 1 commands may be executed by either the A or B RIU except for two discrete commands: 34 (which will execute only when RIU A is on) and 53 (which will execute only when RIU B is on). Telemetry monitors referred to in the following paragraphs are defined in Section 4.7.

4.6.1.1 CU Special Commands

Special commands are executed directly by the CU and are not routed to the multiplex data bus. In the Standby Mode, execution of special commands does not require operation of the CU clock oscillator.

4.6.1.1.1 CUNOOP

This command is a test command used to verify correct operation of the forward link. When sent to the active CU, successful operation will result in an increment of the telemetry monitor CCMDCNT. When sent to the standby CU, successful operation will result in an increment of the telemetry monitor CSCMDCT. Unsuccessful operation will result in no increment of either telemetry monitor above.

4.6.1.1.2 CUSLFN Sel. CU On
CUMAF1 CU Mate Off 1
CUMAF2 CU Mate Off 2
CUEXON Ext OSC Selected

These commands are used to select the desired CU and spacecraft oscillator configuration. When power is first applied to the C&DH (such as ground test start-up), both CU A and CU B will go to the standby state. From this initial state, commands should be addressed to the desired CU in the order CUMAF1, CUMAF2, CUSLFN, CUEXON. The CUSLFN command from the initial state will select the internal clock oscillator; the CUEXON command is then required to select the ultra-stable Landsat-D external oscillator. In normal operation, one CU is on while the other is in standby. If activation of the alternate CU is desired the commands CUMAF1, CUMAF2, and CUSLFN addressed to the standby CU must be sent. This sequence assures that both CU's are not on at the same time, an undesirable condition which could induce a spurious command on the multiplex data bus. During this sequence, both CU's will be in the standby mode until the CUSLFN command is executed, causing a momentary loss of telemetry data. Telemetry verifications of these commands are obtained from the monitors CONCUID, CCUANF, CCUBNF, COSCINX.

4.6.1.1.3 SUPRAN Sel Supervisory Line A ON/B OFF
SUPRBN Sel. Supervisory Line B ON/A OFF
RPLYAN Sel. Reply Line A ON/B OFF
RPLYBN Sel. Supervisory Reply Line B ON/A OFF

These commands are used to select the CU multiplex data bus configuration. SUPRAN and SUPRBN are complementary commands which select the supervisory lines used by the CU to distribute command and telemetry requests. RPLYAN and RPLYBN are complementary commands which select the reply lines used by the CU for telemetry data acquisition. Although both reply lines contain data from all RIU's, only one pair is selected by the CU. Telemetry verifications for these commands are obtained from the monitors CSUPVBA and CRPLYBA.

4.6.1.1.4 TLMHDN CU Hardline Telemetry ON
TLMDHF CU Hardline Telemetry OFF

These complementary commands turn on or off hardline telemetry data monitors from CU A or B. The outputs (NRZ-L data and 1X clock) are available at the C&DH module connector as test points only. Telemetry verifications for these commands are obtained from the monitors CCUAHFN and CCUBHFN.

4.6.1.1.5 OBCD1K Sel 1 Kbps OBC Dump
OBCD32 Sel 32 Kbps OBC Dump

These complementary commands are used to select the bit rate for an OBC memory dump via CU A or B. The selectable rates are 1 KBPS or 32 KBPS. Telemetry verifications for these commands are obtained from the monitors CCUADMP and CCUBDMP.

4.6.1.2 <u>CU Serial Magnitude Commands</u>

CU serial commands are sent to address 170 (RIU 1, serial command enable 0). They must be addressed to the active CU; the standby CU accepts special commands only. If both CU's are in standby (ref. Paragraph 4.6.1.1.2), no commands to address 170 will be executed.

4.6.1.2.1 Telemetry Bit Rate Selection

BR1KB Sel 1 Kbps Bit Rate
BR2KB Sel 2 Kbps Bit Rate
BR4KB Sel 4 Kbps Bit Rate
BR8KB Sel 8 Kbps Bit Rate
BR16KB Sel 16 Kbps Bit Rate
BR32KB Sel 32 Kbps Bit Rate
BR64KB Sel 64 Kbps Bit Rate

These commands are used to select the data rate of the telemetry data stream. Each command is mutually exclusive of the others. Although any rate may be selected, the planned usage for Landsat-D is 1 KBPS or 8 KBPS for real time telemetry data. Telemetry verification for these commands is obtained from the monitor CBITRAT.

4.6.1.2.2 Telemetry Format Selection

CUFLXF Sel CU Flex Format
CUENGF Sel CU Eng Format
CUMISF Sel CU Mission Format
CPMFLX Sel OBC Flex Format

These mutually exclusive commands are used to select the telemetry address source used by the CU format generator. CUFLXF selects a CU flex format which can be obtained from a programmable RAM in the CU. This option is not available on Landsat-D.

CUENGF and CUMISF select either of two fixed ROM's as telemetry address sources. CUENGF selects the Engineering format and CUMISF selects the Mission format.

Another format source is the computer flex format which is selected by CPMFLX. In this format, the OBC provides the addresses from tables which can be loaded into the OBC memory.

Telemetry verification for these commands is obtained from the monitor CFORMAT.

4.6.1.2.3 Dwell Mode Commands

DWELL,V Dwell on Ch. V (0-127)
NODWLL Dwell Mode OFF

Sixteen positions in each telemetry minor frame have digital word assignments which remain unchanged. These fixed words are 0-3, 32-35, 64-67, and 96-99. the DWELL,V command selects the dwell mode for any minor frame word (V) except the fixed words. The selected word will appear in all telemetry locations except the 16 fixed word locations. The NODWLL command is used to exit from the dwell mode. Telemetry verifications for these commands are obtained from the monitors CDWLMOD and CDWLCHN.

4.6.1.3 PMP Commands

Command control of the PMP is attained by discrete commands, and by serial commands to address 172. In order to execute serial commands, the PMP (A or B) for which the commands are intended must be on. This requirement is indicated by listing PMPAON or PMPBON as prerequisite commands in Table 4.6-4. If the appropriate telemetry monitor (CPMPANF or CPMPBNF) indicates logic "1", it is not required to send the PMP ON command before sending serial commands.

4.6.1.3.1 PMP On/Off Control

Each PMP has an associated power supply. In normal operation, both PMP's will probably be on in different operating modes. The PMP to which serial commands are addressed must be on to accept serial commands. PMPAON and PMPAOF control PMP A; PMPBON and PMPBOF control PMP B. Telemetry verifications for these commands are obtained from the monitors PMPANF and PMPBNF.

4.6.1.3.2 PMP Input Data Selection

Each PMP accepts input signals from the following sources:

1. Real time telemetry data from CU A
2. Real time telemetry data from CU B
3. OBC memory dump data from STINT A
4. OBC memory dump data from STINT B
5. Payload correction data from PCD formatter A
6. Payload correction data from PCD formatter B
7. NBTR playback data (NBTR 1 is dedicated to PMP A and NBTR 2 is dedicated to PMP B)
8. External data (not used on Landsat-D)

Selection of inputs for each PMP is controlled using the commands which are listed below (ref. Figure 4.6-1).

PMP A	PMP B	Input Selected
PMPATA	PMPBTB	NBTR playback data
PAMUXA	PBMUXA	PCD from formatter A
PAMUXB	PBMUXB	PCD from formatter B
PANCUA	PBNCUA	CU A data, XPNDR config. normal
PARCUA	PBRCUA	CU A data, XPNDR config. reverse
PANCUB	PBNCUB	CU B data, XPNDR config. normal
PARCUB	PBRCUB	CU B data, XPNDR config. reverse
PANSTA	PBNSTA	STINT A data, XPNDR config. normal
PARSTA	PBRSTA	STINT A data, XPNDR config. reverse
PANSTB	PBNSTB	STINT B data, XPNDR config. normal
PARSTB	PBRSTB	STINT B data, XPNDR config. reverse

The XPNDR configuration normal/reverse selection is imbedded in the CU and STINT selection commands. The PMP outputs are applied to the two transponders (ref. Figure 4.6-3) in a cross-strap arrangement so that, by proper command, the simultaneous connections of PMP A to transponder A and B to B are obtained (normal), or the reverse is obtained (B to A and A to B).

In addition to the above commands, each PMP can provide real time data from the selected CU to its dedicated NBTR record amplifier. The on/off commands for this function control power to drive amplifiers in the PMP's. Commands required for this function are PARTTN, PARTTF, PBRTTN, and PBRTTF (reference switch P6 in Figure 4.6-1).

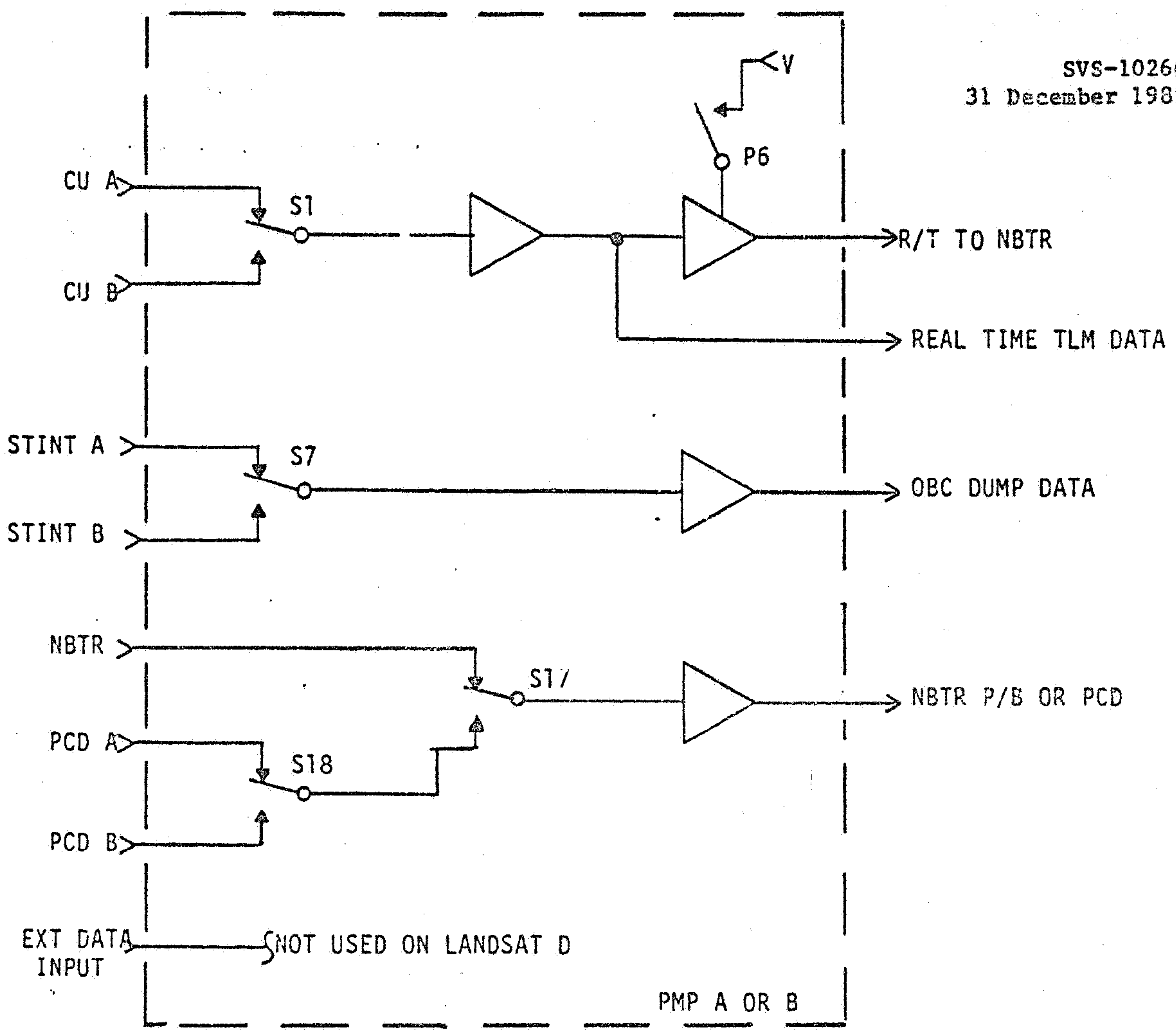
4.6.1.3.3 PMP Output Mode Selection

The data sources described in 4.6.1.3.2 are selected in various combinations for routing to either a STDN or TDRSS transmitter output on the PMP. Data to the STDN output is NRZ-M bi-phase encoded and PSK modulated on a 1.024 MHz subcarrier provided by the active CU. Data to the TDRSS output is NRZ-M encoded and provided on separate I and Q channel outputs to the transmitter. The I channel always contains real time telemetry.

All input/output combinations are established by selecting the appropriate PMP modes. The basic modes available and the configuration of the PMP switches necessary are depicted in Figure 4.6-2. The mode outputs are turned off through control of power to the STDN and TDRSS output amplifiers. The output modes are listed below.

Mode A - Real time telemetry to STDN
Mode B - Real time telemetry and OBC dump to STDN
Mode C - Real time telemetry and NBTR or PCD to STDN
Mode D - Real time telemetry and external data to STDN
Mode E - External data to STDN
Mode F - Real time telemetry to TDRSS
Mode G - Real time telemetry and OBC dump to TDRSS
Mode H - Real time telemetry and NBTR or PCD to TDRSS
Mode I - Real time telemetry and external data to TDRSS

Selection of output mode for each PMP is controlled using the commands listed below. The PMP A-B to XPNDR A-B configuration is imbedded in each command as part of the selection process. A 'normal' command to either PMP connects PMP A outputs to XPNDR A and PMP B outputs to XPNDR B. A 'reverse" command to either PMP connects PMP A outputs to XPNDR B and PMP B outputs to XPNDR A (ref. Figure 4.6-3).



S1 selects real time telemetry data from CU A or B.
S7 selects OBC memory dump data from STINT A or B.
S18 selects payload correction data from formatter A or B.
S17 selects NBTR P/B data or PCD. NBTR 1 is dedicated to PMP A and NBTR 2 to PMP B.
There is no external data input to PMP from Landsat D.
P6 turns on/off telemetry data to NBTR record amplifier.

Figure 4.6-1. PMP Input Data Selection

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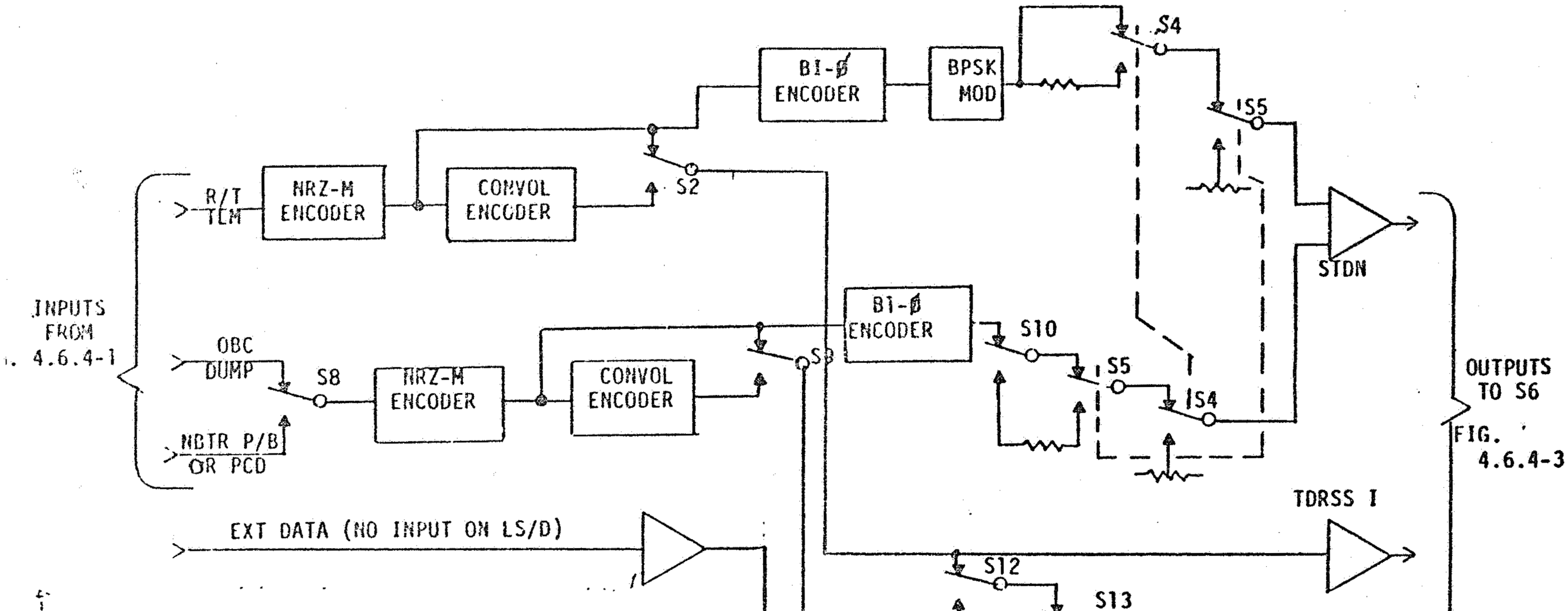

SWITCHES SHOWN IN RESET POSITION R=RESET S=SET

MODE	S4	S5	S8	S10	S12	S13
A	S	R	-	-	-	-
B	R	R	R	R	-	-
C	R	R	S	R	-	-
D	R	R	-	S	-	-
E	-	S	-	S	-	-
F	-	-	-	-	R	R
G	-	-	R	-	S	R
H	-	-	S	-	S	R
I	-	-	-	-	S	S

CONV. ENCODERS	S2	S9
I ON, Q ON	S	S
I ON, Q OFF	S	R
I OFF, Q ON	R	S
I OFF, Q OFF	S	S

Figure 4.6-2. PMP Output Mode Selection

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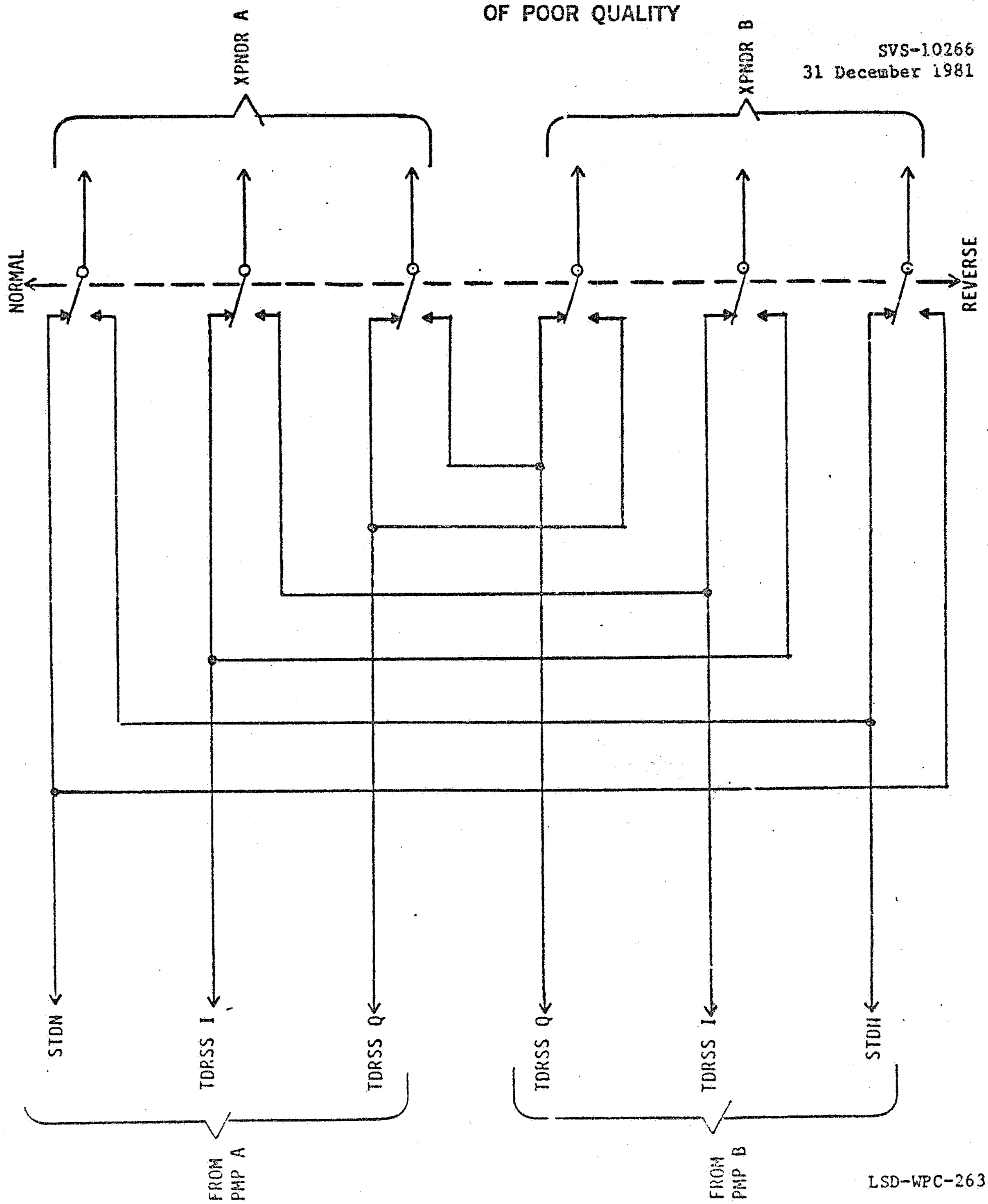


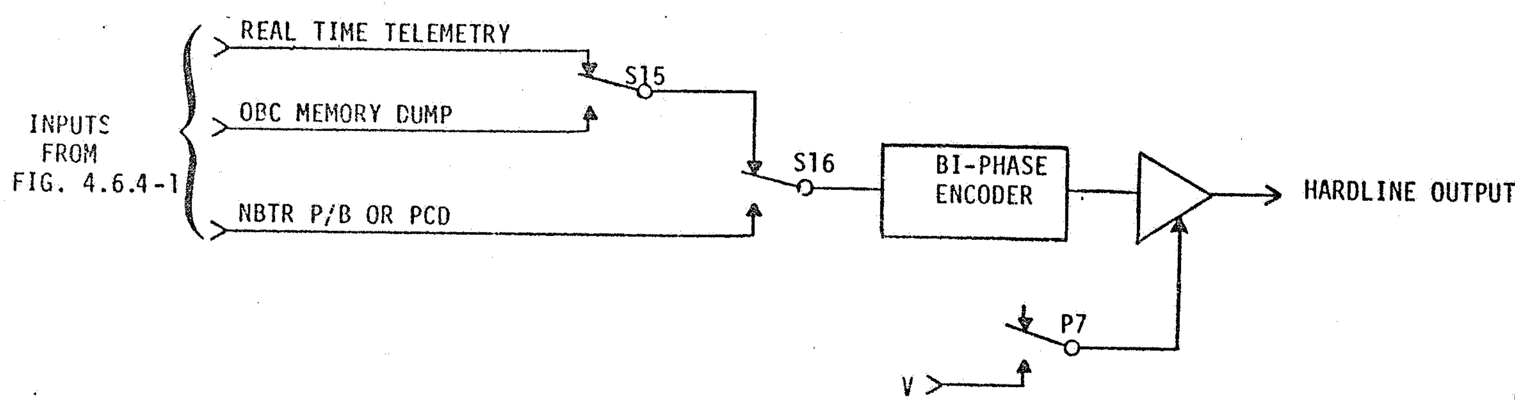
Figure 4.6-3. PMP to Transponder Normal/Reverse Switch

PMP A	PMP B	PMP/XPNDR Configuration
PANMOA	PBNMOA	Mode A normal
PANMOB	PBNMOB	Mode B normal
PANMOC	PBNMOC	Mode C normal
PANMOD	PBNMOD	Mode D normal
PANMOE	PBNMOE	Mode E normal
PANMOF	PBNMOF	Mode F normal
PANMOG	PBNMOG	Mode G normal
PANMOH	PBNMOH	Mode H normal
PANMOI	PBNMOI	Mode I normal
PANMOO	PBNMOO	Mode select off normal
PARMOA	PBRMOA	Mode A reverse
PARMOB	PBRMOB	Mode B reverse
PARMOC	PBRMOC	Mode C reverse
PARMOD	PBRMOD	Mode D reverse
PARMOE	PBRMOE	Mode E reverse
PARMOF	PBRMOF	Mode F reverse
PARMOG	PBRMOG	Mode G reverse
PARMOH	PBRMOH	Mode H reverse
PARMOI	PBRMOI	Mode I reverse
PARMOO	PBRMOO	Mode select off reverse

4.6.1.3.4 PMP Hardline Outputs

Each PMP has a hardline output monitor which can, by command, supply the selected input data described in 4.6.1.3.2 to the module interface connector for ground test monitoring. Hardline output is available simultaneously with any mode described in 4.6.1.3.3. Selection of output for each monitor is controlled using the commands listed below, and the configuration of the select switches is depicted in Figure 4.6-4. The outputs are turned on/off through control of power to the output amplifier (on when selecting data and off for a hardline off command).

PMP A	PMP B	Hardline Output
PAHDOF	PBHDOF	Outputs off
PARTHN	PBRTHN	R/T telemetry from CU A or B
PAMDHN	PBMDHN	OBC memory dump from STINT A or B
PATDHN	PBTDHN	NBTR P/B or PCD



OUTPUT	S15	S16	P7
R/T TLM	R	R	S
OBC DUMP	S	R	S
NBTR OR PCD	-	S	S
OFF	-	-	R

SWITCHES SHOWN IN RESET POSITION

R = RESET · S = SET

Figure 4.6-4. PMP Hardline Output Switching

4.6.1.3.5 Convolutional Encoding

In the TDRSS modes, a 1/2 rate length 7 convolutional encoder can be applied to the I and Q channels independently by command. Encoder in/out selection is controlled using the commands listed below, and the configuration of the select switches is shown in Figure 4.6-2.

PMP A	PMP B	Encoder Selection
PACXNN	PBCXNN	I and Q channel encoders on
PACXFF	PBCXFF	I and Q Channel encoders off
PACXFN	PBCXFN	I channel encoder off, Q channel encoder on
PACXNF	PBCXNF	I channel encoder on, Q channel encoder off

4.6.1.4 Transponder Commands

Command control of the transponders is attained by discrete commands which enable/disable power to the transponder transmitters, and by serial commands to address 173 (transponder A) and address 174 (transponder B).

The transponders can be commanded into either a TDRSS or STDN mode as required. Both transponder transmitters should not be on at the same time in the same modes. Having both on in different modes is acceptable. Upon initial application of spacecraft power, or after power restoration subsequent to a temporary disruption, each transponder will assume the following state:

Receiver on in dual mode
Low TDRSS command rate selected
Transmitter off
Low modulation index selected
STDN telemetry inputs 1 and 2 off
STDN ranging off
Automatic transmitter turn-on inhibited
Automatic aux oscillator to VCO transfer enabled (allowed)

4.6.1.4.1 Transponder Receiver Commands

Both transponder receivers are always powered; there is no off command. Each receiver has two commandable modes selected by the following commands:

RCVR A	RCVR B	Mode
TARSTM	TBRSTM	Dual STDN/TDRSS acquisition
TARSMO	TBRSMO	STDN acquisition only

In the dual mode the receiver simultaneously searches for the TDRSS suppressed carrier signal and the STDN residual-carrier signal, and automatically reconfigures its circuits to process whichever signal is detected. The type of signal detected is indicated by the telemetry monitors CXPARMD and CXPBRMD. In the STDN only mode the receiver is configured to accept a STDN signal only. Telemetry verifications of the receiver mode commands are obtained from the monitors CXPASTD and CXPBSTD.

When a STDN signal is detected, the command detectors in the receivers are automatically configured to accept the STDN 2 KBPS command rate. The command detectors can be configured by command to accept, in the TDRSS mode only, either a medium (1 KBPS) or low (125 BPS) command rate. There is no command rate selection for STDN reception. The TDRSS command rate selection is accomplished using the commands listed below. Telemetry verifications of the commands are obtained from the monitors CXPADET and CXPBDET.

RCVR A	RCVR B	TDRSS Command Rate
TACMRM	TBCMRM	Medium - 1 KBPS
TACMRL	TBCMRL	Low - 125 BPS

4.6.1.4.2 STDN Transmitter Telemetry and Ranging Control

Each transponder has two input ports, designated telemetry inputs 1 and 2, to accept STDN telemetry data for transmission. Provisions are made for turning the STDN data input channels on or off by command. Input 2 is not used on Landsat-D and should be left in the off state. Input 1 receives data from either PMP A or B which is controlled by the PMP STDN mode select commands (ref. Paragraph 4.6.1.3.3). Commands required for telemetry input control are listed below and depicted in Figure 4.6-5. There are no telemetry monitors associated with these commands. One possible indication of line 1 on/off is presence/absence of telemetry data in the STDN downlink data stream.

XPNDR A	XPNDR B	Function
TATL1N	TBTL1N	TLM input 1 on (see Paragraph 4.6.1.4.4)
TATL1F	TBTL1F	TLM input 1 off
TATL2N	TBTL2N	TLM input 2 on (not used)
TATL2F	TBTL2F	TLM input 2 off

The turn-around ranging function in a transponder is available only when the receiver is locked to a STDN or TDRSS forward link signal. STDN ranging (not TDRSS) can be enabled/disabled by the commands listed below and depicted in Figure 4.6-5. Command verifications are obtained from the monitors CXPARNG and CXPBRNG.

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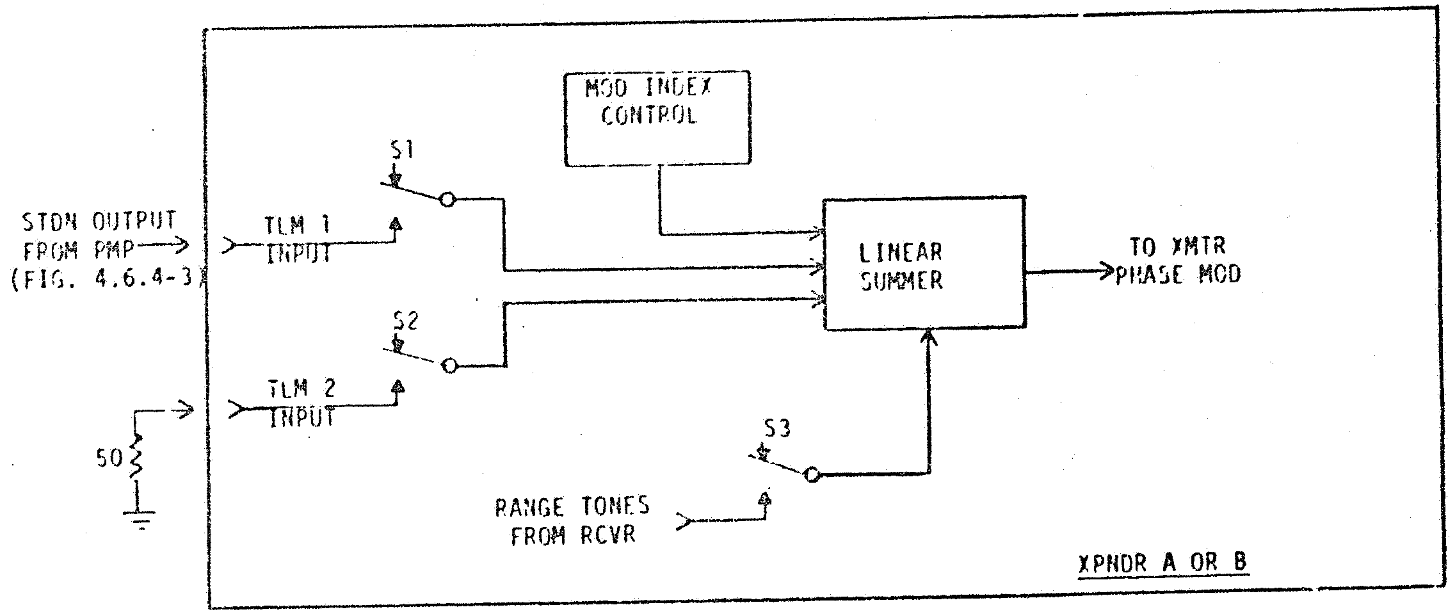

SWITCHES SHOWN IN RESET POSITION. R = RESET S = SET

XMTR A	XMTR B	S1	S2	S3
TATL1N	TBTL1N	S	-	-
TATL1F	TBTL1F	R	-	-
TATL2N	TBTL2N	-	S	-
TATL2F	TBTL2F	-	R	-
TAERNG	TBERNG	-	-	S
TADRNG	TBDRNG	-	-	R

Figure 4.6-5. STDN Transmitter Ranging & Telemetry Control

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XPNDR A	XPNDR B	STDN Ranging Function
TAERNG	TBERNG	Enable
TADRNG	TBDRNG	Disable

4.6.1.4.3 Automatic Oscillator Transfer Commands

If the receiver is not locked to a forward link signal the transponder automatically selects an internal quartz oscillator (TCXO) to obtain the transmitter drive frequency. When the receiver is locked to a STDN or TDRSS signal, the transponder can automatically switch to a voltage controlled oscillator (VCO) in the receiver to control the transmitter drive frequency to exactly 240/221 times the received frequency. The transfer from TCXO to VCO may be inhibited by command so that the transmitter drive frequency is always controlled by the TCXO (ref. Figure 4.6-6). Command verifications are obtained from the monitors CXPAOSC and CXPBOSC.

XMTR A	XMTR B	Auto transfer to VCO
TAAOVN	TBAOVN	Allow (enable)
TAAOVF	TBAOVF	Inhibit (disable)

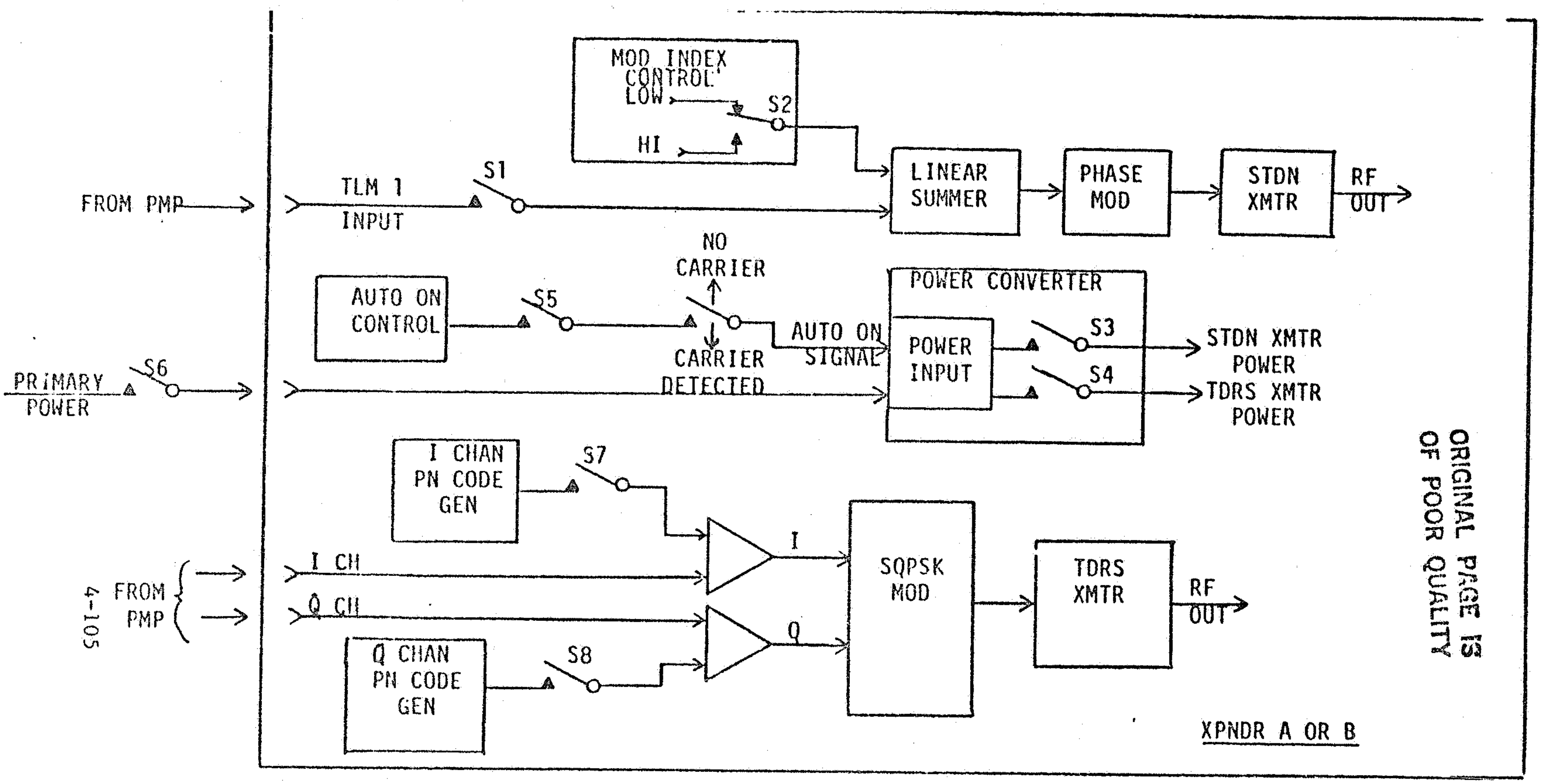
4.6.1.4.4 Transmitter On/Off Control

Power to the transmitters is enabled/disabled by commands external to the transponders (ref. Figure 4.6-7). These commands, listed below, are for backup use only; transmitter on/off control should be obtained by commands to the transponder with the transmitter power enabled. Command verifications are obtained from the monitors CXMTAED and CXMTBED.

XPNDR A	XPNDR B	Transmitter Primary Power
XMTRAE	XMTRBE	Enable
XMTRAD	XMTRBD	Disable

As indicated above, transmitter on/off control should be accomplished by transponder commands instead of the transmitter power enable/disable commands. This requirement is indicated by listing XMTRAE and XMTRBE as prerequisite commands in Table 4.6-4. If the appropriate telemetry monitor (CXMTAED or CXMTBED) indicates logic "1", it is not required to send the enable commands before sending transmitter on/off commands.

The transmitters can be commanded on in either a TDRSS or STDN mode. In the STDN mode, either a high or low modulation index can be selected; TDRSS modulation index is automatically selected and not commandable. Due to the



S = SET, R = RESET.

SWITCHES SHOWN IN R POSITION.
BLANK INDICATES DON'T CARE.

XPNDR A	XPNDR B	S1	S2	S3	S4	S5	S6	S7	S8
XMTRAE	XMTRBE	-	-	-	-	-	S	-	-
XMTRAD	XMTRBD	-	-	-	-	-	R	-	-
TAXSHM	TBXSHM	S	S	S	R	-	S	-	-
TAXSLM	TBXSLM	S	R	S	R	-	S	-	-
TAXTON	TBXTON	-	-	R	S	-	S	-	-
TAXOFF	TBXOFF	-	-	R	R	-	S	-	-
TAAXIF	TBAXIF	-	-	-	-	S	S	-	-
TAAXIN	TBAXIN	-	-	-	-	R	S	-	-
TAINQN	TBINQN	-	-	-	-	-	-	S	S
TAIFQN	TBIFQN	-	-	-	-	-	-	R	S
TAINQF	TBINQF	-	-	-	-	-	-	S	R
TAIFQF	TBIFQF	-	-	-	-	-	-	R	R

Figure 4.6-6. Transmitter On/Off and PN Code Commands

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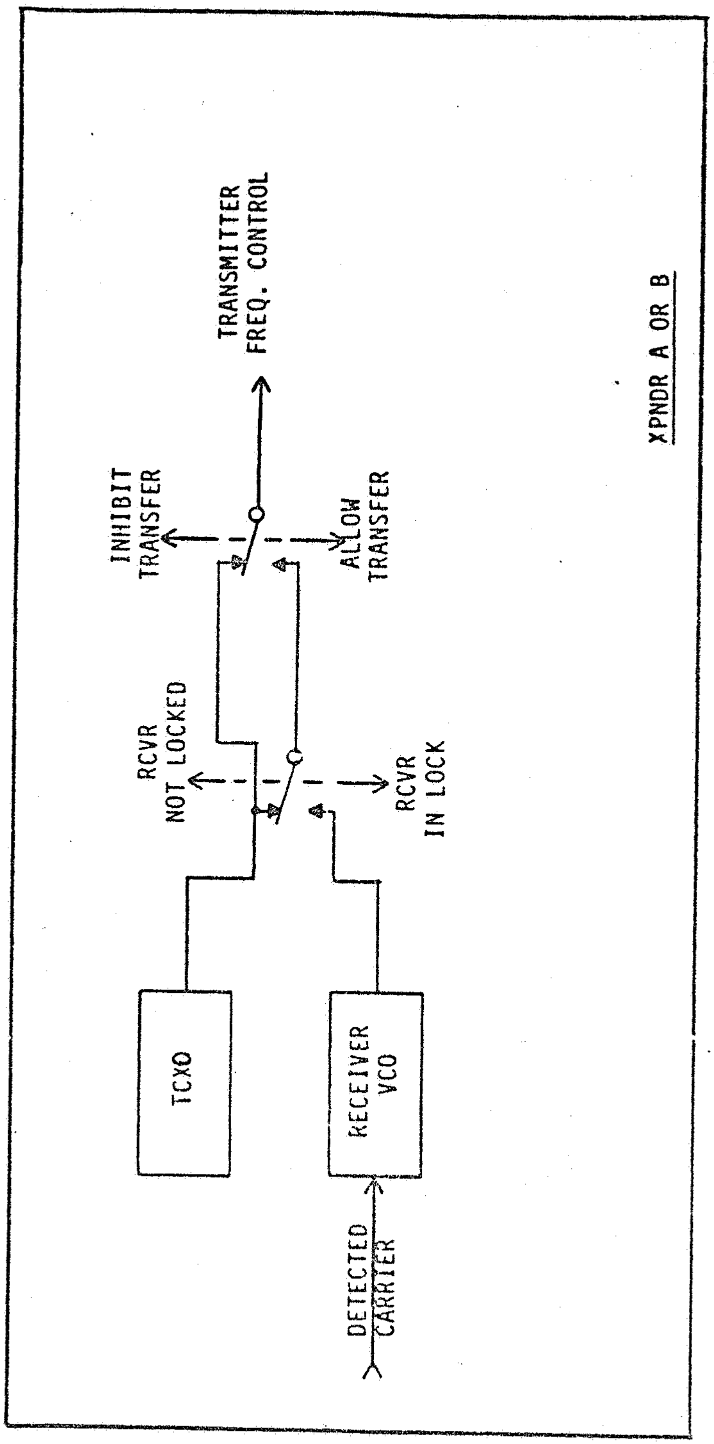

Figure 4.6-7 Automatic OSC Transfer Control

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possibility that STDN telemetry 1 input may be off (Paragraph 4.6.1.4), each STDN transmitter on command includes the telemetry input 1 on command. The transmitters also have an automatic on mode in which the transmitters will automatically turn themselves on when they achieve lock with a forward link signal; this mode can be allowed or inhibited by command. There is no automatic transmitter off feature. The transmitters must be commanded off from any on mode. The transmitter on/off commands are listed below and depicted in Figure 4.6-7.

XPNDR A	XPNDR B	Transmitter On/Off Mode
TAXSHM	TBSXHM	STDN on, high mod index, TLM 1 on
TAXSLM	TBXSLM	STDN on, low mod index, TLM 1 on
TAXTON	TBXTON	TDRSS on
TAXOFF	TBXOFF	STDN and TDRSS off
TAAXIN	TBAXIN	Inhibit automatic turn-on
TAAXIF	TBAXIF	Allow automatic turn-on

Command verifications are obtained from the monitors CXMTANF, CXMTBNF, CXPAMOD, CXPBMOD, CXPAXMT, CXPBXMT, CAUTXMA and CAUTXMB.

4.6.1.4.5 TDRSS Transmitter PN Code Commands

Each transponder has two TDRSS input ports, designated I and Q channel inputs. Data to these ports are from either PMP A or B and controlled by the PMP TDRSS mode select commands (ref. Paragraph 4.6.1.3.3). These data may or may not be convolutionally encoded by the PMP (ref. Paragraph 4.6.1.3.5). By command control, either input can be PSK modulated within the transponder with a PN code of 3M chips per second. The commands for PN code control are listed below and depicted in Figure 4.6-7. Command verifications are obtained from the monitors CXPAPNI, CXPBPNI, CXPAPNQ and CXPBPNQ.

XMTR A	XMTR B	I & Q Channel Codes
TAINQN	TBINQN	I & Q chan on
TAIFQN	TBIFQN	I chan off, Q chan on
TAINQF	TBINQF	I chan on, Q chan off
TAIFQF	TBIFQF	I & Q chan off

4.6.1.5 RF Feed Configuration Control

RF signals to and from the transponders are routed to output ports on the C&DH module for connection to an RF Combiner unit in the Instrument Module for distribution to the omni and high gain antennas. Command controlled RF transfer switches are used in the transmit signal paths to allow transmitter outputs to be connected to either omni or high gain output ports. When a transmitter's output is tied to either port, the other port is terminated with a 50 ohm load. Receiver inputs are not switched; they are always connected to the omni ports.

The commands required for RF switch configuration are listed below and depicted in Figure 4.6-8. In order to effect a configuration change it is necessary to first select the RF switch 28 V bus consistent with the RIU in use. After bus selection, any of the three RF configuration commands can be executed to obtain the desired transmitter feed connections.

Command	XMTR A Feed	XMTR B Feed
S28ARF*	-	-
S28BRF*	-	-
RFCON1	Omni 1	Hi Gain 2
RFCON2	Hi Gain 1	Omni 2
RFCON3	Omni 1	Omni 2

*Either, not both.

Command verifications are obtained from the monitors C28VRFS and CRFSWC.

4.6.1.6 OBC-STINT Commands

RIU 1 provides discrete commands for the following OBC related functions:

- o power supply selection for the STINT, CPM and memories.
- o memory configuration control.
- o computer failure detection circuitry control.

4.6.1.6.1 Power Supply Selection and Control (Figure 4.6-9)

The C&DH power control unit contains two OBC/STINT power supplies. Each is dedicated (i.e. A to A and B to B) to an associated oscillator circuit, a computer failure detection circuit and a STINT/CPM combination. Power supply turn-on is accomplished by the STINT-NSSC ON commands, which also energize the computers. Either supply may be selected for energizing all memories; however, the OBC-STINT pair corresponding to the power supply selected for the memories (A-A and B-B) must be used. The commands for power supply selection and control are listed below:

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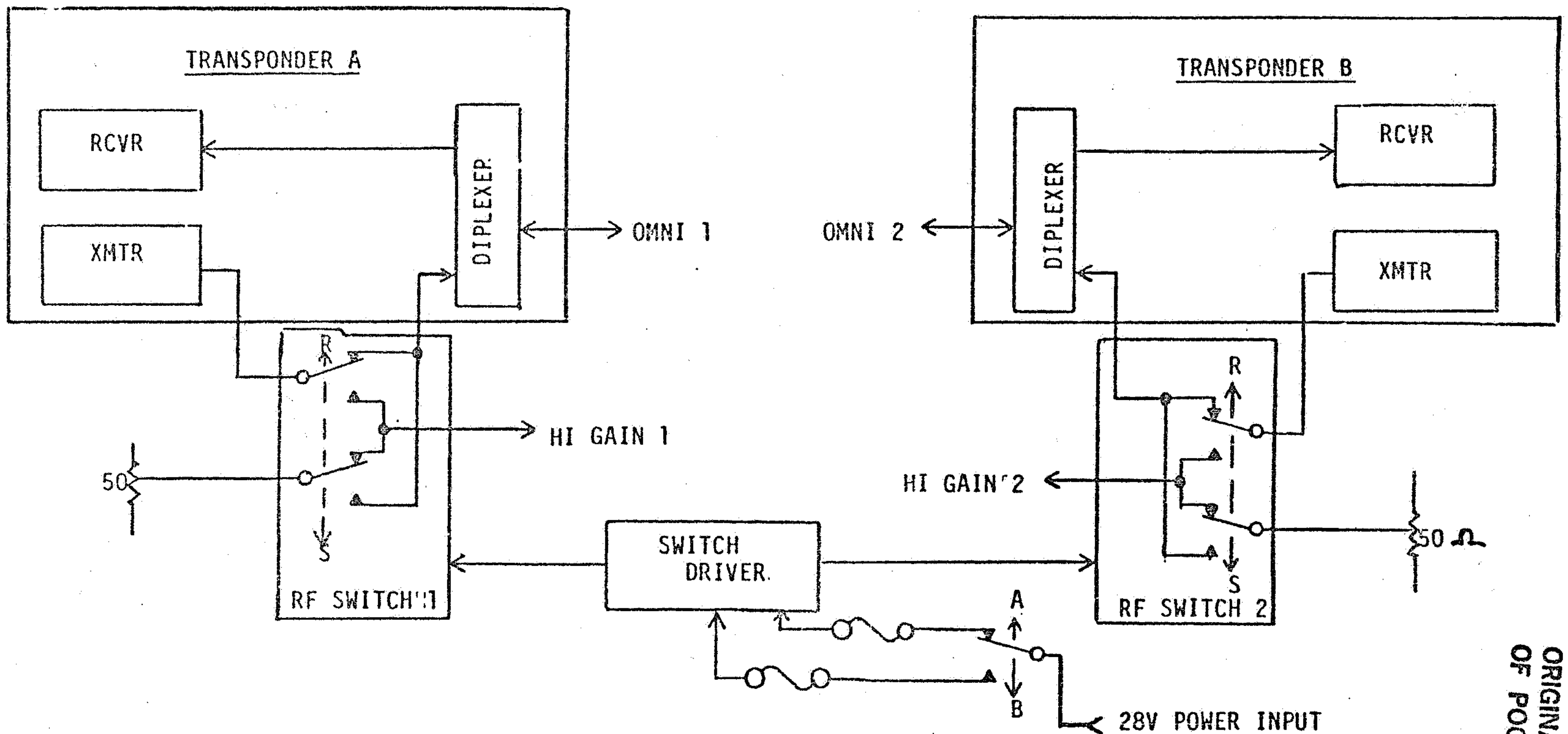

COMMAND	RFS1	RFS2	SA-B	RIU ON	XMTR A	XMTR B
S28ARF	-	-	A	A	-	-
S28BRF	-	-	B	B	-	-
RFCON1	R	S	-	A or B	OMNI 1	HI GAIN 2
RFCON2	S	R	-	A or B	HI GAIN 1	OMNI 2
RFCON3	R	R	-	A or B	OMNI 1	OMNI 2

Figure 4.6-8. RF Switch Configuration Control

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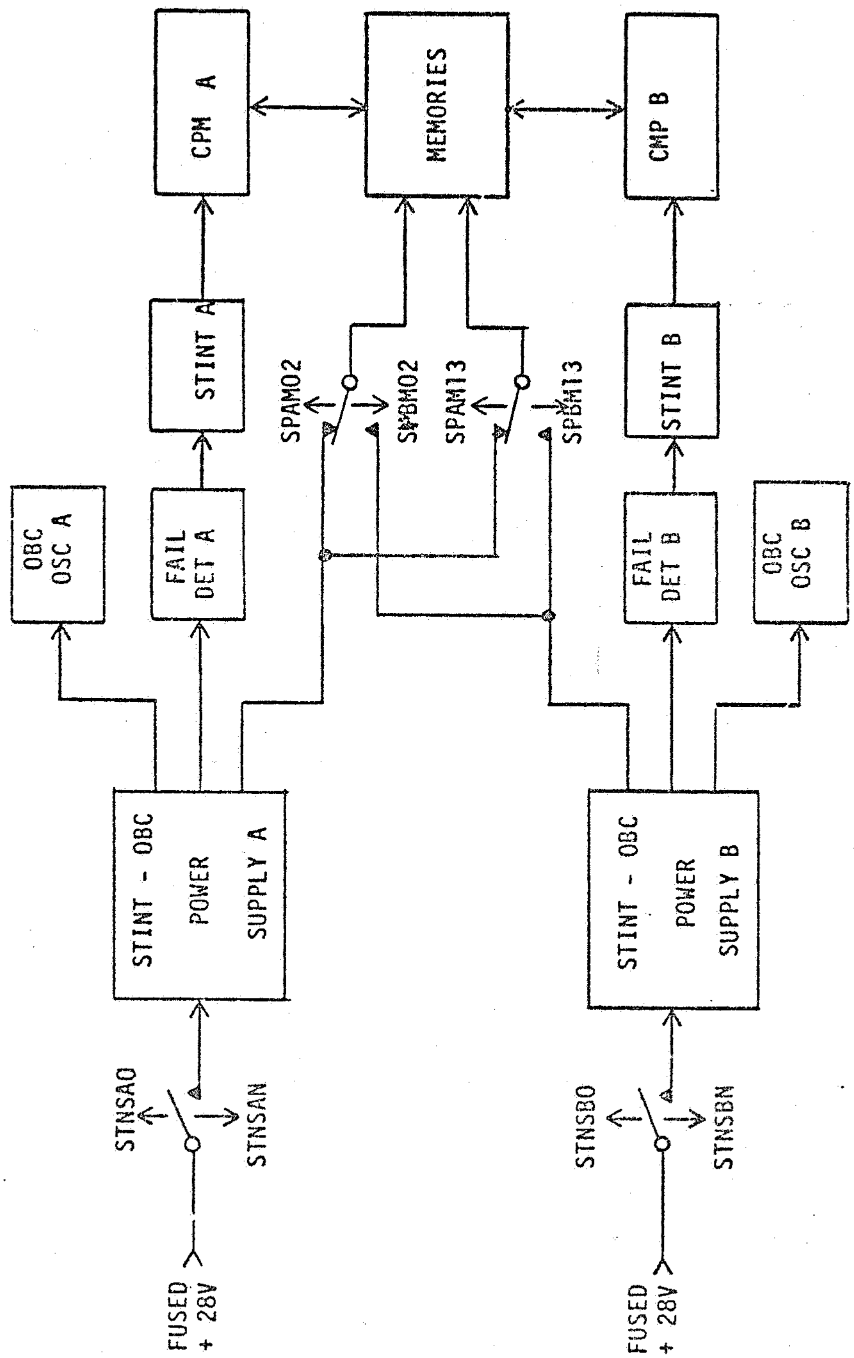

Figure 4.6-9. STINT-OBC Power Selection & Control

OBC-STINT A			OBC-STINT B		
SPAMO2			SPBMO2		
SPAM13			SPBM13		
STNSAN	OR	(ON)	STNSBN	OR	(ON)
STNSAO		(OFF)	STNSBO		(OFF)

Both power supplies shall not be on simultaneously, and both must be off when configuring the memories (4.6.1.6.2). Command verifications are obtained from the monitors CPWRMO2, CPWRM13, CSTOBCA, CSTOBCB.

4.6.1.6.2 Memory Configuration Commands

The full complement of eight memories can be configured by enable/disable commands by which the memories are enabled in pairs and disabled in groups of four. As indicated in Table 4.6-4, the prerequisite for any memory enable/disable command is both OBC/STINT power supplies must be off to prevent damage to the memories or relays. The memory configuration commands are listed below and depicted in Figure 4.6-10. Command verifications are obtained from the monitors CMEMOED, CMEM1ED, CMEM2ED, and CMEM3ED.

MEMOEN	MEM1EN
MEM2EN	MEM3EN
MEMO2D	MEM13D

4.6.1.6.3 Computer Failure Detection Commands (Figure 4.6-11)

Each STINT-CPM pair has its own failure detection circuit which is powered by the dedicated power supply. The circuit checks that the power supply 5 V secondary voltage is within prescribed limits, and that a computer 1-second command has been received from the OBC via either RIU A or B within the last 3 seconds. If either condition is not satisfied, the failure detection circuit generates a halt signal to the computer. The circuitry can be enabled/disabled by command. It must be disabled in order to start the computer because a halted computer does not generate the 1-second commands used by the failure detection circuit. The commands associated with the failure detection circuits are listed below. Telemetry verifications for the enable/disable functions are obtained from the monitors CCFDAED and CCFDBED. The only verification of the 1-second commands is that the OBC has not halted.

OBC A	OBC B	Computer Failure Detection
CPFDDA	CPFDDB	Disable
CPFDEA	CPFDEB	Enable
CA1SEC	CB1SEC	(From operating OBC)

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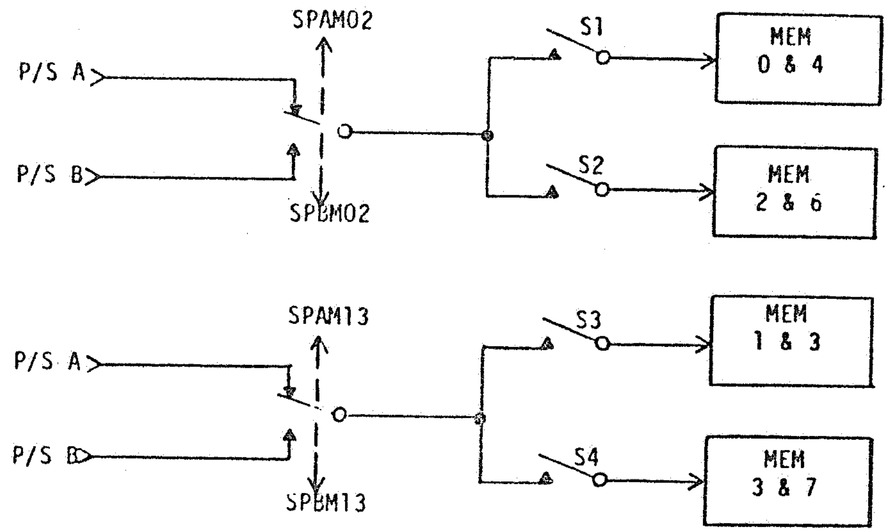

SWITCHES SHOWN IN RESET POSITION. R = RESET S = SET

COMMAND	S1	S2	S3	S4	PREREQUISITES
MEM0EN	S	-	-	-	STNSA0, STNSB0
MEM2EN	-	S	-	-	STNSA0, STNSB0
MEM02D	R	R	-	-	STNSA0, STNSB0
MEM1EN	-	-	S	-	STNSA0, STNSB0
MEM3EN	-	-	-	S	STNSA0, STNSB0
MEM13D	-	-	R	R	STNSA0, STNSB0

Figure 4.6-10. OBC Memory Configuration Commands

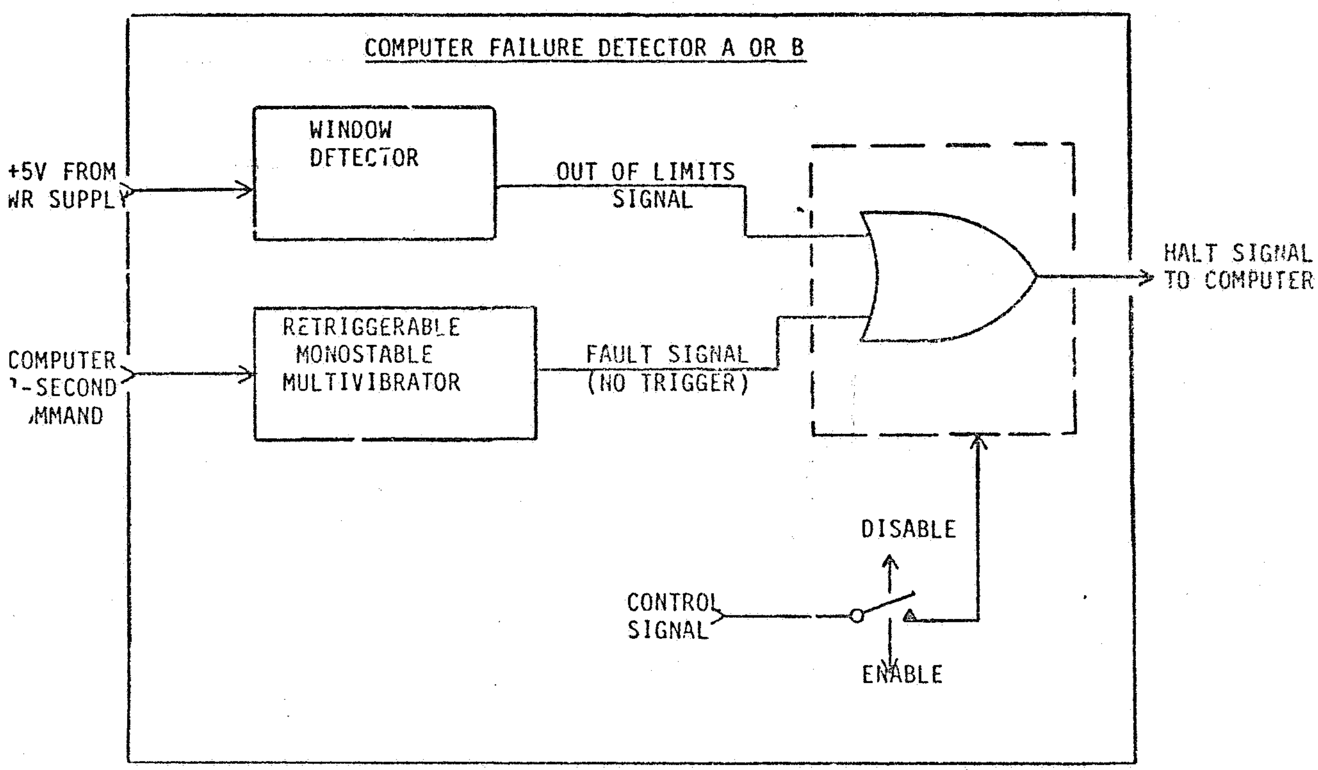

Figure 4.6-11. OBC Failure Detector Control

4.6.1.7 RIU Control

The C&DH RIUs (RIU 1A and 1B) are connected in a redundant configuration such that either can provide communication between the CU and other C&DH components via the multiplex data bus (MDB). An RIU has three modes: Off, Standby 1, and Standby 2 (full on). In the Standby I Mode, the RIU channel can receive only discrete commands. In all modes, the power converters in both RIUs are on and both of the MDB redundant supervisory lines are continuously monitored by the RIUs.

In normal operation, one RIU will be in the Standby 2 state and its mate will be in the Off state. When power is restored after interruption, both will return to their prior states. In order to activate the alternate RIU, it is necessary to address two commands, SRIUEN and RIUSB2, to the off RIU. SRIUEN causes an Off RIU to assume the Standby 1 state. In this mode it can only accept discrete commands. RIUSB2 is then sent to the same RIU, which causes it to assume the Standby 2 (full on) state and simultaneously place its mate in the Off state. A backup mate off command, MRIUDI, is provided in the event RIUSB2 fails to place the mate RIU in the Off state. MRIUDI should be addressed only to a RIU in the Standby 2 state, and never to one in the Standby 1 state. The latter condition will result in one RIU Off and the other in Standby 1 causing the OBC, which requires a full on RIU for self-checking, to halt.

Command verifications are obtained from the monitors CRIUSBA and CMATENF.

4.6.1.8 Module Heater Control

The C&DH contains eight module heaters, configured redundantly, with four heaters on each of two identical circuits. Each circuit contains four resistive five watt heaters, each of which is controlled by a mechanical thermostat having set points of 4.4 $\pm$2.8 degrees C close and 12.8 $\pm$2.8 degrees C open. Discrete commands (HTR1EN and HTR1DI for the prime heater circuit, and HTR2EN and HTR2DI for the redundant heater circuit) provide enable/disable control for the heaters as shown in Figure 4.6-12. Telemetry verifications for these commands are obtained from the monitors CHTR1ED and CHTR2ED.

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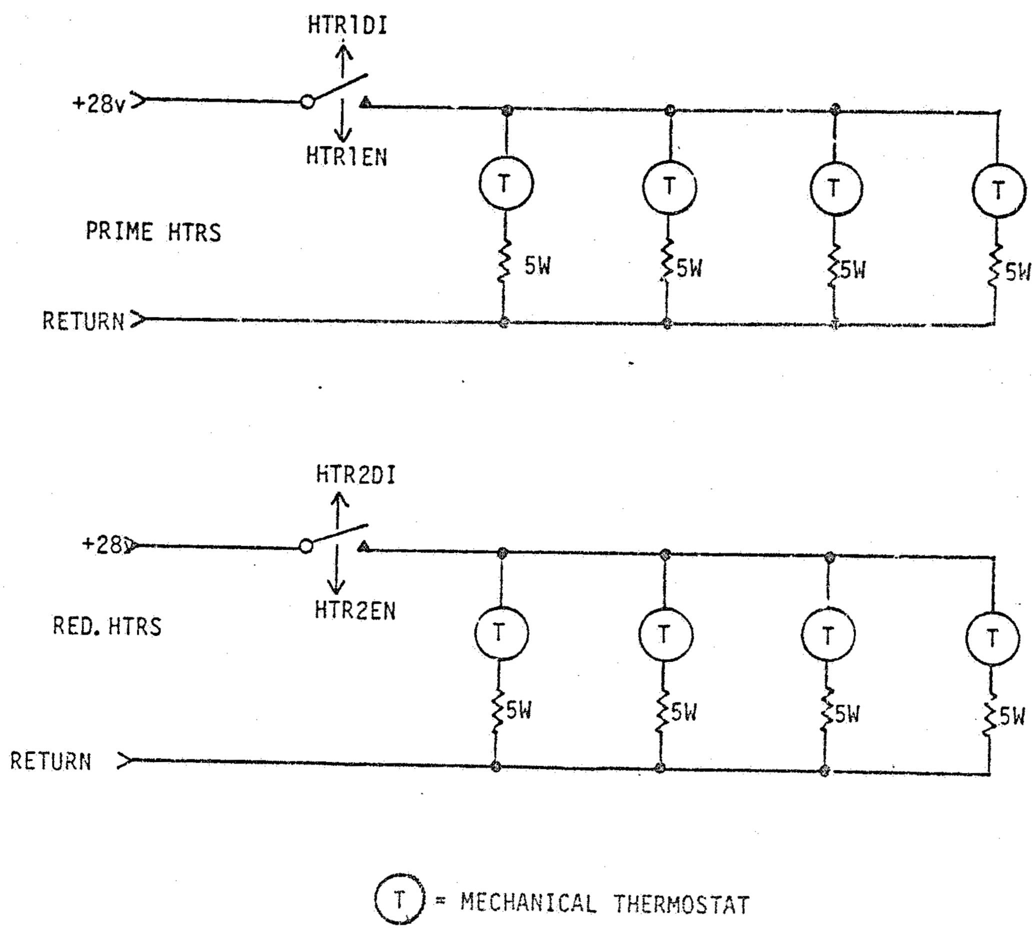

Figure 4.6-12. C&DH Module Heater Control

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4.6.2 COMMAND SEQUENCES

4.6.2.1 Central Unit Sequences

When power is first applied to the C&DH module, both central units will assume the Off (standby) state with internal oscillator selected, 1 KBPS telemetry bit rate selected, and the engineering telemetry format selected. To achieve the normal CU configuration for Landsat, the following sequence should be addressed to the CU (A or B) desired to be active:

CUMAF1 Mate CU OFF 1
CUMAF2 Mate CU OFF 2
CUSLFN Self CU ON (INT. OSC. SEL. and PWR ON)
CUEXON SEL. EXT. OSC
- Select desired bit rate (normally BR8KB)
- Select desired format (normally CUMISF)

If it is desired to switch from an active CU to the alternate (standby) CU, the following sequence should be addressed to the standby CU. Note that this switchover sequence will result in an interruption of all telemetry and command functions, including those to the OBC.

- Halt the OBC
  CUMAF1
  CUMAF2
  CUSLFN
- Start the OBC per 4.6.2.2 or 4.6.2.3

4.6.2.2 OBC Memory Configuration Sequences

Both OBC power supplies must be off when configuring the memories to prevent damage to the memories or relays.

If OBC-A is to be used, the following sequence is required:

STNSAO
STNSBO
SPAMO2
SPAM13
- Configure memories (Paragraph 4.6.1.6 2)
  CPFDEA
  STNSAN
- Start the OBC
  CPFDEA

If OBC-B is to be used, the following sequence is required:

STNSAO
STNSBO
SPBMO2
SPBM13
- Configure memories (Paragraph 4.6.1.6.2)
CPFDDB
STNSBN
- Start the OBC
CPFDEB

4.6.2.3 OBC Restart

Whenever a powered OBC (A or B) has been halted, the following sequence is required to restart the OBC without triggering the failure detection circuit:

OBC-A	OBC-B
CPFDDA	CPFDDB
-Start the OBC	-Start the OBC
CPFDEA	CPFDEB

4.6.2.4 RIU Switchover

To switch the active RIU to its mate, the following command sequence should be sent to the off RIU:

SRIUEN
RIUS32

4.6.3 COMMAND CONSTRAINTS

4.6.3.1 CU Constraints

1. Both CU's should not be on at the same time. If both are on simultaneously, messages on the multiplex data bus may be garbled and there is a possibility of inducing a spurious command on the supervisory bus lines. The command sequences of 4.6.2.1 should be used to ensure that only one CU is on.

2. The required sequence for switchover from one CU to the other (reference 4.6.2.1) will result in interrupting all command and telemetry functions, including those to the OBC. The OBC should be halted, therefore, prior to sending the switchover commands. After

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switchover, the OBC restart procedure (Paragraph 4.6.2.3) should be used to restart the computer.

3. CU serial commands (address 170) should be sent only to the active CU. The off (standby) CU will accept special commands only, and will ignore serial commands while in the off state.

4.6.3.2 OBC/STINT Constraints

1. Both OBC/STINT power supplies must be off when configuring the memories (Paragraph 4.6.2.2).

2. To satisfy OBC operational constraints, only one OBC/STINT pair should be on at any time. Both should not be on simultaneously.

3. To avoid inadvertent activation of the OBC failure detection circuit, the command sequence in 4.6.2.3 is required to start a halted computer.

4.6.3.3 Transponder Constraints

1. The transmitter power enable/disable commands should not be used to turn the transmitters on and off (ref. Paragraph 4.6.1.4.4).

2. Both transmitters should not be on in the same mode, but both may be on in different modes.

4.6.3.4 RF Switch Constraints

1. RIU 1A must be on to execute command S28ARF (Paragraph 4.6.1.5). Conversely, RIU 1B must be on to execute command S28BRF.

2. The transponder transmitters should be off when reconfiguring the RF switches to prevent possible switch damage.

4.6.3.5 PMP Constraints

1. In order to execute PMP serial commands (address 172), the PMP (A or B) for which the commands are intended must be on.

4.6.3.6 RIU Constraints

1. The backup Mate Off command (MRIUDI) should be addressed only to a RIU in the Standby 2 state (ref. Paragraph 4.6.1.7).

4.6.4 FUNCTIONAL SCHEMATICS

This section provides functional schematics as an aid to understanding the command interface. The functional schematics are provided as information only and are superseded by the exact circuits defined on the C&DH drawings.

4.7 C&DH TELEMETRY

Operation of the C&DH system is monitored via 121 telemetry channels from RIU 1 and the central unit (CU). Eight serial digital channels are provided directly by the CU. RIU 1 provides the remaining channels of which 9 are active analog, 19 are passive (conditioned) analog requiring a 1 milliampere source from the RIU, 77 are bilevel digital, and 8 are serial digital.

The telemetry monitors are listed in Table 4.7-1 by function name and acronym. In the table, signal types are designated ALOG for active analog, PASS for passive analog, S for serial digital, and B for bilevel digital functions. The numbers associated with the S and B notations indicate bit numbers of the 8-bit digital word (where bit 0 is the MSB). SMPL RATE defin . the number of times a function is sampled in a telemetry major frame. Telemetry matrix locations for C&DH functions are the same in both the Mission and Engineering telemetry formats.

Telemetry function descriptions are presented in Sections 4.7.1 and 4.7.2. Telemetry derivation circuits for selected functions are presented in Section 4.7.3. For information regarding calibration curves for the telemetered functions, see Appendix A.4.

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Table 4.7-1. C&DH Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
C/DH-01	FRAME SYNC WORD 00 (11111010)	CMFSYNC	S0-7	00	128	CU	4.7.2.2.3
	FRAME SYNC WORD 01 (11110011)		S0-7	01	128	CU	
	FRAME SYNC WORD 02 (00100000)		S0-7	02	128	CU	
C/DH-02	S/C CLOCK (8 MSB)	CCLKMSB	S0-7	87	128	01-06	4.7.2.2.5
C/DH-03	S/C CLOCK (8 MIDDLE BITS)	CCLKISB	S0-7	86	128	01-07	4.7.2.2.5
C/DH-04	S/C CLOCK (8 LSB), 1 BIT=1.024 SECONDS	CCLKLSB	S0-7	64	128	CU	4.7.2.2.5
C/DH-05	MINOR FRAME COUNTER	CFRMCNT	S0-7	65	128	CU	4.7.2.2 3
C/DH-06	CMD COUNTER, SELECTED CU (0-255)	CCMDCNT	S0-7	66	128	CU	4.7.2.3
C/DH-07	DWELL MODE ON/OFF	CDWLMOD	S--0	67	128	CU	4.7.2.2.4
	DWELL MODE CHANNEL (0-127)	CDWLCHN	S1-7	67	128	CU	4.7.2.2.4
C/DH-08	TELEMETRY BIT RATE	CBITRAT	S0-2	03	128	CU	4.7.2.2.1
	FORMAT SELECT	CFORMAT	S3-4	03	128	CU	4.7.2.2.2
	CU B/CU A	CONCUID	S--5	03	128	CU	4.7.2.1.1
	DATA REAL TIME/OBC DUMP	CRTCDMP	S--6	03	128	CU	4.7.2.2.1
	CU DCDR CH A REJECT/NO REJECT	CCHAREJ	S--7	03	128	CU	4.7.2.3
C/DH-09	CU A FLEX FORMAT LOAD/VERIFY	CCUAFLX	S0-7	97,82	1	CU	4.7.2.2.2
C/DH-10	CU B FLEX FORMAT LOAD/VERIFY	CCUBFLX	S0-7	98,82	1	CU	4.7.2.2.2
C/DH-11	STANDBY CU COMMAND COUNTER (0-255)	CSCMDCT	S0-7	96,82	1	01-02	4.7.2.3
C/DH-12	OBC DUMP MEMORY BANK ID, STINT A	CADMPID	S0-3	98,83	1	01-03	4.7.2.8
	TYPE DUMP, STINT A	CADMPHS	S4-5	98,83	1		4.7.2.8
	UNUSED BITS	---	S6-7	98,83	1		---
C/DH-13	OBC DUMP MEMORY BANK ID, STINT B	CBDMPID	S0-3	98,84	1	01-04	4.7.2.8
	TYPE DUMP, STINT B	CBDMPHS	S4-5	98,84	1		4.7.2.8
	UNUSED BITS	---	S6-7	98.84	1		---
C/DH-14	PMP A OPERATING MODE STATUS	CPAMODE	S0-3	96,78	1	01-00	4.7.2.4.5
	PMP A R/T TO TAPE STATUS	CPARTTR	S4-5	96,78	1		4.7.2.4.2
	PMP A HARDLINE OUTPUT STATUS	CPAHDLN	S6-7	96,78	1		4.7.2.4.5
C/DH-15	PMP B OPERATING MODE STATUS	CPBMODE	S0-3	97,78	1	01-01	4.7.2.4.5
	PMP B R/T TO TAPE STATUS	CPBRTTR	S4-5	97,78	1		4.7.2.4.2
	PMP B HARDLINE OUTPUT STATUS	CPBHDLN	S6-7	97,78	1		4.7.2.4.5

Table 4.7-1. C&DH Telemetry List (Cont.)

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
C/DH-16	BILEVEL WORD 010:					01-08	
	XPNDR A RCVR LOCKED/UNLOCKED	CXPARLK	B--0	34	128	01-08	4.7.2.5.1
	XPNDR A REC MODE TDRS/STDN	CXPARMD	B--1	34	128	01-09	4.7.2.5.1
	XPNDR B RCVR LOCKED/UNLOCKED	CXPBRLK	B--2	34	128	01-10	4.7.2.5.1
	XPNDR B REC MODE TDRS/STDN	CXPBRMD	B--3	34	128	01-11	4.7.2.5.1
	XPNDR A CMD DET UNLOCKED/LOCKED	CXPACLK	B--4	34	128	01-12	4.7.2.5.1
	XPNDR B CMD DET UNLOCKED/LOCKED	CXPBCLK	B--5	34	128	01-13	4.7.2.5.1
	CU A COMMAND REJECT/ACCEPT	CCUAREJ	B--6	34	128	01-14	4.7.2.3
	CU B COMMAND REJECT/ACCEPT	CCUBREJ	B--7	34	128	01-15	4.7.2.3
C/DH-17	BILEVEL WORD 020:					01-16	
	XPNDR A REC MODE STDN/DUAL	CXPASTD	B--6	97,106	1	01-22	4.7.2.5.1
C/DH-18	BILEVEL WORD 040:					01-32	
	CU A ON/OFF	CCUANF	B--0	96,108	1	01-32	4.7.2.1.1
	CU A HARDLINE TELEMETRY OFF/ON	CCUAHFN	B--1	96,108	1	01-33	4.7.2.1.3
	CU B ON/OFF	CCUBNF	B--2	96,108	1	01-34	4.7.2.1.1
	CU B HARDLINE TELEMETRY OFF/ON	CCUBHFN	B--3	96,108	1	01-35	4.7.2.1.3
	REPLY LINE B/A	CRPLYBA	B--4	96,108	1	01-36	4.7.2.1.2
	SUPERVISORY LINE B/A	CSUPVBA	B--5	96,108	1	01-37	4.7.2.1.2
	CU OSCILLATOR INTERNAL/EXTERNAL	COSCINX	B--6	96,108	1	01-38	4.7.2.1.1
	RIU 01 B ON/A ON	CRIUSBA	B--7	96,108	1	01-39	4.7.2.9
C/DH-19	BILEVEL WORD 050:					01-40	
	PMP A ON/OFF	CPMPANF	B--0	98,120	1	01-40	4.7.2.4.1
	PMP A SELECT CU B/CU A	CPACUBA	B--1	98,120	1	01-41	4.7.2.4.2
	PMP A R/T CONV ENC IN/OUT	CPARTENC	B--2	98,120	1	01-42	4.7.2.4.4
	PMP A SELECT STINT B/STINT A	CPASTBA	B--3	98,120	1	01-43	4.7.2.4.2
	PMP A STINT/TAPE CONV ENC IN/OUT	CPASTENC	B--4	98,120	1	01-44	4.7.2.4.4
	PMP A SELECT RECORDER A/PCD	CPANIMX	B--5	98,120	1	01-45	4.7.2.4.2
	PMP A SELECT PCD B/A	CPAMXAB	B--6	98,120	1	01-46	4.7.2.4.2
	RIU 01 MATE STANDBY 1/OFF	CMATENF	B--7	98,120	1	01-47	4.7.2.9

Table 4.7-1. C&DH Telemetry List (Cont.)

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
C/DH-20	BILEVEL WORD 060:					01-48	
	PMP B ON/OFF	CPMPBNF	B--0	98,119	1	01-48	4.7.2.4.1
	PMP B SELECT CU B/CU A	CPBCUBA	B--1	98,119	1	01-49	4.7.2.4.2
	PMP B R/T CONV ENC IN/OUT	CPBRTENC	B--2	98,119	1	01-50	4.7.2.4.4
	PMP B SELECT STINT B/STINT A	CPBSTBA	B--3	98,119	1	01-51	4.7.2.4.2
	PMP B STINT/TAPE CONV ENC IN/OUT	CPBSTENC	B--4	98,119	1	01-52	4.7.2.4.4
	PMP B SELECT RECORDER B/PCD	CPBN2MX	B--5	98,119	1	01-53	4.7.2.4.2
	PMP B SELECT PCD B/A	CPBMXAB	B--6	98,119	1	01-54	4.7.2.4.2
	PMP A,B TO XPNDRS - XSTRAP/NORM	CPABXP	B--7	98,119	1	01-55	4.7.2.4.3
C/DH-21	BILEVEL WORD 070:					01-56	
	UNUSED BITS	----	BO-6	96,107	1	---	---
	XPNDR A MOD INDEX HIGH/LOW	CXPAMOD	B--7	96,107	1	01-63	4.7.2.5.4
C/DH-22	BILEVEL WORD 110:					01-72	
	XPNDR A XMTR PRI PWR ENA/DISA	CXMTAED	B--0	97,107	1	01-72	4.7.2.5.4
	XPNDR B XMTR PRI PWR ENA/DISA	CXMTBED	B--1	97,107	1	01-73	4.7.2.5.4
	HEATER 1 ENA/DISA	CHTR1ED	B--2	97,107	1	01-74	4.7.2.10
	HEATER 2 ENA/DISA	CHTR2ED	B--3	97,107	1	01-75	4.7.2.10
	XPNDR A TDRS MULTIPATH/NO MULTIPATH	CXAMPTH	B--4	97,107	1	01-76	4.7.2.5.1
	XPNDR B TDRS MULTIPATH/NO MULTIPATH	CXBMPTH	B--5	97,107	1	01-77	4.7.2.5.1
	XPNDR A XMIT MODE STDN/TDRS	CXPAXMT	B--6	97,107	1	01-78	4.7.2.5.4
	XPNDR A DETECTOR 1 KBPS/125 BPS	CXPADET	B--7	97,107	1	01-79	4.7.2.5.1
C/DH-23	BILEVEL WORD 130:					01-88	
	UNUSED BITS	---	BO-2	97,108	1	---	---
	STACC CU A OBC DUMP 32 KBPS/1 KBPS	CCUADMP	B--3	97,108	1	01-91	4.7.2.8
	XPNDR A RCVR ACQUISITION STATE (MSB)	CXPARAS	B--4	97,108	1	01-92	4.7.2.5.1
	XPNDR A RAS		B--5	97,108	1	01-93	
	XPNDR A RAS		B--6	97,108	1	01-94	
	XPNDR A RAS (LSB)		B--7	97,108	1	01-95	

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Table 4.7-1. C&DH Telemetry List (Cont.)

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
C/DH-24	BILEVEL WORD 140:					01-96	
	XPNDR A STDN RANGING ON/OFF	CXPARNG	B--0	96,106	1	01-96	4.7.2.5.2
	XPNDR A XMTR ON/OFF	CXMTANF	B--1	96,106	1	01-97	4.7.2.5.4
	XPNDR A OSC AUTO TRANSFER DISA/ENA	CXPAOSC	B--2	96,106	1	01-98	4.7.2.5.2
	XPNDR B XMIT MODE STDN/TDRS	CXPBXMT	B--3	96,106	1	01-99	4.7.2.5.4
	XPNDR A XMTR AUTO ON ENA/DISA	CAUTXMA	B--4	96,106	1	01-100	4.7.2.5.4
	XPNDR B XMTR AUTO ON ENA/DISA	CAUTXMB	B--5	96,106	1	01-101	4.7.2.5.4
	XPNDR B PN CODE I CHAN OFF/ON	CXPBPNI	B--6	96,106	1	01-102	4.7.2.5.3
	XPNDR B PN CODE Q CHAN OFF/ON	CXPBPNQ	B--7	96,106	1	01-103	4.7.2.5.3
C/DH-25	BILEVEL WORD 150:					01-104	
	XPNDR B DETECTOR 1 KBPS/125 BPS	CXPBDET	B--0	97,105	1	01-104	4.7.2.5.1
	XPNDR A PN CODE I CHAN OFF/ON	CXPAPNI	B--1	97,105	1	01-105	4.7.2.5.3
	XPNDR A PN CODE Q CHAN OFF/ON	CXPAPNQ	B--2	97,105	1	01-106	4.7.2.5.3
	XPNDR B STDN RANGING ON/OFF	CXPBRNG	B--3	97,105	1	01-107	4.7.2.5.2
	XPNDR B XMTR ON/OFF	CXMTBNF	B--4	97,105	1	01-108	4.7.2.5.4
	XPNDR B OSC AUTO TRANSFER DISA/ENA	CXPBOSC	B--5	97,105	1	01-109	4.7.2.5.2
	XPNDR B REC MODE STDN/DUAL	CXPBSTD	B--6	97,105	1	01-110	4.7.2.5.1
	XPNDR B MOD INDEX HIGH/LOW	CXPBMOD	B--7	97,105	1	01-111	4.7.2.5.4
C/DH-26	BILEVEL WORD 160:					01-112	
	STACC STINT A, NSSC A ON/OFF	CSTOBCA	B--0	98,108	1	01-112	4.7.2.7
	COMPUTER FAILURE DET A ENA/DISA	CCFDAED	B--1	98,108	1	01-113	4.7.2.7
	UNUSED BIT	---	B--2	98,108	1	---	---
	STACC STINT B, NSSC B ON/OFF	CSTOBCB	B--3	98,108	1	01-115	4.7.2.7
	COMPUTER FAILURE DET B ENA/DISA	CCFDBED	B--4	98,108	1	01-116	4.7.2.7
	UNUSED BIT	---	B--5	98,108	1	---	---
	PWR SUPPLY FOR MEM 1,3,5,7 B/A	CPWRM13	B--6	98,108	1	01-118	4.7.2.7
	PWR SUPPLY FOR MEM 0,2,4,6 B/A	CPWRM02	B--7	98,108	1	01-119	4.7.2.7
C/DH-27	BILEVEL WORD 170:					01-120	
	MEM 1,5 ENA/DISA	CMEM1ED	B--0	98,07	1	01-120	4.7.2.7
	MEM 2,6 ENA/DISA	CMEM2ED	B--1	98,07	1	01-121	4.7.2.7
	MEM 3,7 ENA/DISA	CMEM3ED	B--2	98,07	1	01-122	4.7.2.7
	MEM 0,4 ENA/DISA	CMEMOED	B--3	98,07	1	01-123	4.7.2.7

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Table 4.7-1. C&DH Telemetry List (Cont.)

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
C/DH-27	BILEVEL WORD 170 (CONTINUED)						
	28V BUS B/A FOR RF SWITCH	C28VRFS	B--4	98,07	1	01-124	4.7.2.6
	RF SW CONFIGURATION BIT (MSB)	CRFSWC	B--5	98,07	1	01-125	4.7.2.6
	RF SW CONFIGURATION BIT (LSB)		B--6	98,07	1	01-126	4.7.2.6
	STACC CU B OBC DUMP 32 KBPS/1 KBPS	CCUBDMP	B--7	98,07	1	01-127	4.7.2.8
C/DH-28	PMP TEMP	CPMPTMP	PASS	98,46	1	01-21	4.7.1.5
C/DH-29	STACC CU A TEMP	CCUATMP	PASS	98,80	1	01-16	4.7.1.5
C/DH-30	STACC CU B TEMP	CCUBTMP	PASS	98,81	1	01-17	4.7.1.5
C/DH-31	PCU TEMP	CPCUTMP	PASS	98,36	1	01-20	4.7.1.5
C/DH-32	RIU 01 A TEMP	CTRIUA	PASS	96,83	1	01-27	4.7.1.5
C/DH-33	RIU 01 B TEMP	CTRIUB	PASS	96,81	1	01-28	4.7.1.5
C/DH-34	RIU 01 A/B INTERSPACE TEMP	CTRIUAB	PASS	96,80	1	01-30	4.7.1.4
C/DH-35	STINT A TEMP	CTSTNTA	PASS	97,83	1	01-18	4.7.1.5
C/DH-36	STINT B TEMP	CTSTNTB	PASS	97,81	1	01-19	4.7.1.5
C/DH-37	MODULE TEMP BETWEEN XPNDRS A&B	CTXPAB	PASS	97,21	1	01-31	4.7.1.4
C/DH-38	MODULE TEMP NEAR HTR A610 THMSTAT	CTA610	PASS	98,20	1	01-80	4.7.1.4
C/DH-39	MODULE TEMP NEAR HTR A611 THMSTAT	CTA611	PASS	98,59	1	01-81	4.7.1.4
C/DH-40	MEM 0,3 INTERSPACE TEMP	CTMEM03	PASS	97,70	1	01-29	4.7.1.4
C/DH-41	XPNDR A TCXO TEMP	CTXPAXO	PASS	96,70	1	01-23	4.7.1.3
C/DH-42	XPNDR A POWER AMP TEMP	CTXPAPA	PASS	96,69	1	01-24	4.7.1.3
C/DH-43	XPNDR B TCXO TEMP	CTXPBXO	PASS	97,36	1	01-26	4.7.1.3
C/DH-44	XPNDR B POWER AMP TEMP	CTXPBPA	PASS	97,69	1	01-25	4.7.1.3
C/DH-45	EXT OSCILLATOR CASE TEMP	CTEXOSC	PASS	96,16	1	01-89	4.7.1.2.1
C/DH-46	EXT OSC OVEN TEMP	CTXOVEN	PASS	97,16	1	01-88	4.7.1.2.1
C/DH-47	EXT OSC OVEN VOLTAGE	CVXOVEN	ALOG	98,16	1	01-83	4.7.1.2.2
C/DH-48	EXT OSC REG VOLTAGE	CVEXOSC	ALOG	99,16	1	01-82	4.7.1.2.2
C/DH-49	+28V UNREG BUS	CUNRG28	ALOG	98,107	1	01-62	4.7.1.1
C/DH-50	XPNDR A AGC LEVEL	CAGCXPA	ALOG	98,09	4	01-56	4.7.1.6.1
C/DH-51	XPNDR A RF FORWARD POWER	CXPAFWD	ALOG	96,23	4	01-57	4.7.1.6.2
C/DH-52	XPNDR A RF REFLECTED POWER	CXPAREV	ALOG	96,24	4	01-58	4.7.1.6.2
C/DH-53	XPNDR B AGC LEVEL	CAGCXPB	ALOG	98,10	4	01-59	4.7.1.6.1
C/DH-54	XPNDR B RF FORWARD POWER	CXPBFWD	ALOG	97,23	4	01-60	4.7.1.6.2
C/DH-55	XPNDR B RF REFLECTED POWER	CXPBREV	ALOG	97,24	4	01-61	4.7.1.6.2

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4.7.1 ANALOG TELEMETRY FUNCTIONS

The C&DH system utilizes 28 analog telemetry channels of which 19 are passive outputs providing temperature indications. Passive analog outputs are unpowered except during sampling, at which time the RIU provides a 1 milliampere current source to the passive channel as the output is sampled. Active analog channels are energized by the C&DH power supplies, rather than the RIU.

This section presents analog telemetry descriptions using the acronyms in Table 4.7-1. Where possible, monitors have been collected into functional groups for ease in understanding.

Operating limits appear in Table 4.7-2. The limits shown were selected for warning of potential problems during ground test environments. In orbital operation, the telemetry functions should remain well within these limits.

Telemetry derivation circuits for selected analog functions are presented in Section 4.7.3.

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Table 4.7-2. C&DH Analog Telemetry Limits

Function	Mode	Limits	Units
CPMPTMP	S/C ON	0-35	DEG C
CCUATMP	S/C ON	5-40	DEG C
CCUBTMP	S/C ON	5-40	DEG C
CPCUTMP	S/C ON	0-35	DEG C
CTRIUA	S/C ON	0-35	DEG C
CTRIUB	S/C ON	0-35	DEG C
CTRIUAB	S/C ON	0-35	DEG C
CTSTNTA	S/C ON	5-40	DEG C
CTSTNTB	S/C ON	5-40	DEG C
CTXPAB	S/C ON	0-35	DEG C
CTA610	S/C ON	0-35	DEG C
CTA611	S/C ON	0-35	DEG C
CTMEM03	S/C ON	0-35	DEG C
CTXPAPA	S/C ON	5-45	DEG C
CTXPBPA	S/C ON	5-45	DEG C
CTXPAXO	S/C ON	5-40	DEG C
CTXPBXO	S/C ON	5-40	DEG C
CTEXOSC	S/C ON	10-40	DEG C
CTXOVEN	S/C ON	78-88	DEG C
CVEXOSC	S/C ON	10.6 - 12.6	VDC
CVXOVEN	S/C ON	15 - 17.5	VDC
CUNRG28	S/C ON	21.5 - 32.5	VDC
CAGCXPA	S/C ON	--	DBM
CAGCXPB	S/C ON	--	DBM
CXPAFWD	XMTR A ON	TBD	DBM
CXPBFWD	XMTR B ON	TBD	DBM
CXPAREV	XMTR A ON	TBD	DB
CXPBREV	XMTR B ON	TBD	DB

4.7.1.1 +28 Volt Unregulated Bus (CUNRG28)

This function indicates the magnitude of the unregulated voltage provided by the Modular Power Subsystem (MPS). The telemetry voltage is derived from a resistive divider across the C&DH unregulated bus input.

4.7.1.2 External Oscillator Monitors

4.7.1.2.1 External Oscillator Case Temperature (CTEXOSC)
External Oscillator Oven Temperature (CTXOVEN)

CTXOVEN indicates the oven temperature of the temperature controlled crystal oscillator utilized on Landsat-D as the ultra-stable external oscillator selectable by the command CUEXON. When power is first applied to the spacecraft, this function will indicate a slow rise in temperature until the oven controller reaches its set point (nominally 83 degrees C). Once temperature stabilization is achieved, the controller will maintain the oven temperature within a degree or two.

CTEXOSC indicates the temperature of the external oscillator case. The case temperature should remain at or near the C&DH module temperatures. The oven is thermally isolated from the case and there should be little or no heat transfer.

Telemetry derivation circuits for both functions are presented in Figure 4.7-1.

4.7.1.2.2 External Oscillator Regulated Voltage (CVEXOSC)
External Oscillator Oven Voltage (CVXOVEN)

CVEXOSC indicates the regulated voltage applied to the oscillator electronics, and CVXOVEN indicates the voltage applied to the oven temperature controller. Telemetry voltages for both monitors are derived from resistive dividers as shown in Figure 4.7-2.

4.7.1.3 Transponder Temperature Monitors

Function	XPNDR A	XPNDR B
TCXO Temperature	CTXPAXO	CTXPBXO
Power Amplifier Temperature	CTXPAPA	CTXPBPA

CTXPAXO and CTXPBXO indicate the temperatures of the temperature compensated (not oven controlled) crystal oscillators in the transponders. TCXO temperature can be used to predict and verify transmitter frequency from data obtained during thermal/vacuum tests.

CTXPAPA and CTXPBPA indicate the temperatures of the transponder power amplifiers. In normal operation, these temperatures should remain within the limits in Table 4.7-2. If power amplifier temperature reaches the redline limit of 60 degrees C, the affected transmitter should be turned OFF.

Telemetry derivation for all transponder temperature functions is presented in Figure 4.7-3.

4.7.1.4 C&DH Module Structure Temperature Monitors

Five temperature sensors are located on the inner surfaces of the C&DH module to indicate module temperatures Figure 4.7-5 shows the locations of the monitors which are listed below.

CTRIUAB - module temp between RIU A and B
CTMEM03 - module temp between memory modules 0 and 3
CTXPAB - module temp between XPNDR A and B
CTA610 - module temp near heater A610 thermostat
CTA611 - module temp near heater A611 thermostat

All module temperatures are derived using the standard thermistor circuit of Figure 4.7-4.

4.7.1.5 C&DH Component Temperature Monitors

The monitors described in this section indicate the temperatures derived from sensors inside the C&DH components. All temperatures are derived using the standard thermistor circuit of Figure 4.7-4. Component locations in the C&DH module are shown in Figure 4.7-5, and the temperature monitors are listed below.

CPMPTMP - PMP temperature
CCUATMP - CU A temperature
CCUBTMP - CU B temperature
CPCUTMP - Power control unit temperature
CTRIUA - RIU 1A temperature
CTRIUB - RIU 1B temperature
CTSTNTA - STINT A temperature
CTSTNTB - STINT B temperature

4.7.1.6 Transponder RF Monitors

4.7.1.6.1 Receiver AGC Monitors

CAGCXPA - Transponder A AGC level
CAGCXPB - Transponder B AGC level

These functions indicate the received RF signal strength at the transponder receiver. Since signal strength is a function of the TDRSS or STDN forward link transmitters, no limits were defined for these functions in Table 4.7-2. The type of signal received (TDRSS or STDN) and whether the receiver is inlock with that signal are indicated by the receive mode and receiver-in-lock digital monitors of Paragraph 4.7.2.5.1.

4.7.1.6.2 Transmitter RF Power Monitors

CXPAFWD - Transponder A RF forward power
CXPAREV - Transponder A RF reflected power
CXPBFWD - Transponder B RF forward power
CXPBREV - Transponder B RF reflected power

Forward power telemetry provides an indication of the power from the transmitter RF output to the antenna.

Reflected power telemetry provides an indication of the power reflected back to the transmitter RF output from the transmission line and antenna.

4.7.2 DIGITAL TELEMETRY FUNCTIONS

The C&DH digital monitors provide command verification, subsystem status, and diagnostic information. This section presents digital telemetry descriptions using the acronyms in Table 4.7-1. Where possible, monitors are collected into functional groups for ease in understanding.

4.7.2.1 Central Unit (CU) Status Telemetry

4.7.2.1.1 CU and Oscillator Monitors

CONCUID, CCUANF, CCUBNF and COSCINX indicate the CU status resulting from the special commands CUMAF1, CUMAF2, CUSLFN and CUEXON described in Paragraph 4.6.1.1.2. They are decoded as follows:

CONCUID	0 = CU A active 1 = CU B active
CCUANF	0 = CU A OFF 1 = CU A ON
CCUBNF	0 = CU B OFF 1 = CU B ON
COSCINX	0 = External oscillator selected 1 = Internal oscillator selected

CONCUID is valid only whenone CU is on. If both are on (a forbidden state) the indication is ambiguous, and if both are off there is no telemetry data.

4.7.2.1.2 Multiplex Data Bus (MDB) Monitors

CSUPVBA and CRPLYBA indicate the MDB status resulting from the special commands SUPRAN, SUPRBN, RPLYAN and RPLYBN described in Paragraph 4.6.1.1.3. They are decoded as follows:

CSUPVBA	0 = Supervisory line A selected
	1 = Supervisory line B selected
CRPLYBA	0 = Reply line A selected
	1 = Reply line B selected

4.7.2.1.3 Hardline Telemetry Output Monitors

Each CU has a hardline telemetry output to the C&DH module connector. The outputs are not used on Landsat-D. The commands to turn the outputs on/off, however, are included in the C&DH commands (Paragraph 4.6.1.1.5) and are verified by the following monitors:

CCUAHFN	0 = CU A hardline telemetry output ON
	1 = CU A hardline telemetry output OFF
CCUBHFN	0 = CU B hardline telemetry output ON
	1 = CU B hardline telemetry output OFF

4.7.2.2 <u>CU Telemetry Data Monitors</u>

4.7.2.2.1 Telemetry Bit Rate and Data Type

CBITRAT provides verification of the commands in Paragraph 4.6.1.2.1. This monitor, which indicates the bit rate of the real time telemetry data stream from the active CU, is decoded as follows:

000 = 1 kbps
001 = 2 kbps
010 = 4 kbps
011 = 8 kbps
100 = 16 kbps
101 = 32 kbps
110 = 64 kbps
111 = 128 kbps (not used on MMS)

CRTCDMP indicates whether the data stream from the active CU consists of real time telemetry data or OBC memory dump data. Since OBC memory dump data is via the ?MP on Landsat rather than via the CU, this monitor always indicates real time telemetry data.

CRTCDMP 0 = OBC memory dump data
1 = real time telemetry data

4.7.2.2.2 Telemetry Format

CFORMAT indicates the telemetry address source selected by the commands in Paragraph 4.6.1.2.2 for use by the CU format generator. It is decoded as follows:

CFORMAT 00 = CU flex format (not available on Landsat)
01 = Engineering format (ROM 1)
10 = Mission format (ROM 2)
11 = OBC flex format

The monitors CCUAFLX and CCUBFLX are load/verify indicators for loading a flex format into programmable RAM's in each CU. Since the CU flex format is not available on Landsat, these monitors should be ignored.

4.7.2.2.3 Minor Frame Sync and Counter

CMFSYNC is a 24-bit sync pattern appearing at the start of every telemetry minor frame. Each minor frame consists of 128 8-bit words numbered 0 through 127. There are 128 minor frames, also numbered 0 through 127, in a telemetry major frame. The bit pattern of CMFSYNC appears in Table 4.7-1 in binary form and in octal and hexadecimal form below.

$$CMFSYNC = (76571440)\{8\} = (FAF320)\{16\}$$

CMFCNT is the output of a counter which starts at 0 (or 128) for minor frame zero, and increments by one for each subsequent minor frame up to 255. Since a telemetry major frame contains 128 minor frames, only the 7 LSB of CMFCNT should be used so that the telemetry output will always count 0-127 instead of 0-127, 128-255, 0-127, etc.

4.7.2.2.4 Dwell Mode Indicators

In the dwell mode, any minor frame word except the fixed words may be selected by the commands in Paragraph 4.6.1.2.3 and will appear in every telemery frame location except fixed word locations. Decoding of the monitors is as follows.

CDWLMOD 0 = not in dwell mode
1 = dwell mode

CDWLCHN = channel selected for dwell

4.7.2.2.5 Spacecraft Clock Monitor

The spacecraft clock telemetry monitor is a 24-bit word which is the output of a 1.024 second counter controlled in such a manner that each 1.024 second increment is coincident with the start of a telemetry minor frame. Thus, regardless of telemetry bit rate, the monitor always displays the time at the start of the minor frame in which a 1-bit change occurred. The counter is set to zero when the CU is in standby.

Using 24 bits with a 1.024 second update, the maximum count is approximately 200 days. Decoding of the three 8-bit words comprising the spacecraft clock is as shown below:

Function	Bits 0 to 7	Elapsed Time
CCLKLSB	00000000	0
	00000001	1.024 seconds
	11111111	262.12 sec (4.352 min)
CCLKISB	00000000	0
	00000001	4.369 min (.0728 hr)
	11111111	18.568 hrs
CCLKMSB	00000000	0
	00000001	18.641 hrs
	11111111	4753.5 hrs (198.1 days)

4.7.2.3 CU Command Signal Monitors

Both transponder receivers are continuously operational and provide forward link signals to redundant command decoder channels in the active CU for command processing (receiver A to decoder channel A, and B to B). CCHAREJ indicates whether the channel A decoder in the active CU has rejected a command from transponder receiver A. A valid command may still be obtained from decoder channel B. The channel B command decoder has no command reject telemetry in the data stream. Decoding is shown below:

CCHAREJ 1 = command rejected by channel A
0 = command not rejected

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CCMDCNT increments by one whenever a command is accepted by the active CU. The monitor counts to a maximum of 255.

CSCMDCT increments by one whenever a special command is accepted by the standby CU rather than the active CU. This monitor also counts to a maximum of 255.

Each CU has a separate monitor indicating whether that CU has rejected or accepted a command. The monitors CCUAREJ (CU A) and CCUBREJ (CU B) are decoded identically as shown below:

0 = command accepted by CU
1 = command rejected by CU

4.7.2.4 PMP Status Telemetry

PMP A telemetry monitors are decoded in the same manner as PMP B telemetry monitors. In the following paragraphs, acronyms for PMP B functions which are identical to PMP A functions are enclosed in parentheses. Example: PMP A (PMP B).

4.7.2.4.1 PMP Power Monitors

CPMPANF (CPMPBNF) indicates the on/off status of PMP A(B) resulting from the commands described in Paragraph 4.6.1.3.1. Decoding is shown below:

0 = PMP A(B) off
1 = PMP A(B) on

4.7.2.4.2 PMP Input Monitors

The following monitors provide verification of the commands for input data selection in Paragraph 4.6.1.3.2.

CPACUBA (CPBCUBA) indicates which CU has been selected as the real time telemetry data source.

0 = CU A selected
1 = CU B selected

CPASTBA (CPBSTBA) indicates which OBC/STINT has been selected as the OBC memory dump source.

0 = STINT A selected
1 = STINT B selected

CPAN1MX (CPBN2MX) and CPAMXAB (CPBMXAB) indicate whether NBTR 1(2) playback data or payload correction data (PCD) has been selected as a PMP A(B) data input. The monitors are decoded as shown below.

CPAN1MX (CPBN2MX)	CPAMXAB (CPBMXAB)	Input selected
0	0	PCD from formatter A
0	1	PCD from formatter B
1	0	NBTR 1(2) playback data
1	1	NBTR 1(2) playback data

CPARTTR (CPBRTTR) indicates whether PMP A(B) is configured to route real time telemetry data to the record amplifier of NBTR 1(2). PMP A is dedicated to NBTR 1 and PMP B to NBTR 2.

00 = Real time telemetry to NBTR 1(2) OFF
01 = Not used
10 = Real time telemetry to NBTR 1(2) ON
11 = Not used

4.7.2.4.3 PMP-Transponder Configuration

The normal PMP to transponder configuration is PMP A to transponder A and PMP B to transponder B. The reverse (cross-strap) configuration is PMP A to transponder B and PMP B to transponder A. A single monitor, CPABXP, is used to determine the configuration.

CPABXP 0 = Normal (A to A, B to B)
1 = Reverse (A to B, B to A)

4.7.2.4.4 Convolutional Encoder Monitors

Each PMP provides two outputs, identified as I and Q-channels, to the TDRSS transmitter inputs of the transponders. The I-channel always outputs real time telemetry data. The Q-channel outputs PCD, NBTR playback data, or OBC memory dump data depending upon which input has been selected (reference Paragraph 4.7.2.4.2). CPARTENC (CPBRTENC) and CPASTENC (CPBSTENC) indicate, respectively, whether the I and Q-channel outputs are convolutionally encoded in response to the commands of Paragraph 4.6.1.3.5. All are decoded in the same manner.

0 = Convolutional encoder OFF (out)
1 = Convolutional encoder ON (in)

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4.7.2.4.5 PMP Output Monitors

CPAMODE (CPBMODE) indicates the PMP outputs selected by the commands of Paragraph 4.6.1.3.3 for return link data transmission via the transponders. Decoding is as shown below:

0000 = Mode select outputs OFF
1000 = Mode A - real time telemetry (TLM) to STDN
0100 = Mode B - real time TLM & OBC dump to STDN
1100 = Mode C - real time TLM & NBTR or PCD to STDN
0010 = Mode D - real time TLM and external data to STDN
1010 = Mode E - external data to STDN
0110 = Mode F - real time TLM to TDRSS
1110 = Mode G - real time TLM & OBC dump to TDRSS
0001 = Mode H - real time TLM & NBTR or PCD to TDRSS
1001 = Mode I - real time TLM and external data to TDRSS

CPAHDLN (CPBHDLN) indicates PMP hardline output data modes selected by the commands of Paragraph 4.6.1.3.4. Decoding is as shown below:

00 = Hardline outputs OFF
01 = OBC memory dump data to hardline
10 = Real time telemetry data to hardline
11 = PCD or NBTR playback data to hardline

4.7.2.5 Transponder Status Telemetry

Transponder A telemetry monitors are decoded in the same manner as transponder B telemetry monitors. In the following paragraphs, acronyms for transponder B functions which are identical to transponder A functions are enclosed in parentheses.

4.7.2.5.1 Transponder Receiver Monitors

CXPARAS indicates the transponder A receiver acquisition state (RAS). Transponder B has no RAS telemetry in the data stream.

0000 = Not used
0001 = Start code and CW search
0010 = Side lobe search no. 1
0011 = PN loop acquisition
0100 = Carrier loop acquisition
0101 = Side lobe search no. 2
0110 = Long code search
0111 = Multipath search
1000 = TDRSS tracking mode

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1001 = Not used
1010 = Not used
1011 = STDN mode acquisition
1100 = STDN tracking mode

CXPASTD (CXPBSTD) indicates the receive mode in which the transponder has been placed by the mode commands of 4.6.1.4.1.

0 = Dual (STDN and TDRSS) receive mode commanded
1 = STDN only receive mode commanded

CXPARMD (CXPBRMD) indicates the receive mode of the transponder resulting from an uplink signal. In the dual mode above, the receive mode will be either TDRSS or STDN depending upon which signal is first detected. In the STDN only mode, the receive mode can only be STDN.

0 = STDN receive mode
1 = TDRSS receive mode

CXPARLK (CXPBRLK) indicates whether the transponder is in lock with a STDN or TDRSS uplink signal, or neither. If in lock, the receive mode monitors above will indicate which type signal.

0 = Receiver in lock
1 = Receiver not in lock

CXPACLK (CXPBCLK) indicates whether the command detector in the receiver is in lock. A receiver in lock and a detector in lock signal must both be present before the CU will process command signals from the receiver.

0 = Receiver command detector in lock
1 = Receiver command detector not in lock

CXPADET (CXPBDET) indicates the bit rate selected for the transponder command detector in the TDRSS receive mode. The commands for selection are described in Paragraph 4.6.1.4.1. In the STDN receive mode, the command signal bitrate is 2 kbps and is not selectable by command.

0 = 125 bps (low) TDRSS command rate
1 = 1 kbps (medium) TDRSS command rate

CXPAMPTH (CXPBMPTH) indicates whether a multipath is present when the transponder is in the TDRSS receive mode. Multipaths are possible, especially when the line of sight between TDRSS and Landsat is near the earth horizon.

0 = No multipath
1 = Multipath

4.7.2.5.2 Ranging and Oscillator Command Monitors

CXPARNG (CXPBRNG) provides verification for the STDN ranging enable/disable commands in Paragraph 4.6.1.4.2.

0 = STDN ranging OFF (disabled)
1 = STDN ranging ON (enabled)

CXPAOSC (CXPBOSC) provides verification for the automatic oscillator inhibit/allow commands in Paragraph 4.6.1.4.3.

0 = Auto transfer from TCXO to VCO enabled (allowed)
1 = Auto transfer from TCXO to VCO disabled (inhibited)

4.7.2.5.3 PN Code Monitors

The I and Q-channel signals from the PMP (reference Paragraph 4.7.2.4.4) may or may not be PSK modulated within the transponder with a PN code. Verification of PN code control commands (Paragraph 4.6.1.4.5) is obtained from the monitors CXPANI (CXPBPNI) and CXPAPNQ (CXPBPNQ). All are decoded in the same manner.

0 = PN code (I or Q-channel) ON
1 = PN code (I or Q-channel) OFF

4.7.2.5.4 Transmitter Status Monitors

CXMTAED (CXMTBED) indicates the status of enable/disable relays in series with the transmitter primary power input lines. In normal usage the relays remain in the enable position and transmitter power on/off is controlled by the commands in Paragraph 4.6.1.4.4.

0 = Transmitter primary power disabled
1 = Transmitter primary power enabled

CXMTANF (CXMTBNF) indicates the on/off status of the transmitter.

0 = Transmitter OFF
1 = Transmitter ON

CAUTXMA (CAUTXMB) indicates whether the transmitter automatic turn-on feature is allowed. If allowed, the transmitter will turn itself on when the transponder receiver detects a STDN or TDRSS uplink signal, at which time CXMTANF (CXMTBNF) will become a logic "1". There is no automatic turn-off feature. The transmitter must be commanded off from any on mode.

0 = Transmitter auto-on disabled (inhibited)
1 = Transmitter auto-on enabled (allowed)

CXPAXMT (CXPBXMT) indicates whether the STDN or TDRSS transmit mode has been selected by command.

0 = TDRSS transmit mode
1 = STDN transmit mode

CXPAMOD (CXPBMOD) indicates whether a high or low modulation index has been selected for a transmitter. In normal operation, low modulation index will be used only in PMP mode A - real time telemetry to STDN.

0 = Low modulation index
1 = High modulation index

4.7.2.6 RF Switch Telemetry

The telemetry monitors in this section provide verification for the commands of Paragraph 4.6.1.5.

C28VRFS indicates which 28 volt bus has been selected for use during RF switch configuration commands.

C28VRFS 0 = 28V bus A for RF switch
1 = 28V bus B for RF switch

CRFSWC provides verification of the RF switch configuration commands. The RF switches are used in the transponder transmit signal paths to route the transmitter outputs to omni or high gain antennas. Decoding is as shown below:

CRFSWC	Configuration	XMTR A	XMTR B
00	Not used	--	--
01	2	Hi gain	Omni
10	1	Omni	Hi gain
11	3	Omni	Omni

4.7.2.7 OBC Discrete Command Telemetry

The telemetry monitors in this paragraph provide verification of discrete commands addressed to the OBC via the C&DH RIU (Section 4.6.1.6). Commands routed directly to the OBC (not through the RIU) are described in Section 6.0 of this document.

CSTOBCA (CSTOBCB) indicates the status of the STINT-OBC power supplies resulting from the commands of Paragraph 4.6.1.6.1.

0 = STINT, NSSC A(B) OFF
1 = STINT, NSSC A(B) ON

CCFDAED (CCFDBED) indicates the status of the OBC failure detection circuits resulting from the commands of Paragraph 4.6.1.6.3.

0 = Computer failure detector A(B) disabled
1 = Computer failure detector A(B) enabled

CPWRM02 indicates which STINT-OBC power supply has been selected for memories 0, 2, 4 and 6. CPWRM13 indicates which power supply has been selected for memories 1, 3, 5 and 7. Both monitors are decoded in the same manner.

0 = Power supply A selected
1 = Power supply B selected

CMEM0ED, CMEM1ED, CMEM2ED and CMEM3ED indicate, respectively, the enable/disable status of memory pairs 0 and 4, 1 and 5, 2 and 6, 3 and 7. All are decoded in the same manner.

0 = Memory pair X disabled
1 = Memory pair X enabled

4.7.2.8 OBC Memory Dump Monitors

CCUADMP (CCUBDMP) indicates the bit rate selected by the CU special commands of Paragraph 4.6.1.1.5 for an OBC memory dump.

0 = 1 kbps dump rate
1 = 32 kbps dump rate

CADMPHS (CBDMPHS) indicates the type of dump from OBC A(B) which has been requested by computer commands.

00 = Software dump
01 = Hardware dump
10 = Not used
11 = No dump

CADMPID (CBDMPID) indicates which memory bank via OBC A(B) has been selected for dump. There are eight memories identified 0 through 7. Each memory has two banks with 0 and 1 in memory 0, banks 2 and 3 in memory 1, etc. Decoding of memory bank dump identification telemetry is shown below.

0000 = Memory bank 15
0001 = Memory bank 14
0010 = Memory bank 13
0011 = Memory bank 12
0100 = Memory bank 11
0101 = Memory bank 10
0110 = Memory bank 9
0111 = Memory bank 8
1000 = Memory bank 7
1001 = Memory bank 6
1010 = Memory bank 5
1011 = Memory bank 4
1100 = Memory bank 3
1101 = Memory bank 2
1110 = Memory bank 1
1111 = Memory bank 0

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4.7.2.9 RIU Status Monitors

CRIUSBA and CMATENF indicate RIU 1A and 1B status resulting from the commands of Paragraph 4.6.1.7.

CRIUSBA	CMATENF	RIU 1A/1B STATUS
0	0	A ON, B OFF
0	1	A ON, B standby 1
1	0	B ON, A OFF
1	1	B ON, A standby 1

4.7.2.10 Heater Status Monitors

CHTR1ED and CHTR2ED provide command verification for the prime and redundant heater enable/disable commands of Paragraph 4.6.1.8. Both monitors are decoded in the same manner.

0 = Heater 1(2) disabled
1 = Heater 1(2) enabled

4.7.3 TELEMETRY DERIVATION SCHEMATICS

Figures 4.7-1 through 4.7-4 depict functional schematics showing the derivation of the telemetry functions. These figures should aid in understanding the telemetry interface. Note that the functional schematics are provided as information only and are superseded by the exact circuits defined on C&DH drawings.

4.7.4 COMPONENT LOCATIONS

Figure 4.7-5 shows the location of components in the C&DH Module.

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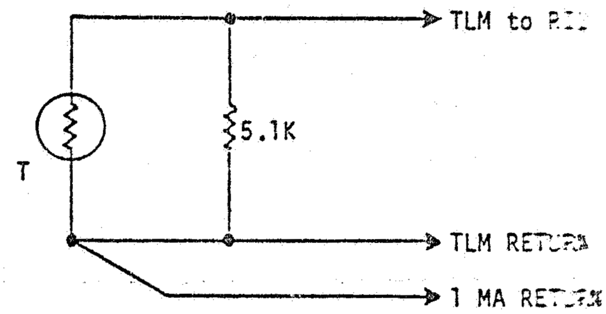
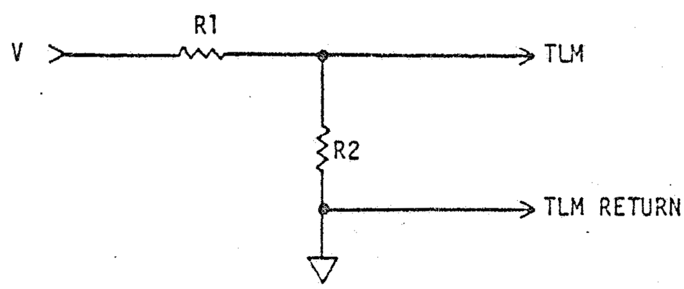


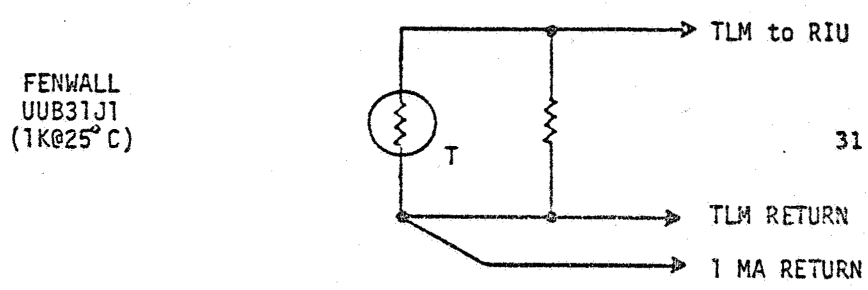
TLM	T
CTEXOSC	S - 311 - P18 - 01
CTXOVEN	S - 311 - P18 - 07

Figure 4.7-1. External Oscillator Temp Monitors



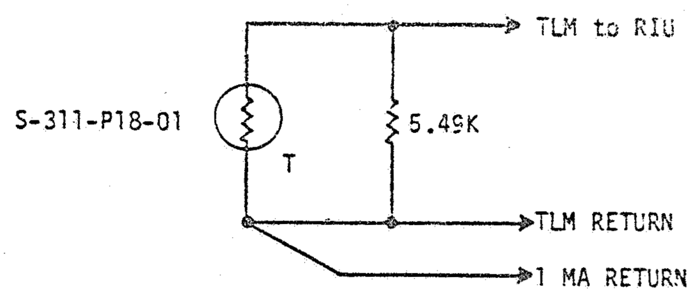
TLM	V	R1	R2
CVEXOSC	11.6	8.45K	4.99K
CVXOVEN	17	12.1K	4.99K

Figure 4.7-2. External Oscillator Voltage Monitors



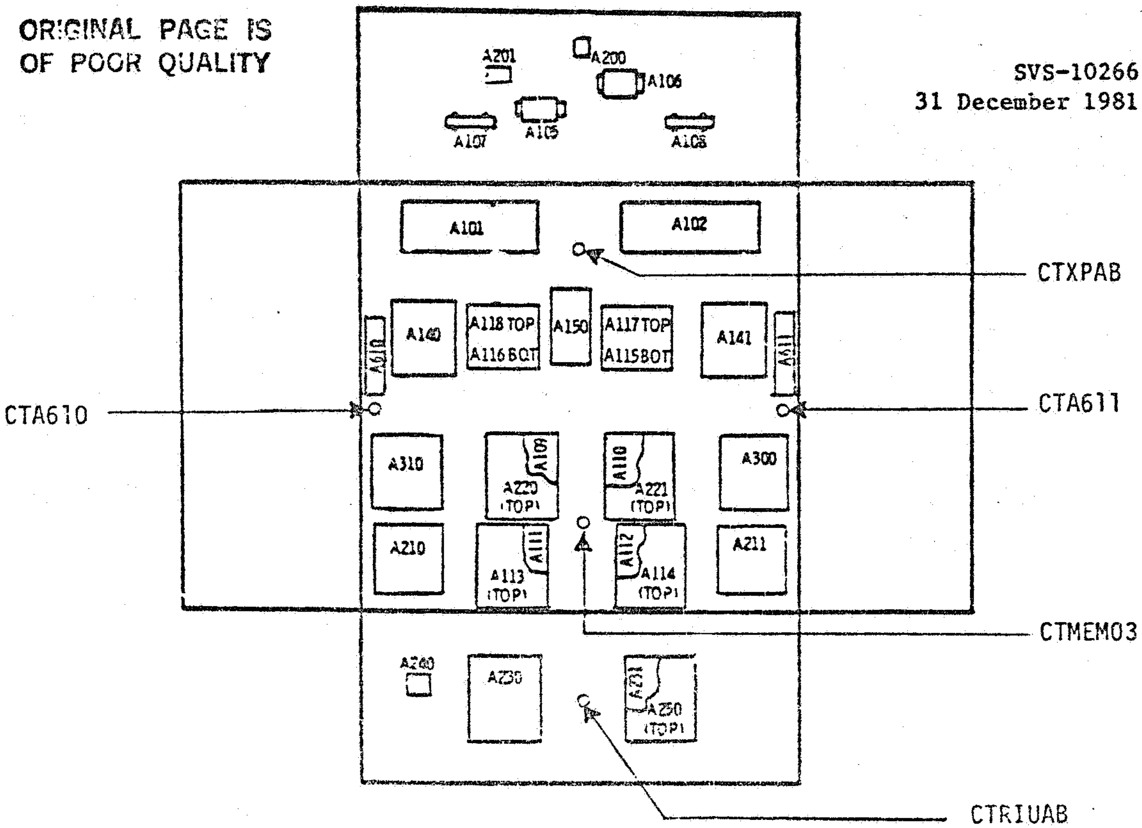
TLM: CTXPAXO
CTXPBXO
CTXPAPA
CTXPBPA

Figure 4.7-3. Transponder Temp Monitors



TLM: CPMPTMP	CTSTNTA	CPCUTMP
CCUATMP	CTSTNTB	CTRIUAB
CCUBTMP	CTXPAB	CTMEM03
CTRIUA	CTA610	
CTRIUB	CTA611	

Figure 4.7-4. Standard Thermistor Circuit



LEGEND

A101	TDRSS Transponder A	A200	RF Switch 1
A102	TDRSS Transponder B	A201	RF Switch 2
A105	Diplexer A	A210	Control Unit A (CU)
A106	Diplexer B	A211	Control Unit B (CU)
A107	Band Reject Filter A	A220	Standard Interface for Computer A (STINT)
A108	Band Reject Filter B	A221	Standard Interface for Computer B (STINT)
A109	Central Processor Module A (CPM)	A230	Remote Interface Unit A (RIU)
A110	Central Processor Module B (CPM)	A231	Remote Interface Unit B (RIU)
A111	Memory Module 1	A240	Bus Coupling Unit BCU A & B
A112	Memory Module 0	A250	Expander Unit EU A & B
A113	Memory Module 3	A300	Power Control Unit A (PCU)
A114	Memory Module 2	A300	Power Control Unit B (PCU)
A115	Memory Module 5 (MU)	A310	Pre-Modulator Processor PMP A & B
A116	Memory Module 4 (MU)	A150	External Occillator
A140	NASA Standard Tape Recorder A (NSTR)	A117	Memory Module 7 (MU)
A141	NASA Standard Tape Recorder B (NSTR)	A118	Memory Module 6 (MU)

Figure 4.7-5. Component Location Diagram

5.0 NARROWBAND TAPE RECORDER

SECTION 5.0

NARROWBAND TAPE RECORDERS

The Landsat-D spacecraft has two identical narrowband tape recorders designated NBTR1 and NBTR2. Each recorder can record or playback data, but not both simultaneously. Each recorder has a minimum capacity of 238 minutes of recording. Playback time, based on this minimum capacity, will be 14.9 or 7.45 minutes depending on tape speed. A playback will be shorter if less than a full tape has been recorded. A winding capability allows tape to be moved in the forward or reverse direction at a high speed without erasure of previously recorded data. In this mode the tape can be moved end to end in 3.7 minutes. Each recorder is comprised of a Transport Unit (TU) and an Electronics Unit (EU). Each recorder contains a minimum of 500 feet of useful tape. Primary, secondary and tertiary sensors stop the recorder when they sense either beginning of tape (BOT) and end of tape (EOT). When in the record mode, they stop the recorder when they sense EOT and in the playback mode when they sense BOT.

Note that the above values are based on the minimum tape capacity; it is expected that the actual capacity will be somewhat greater than 238 minutes.

5.1 NBTR FUNCTIONAL DESCRIPTION

The Landsat-D tape recorder is a slightly modified version of the 10^8 bit GSFC standard tape recorder, a block diagram of which is shown in Figure 5.1-1.

Digital data recording is accomplished by demultiplexing the input data onto 2 channels that are recorded in parallel and 4 times redundantly (groups A through D) on the magnetic tape as shown in Figure 5.1-2. Upon playback, one of the 4 pairs (selected by command) of redundant signal channels is deskewed and dejittered and finally combined into a single output.

During recording, the tape speed is controlled by the externally supplied data input clock. During playback, the timing reference is derived from a crystal oscillator located within the recorder. Tape motion is achieved by using a brushless DC motor whose speed is controlled by a tachometer sensor. During recording this sensor compares motor speed with the external data timing reference. During playback, the tachometer sensor is replaced by the off-tape playback signal which is compared to the internal crystal oscillator.

The recorder is provided with a multiplexed (binary logic) command system. As such, it does not have any memory during periods when the recorder is turned off. Thus, a full set of commands is generally required to establish the desired recorder operating mode. The commands are stored while the recorder is in the standby mode.

Power ON/Power OFF and the EU/TU interchange is effected by the use of latching relays.

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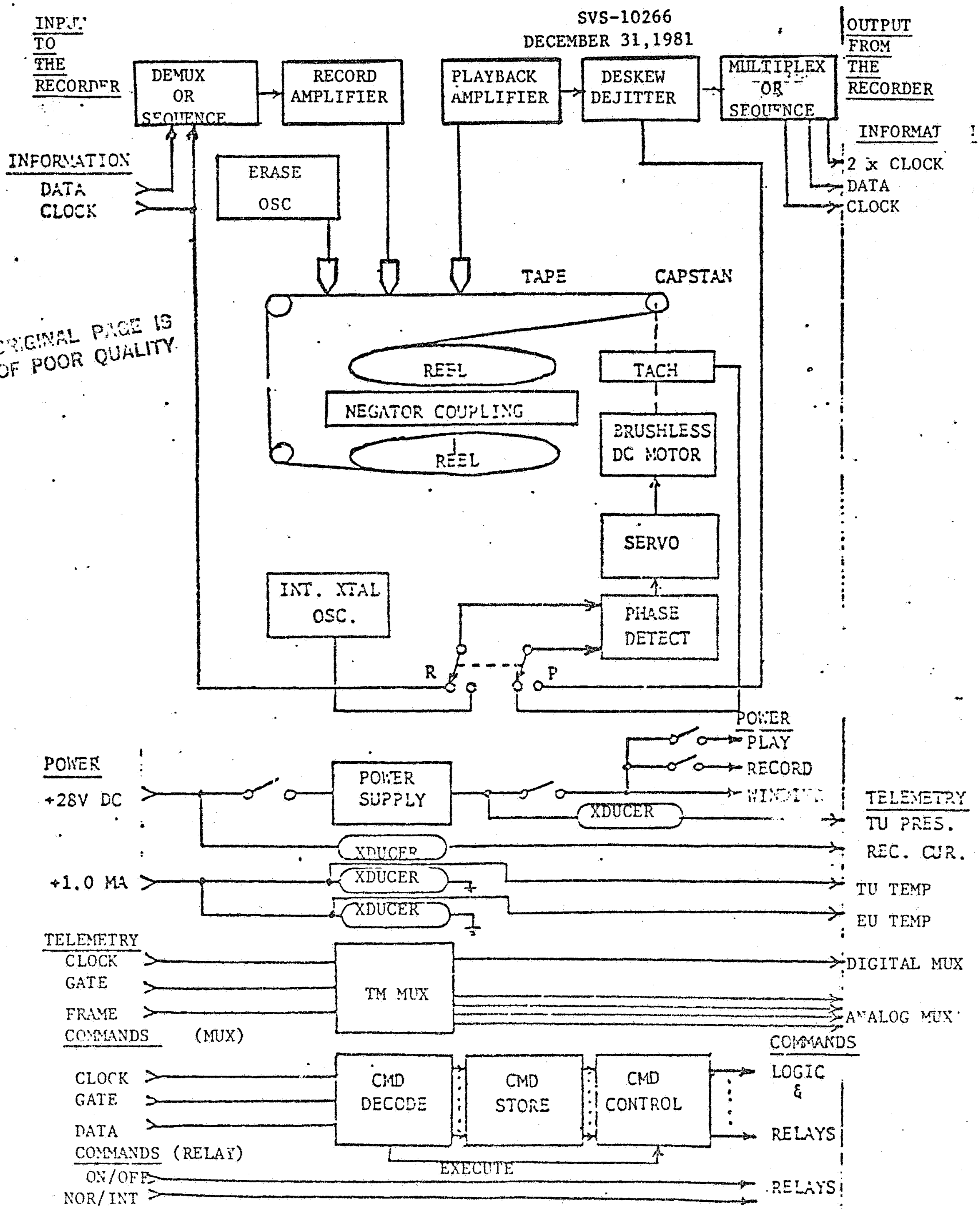

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Figure 5.1-1. Narrowband Tape Recorder (NBTR) Functional Block Diagram

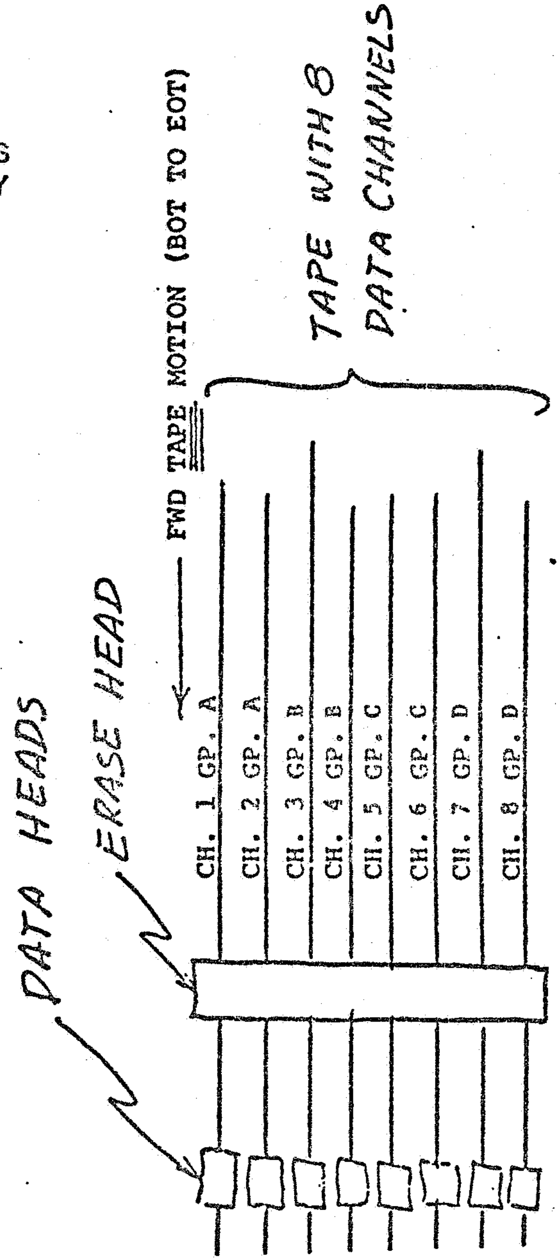

Figure 5.1-2. NBTR 8 Data Channel Designation

The commanded operating mode, the actual operating mode, and various other vital recorder functions and conditions are monitored by a telemetry system. The majority of these signals are made available to the spacecraft in multiplexed format, their timing being controlled by externally generated signals. Temperature, pressure and total recorder current are available in a non-multiplexed format.

Each tape recorder is dedicated to a PMP. Tape recorder 1 and tape recorder 2 are dedicated to PMP-A and B respectively. The signals to the tape recorder consist of NRZ-L data, plus a 1X clock. Tape recorder playback provides an NRZ-L serial data stream, a 1X clock and a 2X clock signal. Tape recorder A&B record and playback functions are obtained from PMP-A and PMRB respectively. When in the record mode, the tape recorder receives data and a 1X clock signals from differential drivers in the associated PMP. The data consists of the serial R/T telemetry bit stream from the selected CU. The NRZ-L data rate can range from 1 Kbps to 64 Kbps depending upon CU mode. A data rate of 8 Kbps is anticipated. Playback NRZ-L serial data rate for Landsat-D is expected to be 128 Kbps to TDRS and 256 Kbps to GSTDN.

Primary end of tape protection is provided by reading the footage counter telemetry and generating beginning of tape (BOT) signal on a low count detector, and end of tape (EOT) signal on a high count detector. The footage indicator telemetry is derived from a counter reading the outside code pattern of a code wheel mounted on the capstan tape drive shaft. The counter begins after a reset pulse and counts until one revolution of the takeup reel is completed. The counter value is transferred to the telemetry just prior to reset and continuation of the next count cycle.

Secondary end of tape protection is provided by optical detection with a LED through a window near the beginning and end of tape.

A tertiary end of the tape protection is provided by a mechanical mechanism which trips a micro switch and brakes the tape reel to a stop when the buildup of tape on a reel exceeds a predetermined limit. The mechanism is on both wheels and provides BOT protection on one reel and EOT protection on the other reel.

5.2 NBTR PERFORMANCE CAPABILITIES

The NBTR performance characteristics are summarized in Table 5.2-1.

Table 5.2-1. NBTR Capability Summary

Function	Capability	Landsat-D Implementation
Select Tape Speed	21 Commandable tape speeds	3 tape speeds used 13.386 IPS 6.693 IPS 0.418 IPS
Tape Direction Control	FWD & REV	Same
Motor Encoder LED Selection	PRI & SEC	Same
Tape Erase	ON/OFF	Automatically selected by record/play control
Tape Track Selection	4 pair selection 2 groups of 4 tracks	4 pair selection only
Mode Selection	STOP/RECORD/PLAY/WIND	Same
Channel Muliplexing	4 channel parallel 8 channel parallel	8 channel only
Timing Reference	External & Internal Crystal	External - RECORD Internal - PLAYBACK and WIND

5.3 NBTR OPERATING MODES

The basic NBTR operating mode selections and the resultant operations are summarized in Table 5.3-1.

Table 5.3-1. NBTR Operating Modes

MODE	SPEED	RATE	FULL TAPE TIME
Record	0.42 ips (Record runs from BOT to EOT)	8 Kbps	>238 min.
Playback 16/1	6.7 ips (Playback runs EOT to BOT)	128 Kbps	>14.9 min.
Playback 32/1	13.4 ips (Playback runs EOT to BOT)	256 Kbps	>7.45 min.
Wind	>33 ips (Commandable Either Direction)		>3.1 min.
Erase	(Automatically ON during RECORD) (Automatically OFF during PLAYBACK)		
Stop (Standby)	(Tape motion halted, not confused with OFF)		
Group (A,B,C,D)	(Selects pair of channels for playback)		
Clock (Ext,Int)	(Selects data clock (Ext.) or Internal Oscillator for speed timing reference)*		
Encoder	(Primary or Secondary)		

*Not commandable in Landsat-D operations.

As a result of these modes, and also the power off mode, there are 20 NBTR operational mode transitions which are shown in Figure 5.3-1 and further discussed in Paragraph 5.3.5.

5.3.1 NBTR POWER UP

After the application of power and in the absence of any specific command, the recorder will be in the following configuration:

Stop Execute
Erase Off
Fwd Direction
Primary Encoder (Note 1)
Group A

NOTE 1: In the event the primary encoder (motor LED's) have failed, it will be necessary to send a serial magnitude command (3970_{16}) to select the secondary encoders each time the NBTR is powered up.

No specific tape speed is selected, thus any value may appear. The tape will remain stationary.

5.3.2 NBTR RECORD MODE

Recording will be only accomplished in beginning of Tape (BOT) to End of Tape (EOT) Direction. Commands are sent to configure the recorder for recording. The 8 Kbps serial telemetry will be serial to parallel converted and recorded on two channels four times redundantly filling all eight tracks. During recording the tape speed is controlled by the externally supplied data input clock. For Landsat-D intermittent recordings will be made. Under these conditions each now execute command will cause the recorder to continue the recording process from its stopped location. If the recorder is commanded to standby or PWR OFF or if there is a power loss, then a full set of commands will be necessary to establish the desired operating mode. The RECORD mode automatically invokes the Erase On state.

5.3.3 NBTR PLAYBACK MODE

Playback will be in the End of Tape to Beginning of Tape direction. Playback speed can be commanded from two speeds, 6.693 ips for 128 Kbps or 13.386 ips for 256 Kbps playback. The group command selects the pair of channels to be played back (group A,B,C,D). The ERASE function is automatically OFF and tape speed is controlled by comparison of off tape signal to an internal crystal oscillator. Primary, secondary or tertiary BOT sensors stop tape motion at the end of the tape. The two channels selected for playback are deskewed and dejittered and combined into a single output. The data output from the tape recorder during playback is reversed in time; i.e. data recorded 110 will be played back as 011. A 1X clock (128 KHz or 256 KHz) and a 2X clock (256 KHZ or 512 KHZ) signal will also be provided as output to the PMP. The PLAYBACK mode automatically invokes the Erase Off state.

5.3.4 NBTR WIND MODE

The tape can be moved in BOT to EOT or EOT to BOT direction at a rate of 33 ips by command. The EXECUTE STOP command will halt tape transport at any point.

5.3.5 NBTR OPERATIONAL MODE TRANSITIONS

Figure 5.3-1 depicts the 20 transitions between the operating modes which are available for the NBTR. The transitions are achieved through the use of various combinations of Serial Magnitude (SM) and Discrete Commands (DC). Table 5.3-1 provides the sequence of commands necessary to achieve the transition desired. Selection of the desired NBTR is accomplished by selecting the appropriate RIU-1 channel through the use of discrete commands or addressing channels 75 (for NBTR 1) or 76 (for NBTR-2) for the SM commands. The sequence of commands shown in Table 5.3-2 also shows the data portion of the SM commands, in hexadecimal, and the discrete commands in decimal values.

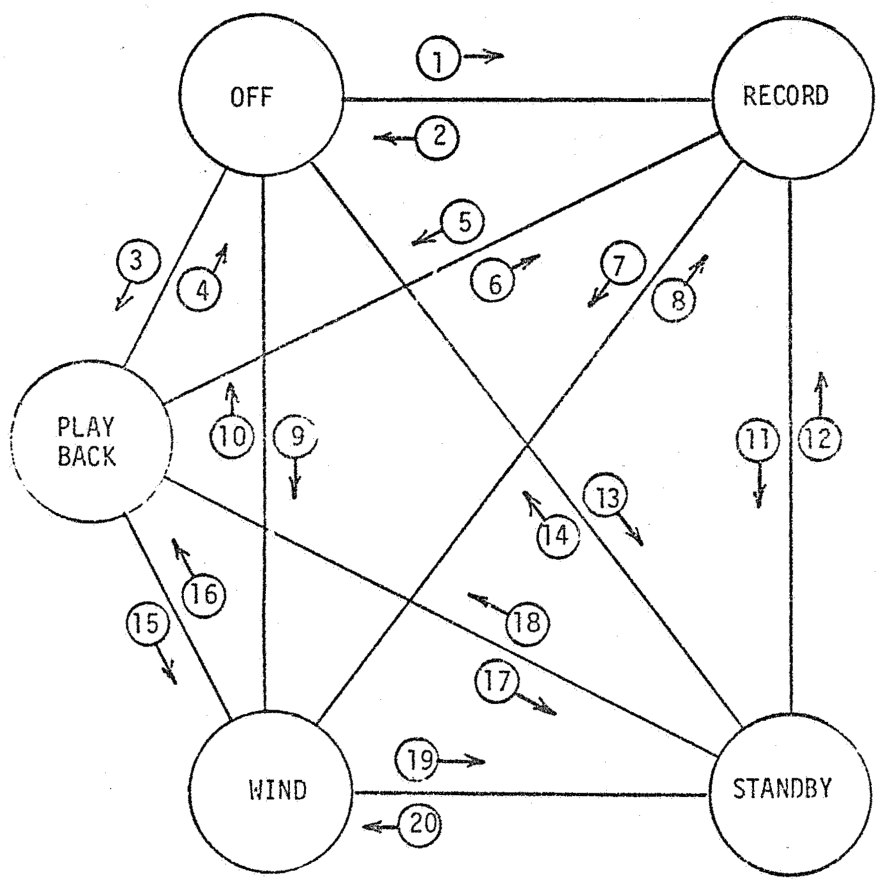

FIGURE 5.3-1 NBTR MODE TRANSITIONS

TABLE 5.3-2 MODE TRANSITION SEQUENCES

TRANSITION	COMMAND FUNCTION	SM CMD 0175 (NBTR1) / 0176 (NBTR2) PLUS	DC NBTR1/NBTR2	COMMENTS
(1) OFF to RECORD	POWER ON	--	0160/0159	AUTOMATIC:
	FWD SPEED 0.418	2E70	--	- ERASE ON
	RECORD EXECUTE	5370	--	- EXTERNAL CLOCK
				- 2 TRK MUX
				• CONTINUES UNTIL EOT OR MODE CHANGE
(2) RECORD to OFF	POWER OFF	--	0162/0161	
(3) OFF to PLAYBACK	POWER ON	--	0160/0159	• CONTINUES UNTIL BOT OR MODE CHANGE
	DIRECTION REVERSE	3170	--	
	SPEED 13.386 (GSTDN)	2970	--	SELECT ONE
	SPEED 6.693 (TDRS)	2A70	--	
	GROUP A (TRK 1 & 2)	4870	--	SELECT ONE
	GROUP B (TRK 3 & 4)	4970	--	
	GROUP C (TRK 5 & 6)	4A70	--	
	GROUP D (TRK 7 & 8)	4B70	--	
	PLAYBACK EXECUTE	5470	--	
(4) PLAYBACK to OFF	POWER OFF	--	0162/0161	
(5) RECORD to PLAYBACK	DIRECTION REVERSE	3170	--	• CONTINUES UNTIL BOT OR MODE CHANGE
	SPEED 6.693 (TDRS)	2A70	--	SELECT ONE
	SPEED 13.386 (GSTDN)	2970	--	
	GROUP A (TRK 1 & 2)	4870	--	SELECT ONE
	GROUP B (TRK 3 & 4)	4970	--	
	GROUP C (TRK 5 & 6)	4A70	--	
	GROUP D (TRK 7 & 8)	4B70	--	
	PLAYBACK EXECUTE	5470	--	

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TABLE 5.3-2 MODE TRANSITION SEQUENCES - cont'd

TRANSITION	COMMAND FUNCTION	SM CMD 0175 (NBTR1) 0176 (NBTR2) PLUS	DC NBTR1/NBTR2	COMMENTS
(6) PLAYBACK to RECORD	DIRECTION FORWARD SPEED 0.418 RECORD EXECUTE	3070 2E70 5370	-- -- --	• CONTINUES UNTIL EOT OR MODE CHANGE
(7) RECORD to WIND	DIRECTION FORWARD DIRECTION REVERSE WIND EXECUTE	3070 3170 5570	-- -- --	SELECT ONE SPEED SET AT 33 ips • CONTINUES UNTIL EOT/BOT OR MODE CHANGE
(8) WIND to RECORD	DIRECTION FORWARD SPEED 0.418 ips RECORD EXECUTE	3070 2E70 5370	-- -- --	• CONTINUES UNTIL EOT OR MODE CHANGE
(9) OFF to WIND	POWER ON DIRECTION FORWARD DIRECTION REVERSE WIND EXECUTE	-- 3070 3170 5570	0160/0159 -- -- --	• CONTINUES UNTIL EOT/BOT OR MODE CHANGE SELECT ONE SPEED SET AT 33 ips
(10) WIND to OFF	POWER OFF	--	0162/0161	
(11) RECORD to STANDBY	STOP EXECUTE	5070	--	
(12) STANDBY to RECORD	DIRECTION FORWARD SPEED 0.418 ips RECORD EXECUTE	3070 2E70 5370	-- -- --	• CONTINUES UNTIL EOT OR MODE CHANGE

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TABLE 5.3-2 MODE TRANSITION SEQUENCES - cont'd

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TRANSITION	COMMAND FUNCTION	SM CMD 0175 (NBTR1) 0176 (NBTR2) PLUS	DC NBTR1/NBTR2	COMMENTS
(13) OFF to STANDBY	POWER ON	--	0160/0159	
	DIRECTION FORWARD	3070	--	SELECT ONE
	DIRECTION REVERSE	3170	--	
	SPEED 0.418 ips	2E70	--	SELECT ONE
	SPEED 6.693 ips	2A70	--	
	SPEED 13.386 ips	2970	--	
	GROUP A (TRK 1 & 2)	4870	--	SELECT ONE
	GROUP B (TRK 3 & 4)	4970	--	
	GROUP C (TRK 5 & 6)	4A70	--	
	GROUP D (TRK 7 & 8)	4B70	--	
	STOP EXECUTE	5070	--	
(14) STANDBY to OFF	POWER OFF	--	0162/0161	
(15) PLAYBACK to WIND	DIRECTION FORWARD	3070	--	SELECT ONE
	DIRECTION REVERSE	3170	--	
	WIND EXECUTE	5570	--	• CONTINUES UNTIL BOT/EOT OR MODE CHANGE
(16) WIND to PLAYBACK	DIRECTION REVERSE	3170	--	• CONTINUES UNTIL BOT OR MODE CHANGE
	SPEED 6.693 (TDRS)	2A70	--	SELECT ONE
	SPEED 13.386 (GSTDN)	2970	--	
	GROUP A (TRK 1 & 2)	4870	--	SELECT ONE
	GROUP B (TRK 3 & 4)	4970	--	
	GROUP C (TRK 5 & 6)	4A70	--	
	GROUP D (TRK 7 & 8)	4B70	--	
	PLAY EXECUTE	5470	--	
(17) PLAYBACK to STANDBY	STOP EXECUTE	5070	--	

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TABLE 5.3-2 MODE TRANSITION SEQUENCES - cont'd

TRANSITION	COMMAND FUNCTION	SM CMD 0175 (NBTR1) / 0176 (NBTR2) PLUS	DC NBTR1/NBTR2	COMMENTS
18 STANDBY to PLAYBACK	DIRECTION REVERSE	3170	--	• CONTINUES UNTIL BOT OR MODE CHANGE
	SPEED 6.693 (TDRS)	2A70	--	SELECT ONE
	SPEED 13.386 (GSTDN)	2970	--	
	GROUP A (TRK 1 & 2)	4870	--	SELECT ONE
	GROUP B (TRK 3 & 4)	4970	--	
	GROUP C (TRK 5 & 6)	4A70	--	
	GROUP D (TRK 7 & 8)	4B70	--	
	PLAY EXECUTE	5470	--	
19 WIND to STANDBY	STOP EXECUTE	5070	--	
20 STANDBY to WIND	DIRECTION FORWARD	3070	--	SELECT ONE
	DIRECTION REVERSE	3170	--	
	WIND EXECUTE	5570	--	SPEED SET AT 33 ips • CONTINUES UNTIL EOT/BOT OR MODE CHANGE

To illustrate the command sequences shown in Table 5.3-2, transition 1, going from Off to Record, uses both discrete and SM commands. Initially discrete command 0160 would be sent to RIU 01, channel 60, for NBTR 1 Power On. If NBTR 2 were desired, a DC 0159 would be sent to RIU 01, channel 59. The actual command format for these commands is described in the Data Format control Book, Volume III, Command. In order to command a forward speed of 0.418 ips, it would then be necessary to send a SM command of 0175 to select the proper channel for NBTR 1 (0176 for NBTR 2) followed by the hexadecimal value of 2E70. The final command would be to send the record execute SM command of 0175 (or 0175) followed by the hexadecimal value of 5370.

Figure 5.3-3 is also provided to aid in the resolution of any tape speed anomaly which may occur after a transition to the record or playback mode. As shown, a number of command values (provided in hexadecimal) will cause either erroneous or desired tape speeds. The purpose of the figure is not to substitute alternate command data for the normal commands, but to aid in the interpretation of tape speed results, should an anomaly be detected.

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- NORMAL HEXADECIMAL <u>RECORD</u> TAPE SPEED COMMAND = 2E70 (0.418 ips)

<table>
<tr><td>RESULTANT RECORD SPEED</td><td colspan="4">RECORDER WILL NOT SERVO LOCK, BUT WILL RUN NOMINALLY AT 1/2 SPEED CAUSING DATA LOSS</td><td colspan="3">RECORDER WILL SERVO LOCK AT 0.418 ips</td></tr>
<tr><td>POSSIBLE HEXADECIMAL RECORDER CMD DATA INPUTS</td><td>1870
2070
2870</td><td>1970
2170
2970</td><td>1A70
2270
2A70</td><td>1B70
2370
2B70</td><td>1C70
2470
2C70</td><td>1D70
2570
2D70</td><td>1E70
2670
2E70</td></tr>
<tr><td rowspan="2">RESULTANT PLAYBACK SPEED</td><td>6.69 ips</td><td>13.4 ips</td><td>6.69 ips</td><td>13.4 ips</td><td>6.69 ips</td><td colspan="2" rowspan="2">RECORDER WILL NOT SERVO LOCK BUT WILL RUN AT LESS THAN 6.69 ips</td></tr>
<tr><td colspan="5">RECORDER WILL SERVO LOCK AT ABOVE SPEEDS.</td></tr>
</table>

- NORMAL HEXADECIMAL <u>PLAYBACK</u> TAPE SPEED COMMAND = 2970 (13.4 ips)
  or
  2A70 (6.69 ips)

- NORMAL HEXADECIMAL <u>WIND</u> TAPE SPEED COMMAND = 5570 (33 ips)

  <u>NOTE</u>: REGARDLESS OF SPEED COMMANDED, THE NBTR WILL ALWAYS WIND AT 33 ips.

FIGURE 5.3-3 NBTR SPEED COMMAND RESPONSES

5.4 NBTR CONSTRAINTS

1. Avoid repeated successive motor starts. As a guide, consider no more than 5 STARTS in any 2 minutes.

2. If the recorder is at EOT, do not EXECUTE commands leading to forward tape motion.

3. If the recorder is at BOT, do not execute commands leading to reverse tape motion.

4. Tape should be moved end to end during ambient temperature excursions greater than 15°C, though not necessarily in one reeling; i.e., tape should not remain on either reel over a 15°C range.

5.5 NBTR REDUNDANCY/CROSS STRAPPING

Telemetry data storage and retrieval is provided by two dedicated, redundant tape recorder PMP pairs (A and B).

5.6 NBTR COMMANDS

Each of the Narrowband Tape Recorders is controlled by 2 discrete commands and 15 serial commands.

5.6.1 DISCRETE COMMANDS

The discrete commands are given in Table 5.6-1.

Table 5.6-1. Discrete Command List

RIU	CHAN	ACRONYM	Command Name
1	60	APWRON	NBTR 1 Power ON
1	62	APWROFF	NBTR 1 Power OFF
1	59	BPWRON	NBTR 2 Power ON
1	61	BPWROFF	NBTR 2 Power OFF

A 1-second (minimum) delay is required after the Power-ON command to allow voltages within the recorder to stabilize prior to sending serial commands to configure the recorder.

5.6.2 SERIAL COMMANDS

The serial commands are divided into two categories:

1. Preparatory
2. Executing

The preparatory commands prepare the recorder for the executing command that will follow. The conditions specified by the preparatory commands do not take effect until an executing command is given. The preparatory commands determine the following conditions:

1. Direction of tape motion
2. Speed of tape motion
3. Which playback group will be used (for playback mode only)
4. Which motor encoder will be used

The serial commands are given in Table 5.6-2, with acronyms and bit patterns.

Serial commands for NBTR1 are addressed to RIU1, Channel 5. Serial commands for NBTR2 are addressed to RIU 1, Channel 6. In each case, a 7 indicates a serial command. Thus, the address for a serial command to NBTR1 is 175, and for NBTR 2 is 176.

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Table 5.6-2. Serial Command List

Command Name	Acronym	Binary				Hex
Do Nothing	Note 1	X111	XXXX	--	--	--
Preparatory						
Direction Forward	*FWD	0011	0000	0111	0000	3070
Direction Reverse	*REV	0011	0001	0111	0000	3170
Select Speed 22=0.418 ips	*S22	0010	1110	0111	0000	2E70
Select Speed 18=6.693 ips	*S18	0010	1010	0111	0000	2A70
Select Speed 17=13.386 ips	*S17	0010	1001	0111	0000	2970
Select PB Group A	*GRPA	0100	1000	0111	0000	4870
Select PB Group B	*GRPB	0100	1001	0111	0000	4970
Select PB Group C	*GRPC	0100	1010	0111	0000	4A70
Select PB Group D	*GRPD	0100	1011	0111	0000	4B70
Select Primary Encoder	*PEN	0011	1000	0111	0000	3870
Select Secondary Encoder	*SEN	0011	1001	0111	0000	3970
Executing						
Stop Execute (Standby)	*STOPX	0101	0000	0111	0000	5070
Record Execute	*RECX	0101	0011	0111	0000	5370
Playback Execute	*PBX	0101	0100	0111	0000	5470
Wind Execute	*WINDX	0101	0101	0111	0000	5570

*For NBTR1, insert A. For NBTR2, insert B.

NOTE 1: The Do Nothing command is X111 XXXX, where the X's represent "Don't Care" bits. The recorders will ignore that command. The second half of each 16-bit spacecraft command in Table 5.6-2 is the "Do Nothing" command.

The recorders can accept two serial commands in each 16-bit spacecraft command. It is possible, for example, to give *FWD and *S22 in the same command as binary 0011 0000 0010 1110 (Hex 302E).

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The recorders ignore the first and ninth bit of each 16-bit command. The example above can be written X011 0000 X010 1110, where the X's indicate 'Don't Care' bits. In Table 5.6-2, the first and ninth bits are zeroes.

Among the 5 modes of recorder operation (OFF, RECORD, PLAYBACK, WIND, STANDBY), the recorder may be commanded from any one mode to any other mode.

5.6.3 COMMAND SEQUENCES

Table 5.6-3 shows the sequence of commands to go into any one of the five modes. If the recorder is already ON, it is, of course, not necessary to turn it ON again. However, it will do no harm to give the ON command when the recorder is already ON. Always, there should be a 1-second delay after giving the ON command prior to giving any other recorder command.

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MODE	PREPARATORY												EXECUTE				
	PWR ON	DIRECTION		SPEED			PB GROUP				MOTOR ENCODE						PWR OFF
		FWD	REV	REC 0.418 IPS	PB 6.693 IPS	PB 13.386 IPS	A	B	C	D	PRI	SEC	REC	PB	WIND	STOP	
RECORD	X	X		X							X	*	X				
PLAYBACK																	
128 KBPS	X		X		X		X	*	*	*	X	*		X			
256 KBPS	X		X			X	X	*	*	*	X	*		X			
WIND																	
FWD	X	X									X	*					
REV	X		X								X	*			X		
STANDBY	X															X	
OFF																	X
HEX VALUE OF SERIAL COMMAND		30	31	2E	2A	29	48	49	4A	4B	38	39	53	54	55	50	

*MAY BE SELECTED IN PLACE OF X'd COMMAND

TABLE 5.6-3 COMMAND SEQUENCES

If the recorder is operating in a mode that uses the same preparatory command as the next desired mode, it is not necessary to give that preparatory command again. For example, if the recorder is in the RECORD mode and, therefore moving forward, it is not necessary to give the Forward command again prior to commanding Wind, as long as power remains ON.

At initial turn-ON of the recorder, and prior to any further commanding, the recorder is automatically placed into the following configuration:

Direction	- FWD
Speed	- No specific speed - may be any value
PB Group	- A
Motor Encoder	- Primary
Execute	- Stop (Standby)

5.6.4 COMMAND VERIFICATION

Methods of command verification are given in Table 5.6-4 which lists commands by acronym, their prerequisite commands, complement commands, and a reference paragraph for command descriptions.

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Table 5.6-4. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	Telemetry Verification	Remarks
*PWRON	5.6.5.1	--	*PWROFF	*SYNC1	Bit 0=1
*PWROFF	5.6.5.1	--	*PWRON	*SYNC1	Bit 0=0
*FWD	5.6.5.2	*PWRON	*REV	*DIRCD=0 *TPDIR=0	After *FWD After Execute
*REV	5.6.5.2	*PWRON	*FWD	*DIRCD=1 *TPDIR=1	After *REV After Execute
*S22	5.6.5.3	*PWRON	*S18 *S17	*IPS=01110	
*S18	5.6.5.3	*PWRON	*S22 *S17	*IPS=01010	
*S17	5.6.5.3	*PWRON	*S22 *S18	*IPS=10010	
*GRPA	5.6.5.4	*PWRON	*GRPB *GRPC *GRPD	*PBGRP=00 *POGRP=00	After *GRPA After *PBX
*GRPB	5.6.5.4	*PWRON	*GRPA *GRPC *GRPD	*PBGRP=10 *CPGRP=01	After *GRPB After *PBX
*GRPC	5.6.5.4	*PWRON	*GRPA *GRPB *GRPD	*PBGRP=01 *POGRP=10	After *GRPC After *PBX
*GRPD	5.6.5.4	*PWRON	*GRPA *GRPB *GRPC	*PBGRP=11 *OPGRP=11	After *GRPD After *PBX
*PEN	5.6.5.5	*PWRON	*SEN	*ENCOD=0	
*SEN	5.6.5.5	*PWRON	*PEN	*ENCOD=1	
*STOPX	5.6.5.6	*PWRON NOTE 1	*RECX *PBX *WINDX	*MODE=000	
*RECX	5.6.5.6	*PWRON NOTE 1	*STOPX *PBX *WINDX	*MODE=110	
*PBX	5.6.5.6	*PWRON NOTE 1	*STOPX *RECX *WINDX	MODE=001	
WINDX	5.6.5.6	*PWRON NOTE 1	*STOPX *RECX *PBX	*MODE=101	

*NBTR 1 commands begin with A; NBTR 2 with B.
NBTR 1 telemetry begins with N1; NBTR 2 with N2.

NOTE 1: The appropriate preparatory commands of Table 5.6-3 are prerequisite.

5.6.5 COMMAND DESCRIPTIONS

This section provides descriptions of the command functions using the acronyms in Tables 5.6-1 and 5.6-2. All NBTR commands are addressed to RIU 1 (A or B).

The asterisk at the beginning of the command acronyms is the designation of the recorder; use A for NBTR1 and B for NBTR2.

Functional schematics are provided as an aid to understanding the command interface. Exact circuit details are defined by drawings elsewhere.

5.6.5.1 *PWRON / *PWROFF

The power ON and power OFF discrete commands control a latching relay in the Electronics unit to switch primary 28 volts to the recorder DC/DC converter, as shown in Figure 5.6-1. A 1-second delay should follow the *PWRON commands.

5.6.5.2 *FWD / *REV

These two serial commands are preparatory, and control the direction of the tape motion. *FWD results in tape motion toward EOT. *REV results in tape motion toward BOT. Reference Figure 5.6-2.

5.6.5.3 *S22 / *S18 / *S17

These three serial commands are preparatory, and control the speed of tape motion. *S22 must be used for recording; *S18 must be used for playback at 128 kbps; *S17 must be used for playback at 256 kbps. Reference Figure 5.6-2.

5.6.5.4 *GRPA / *GRPB / *GRPC / *GRPD

These four serial commands are preparatory, and selection is required prior to a playback execute command. They each select a pair of tracks to be used during playback. Reference Figure 5.6-2.

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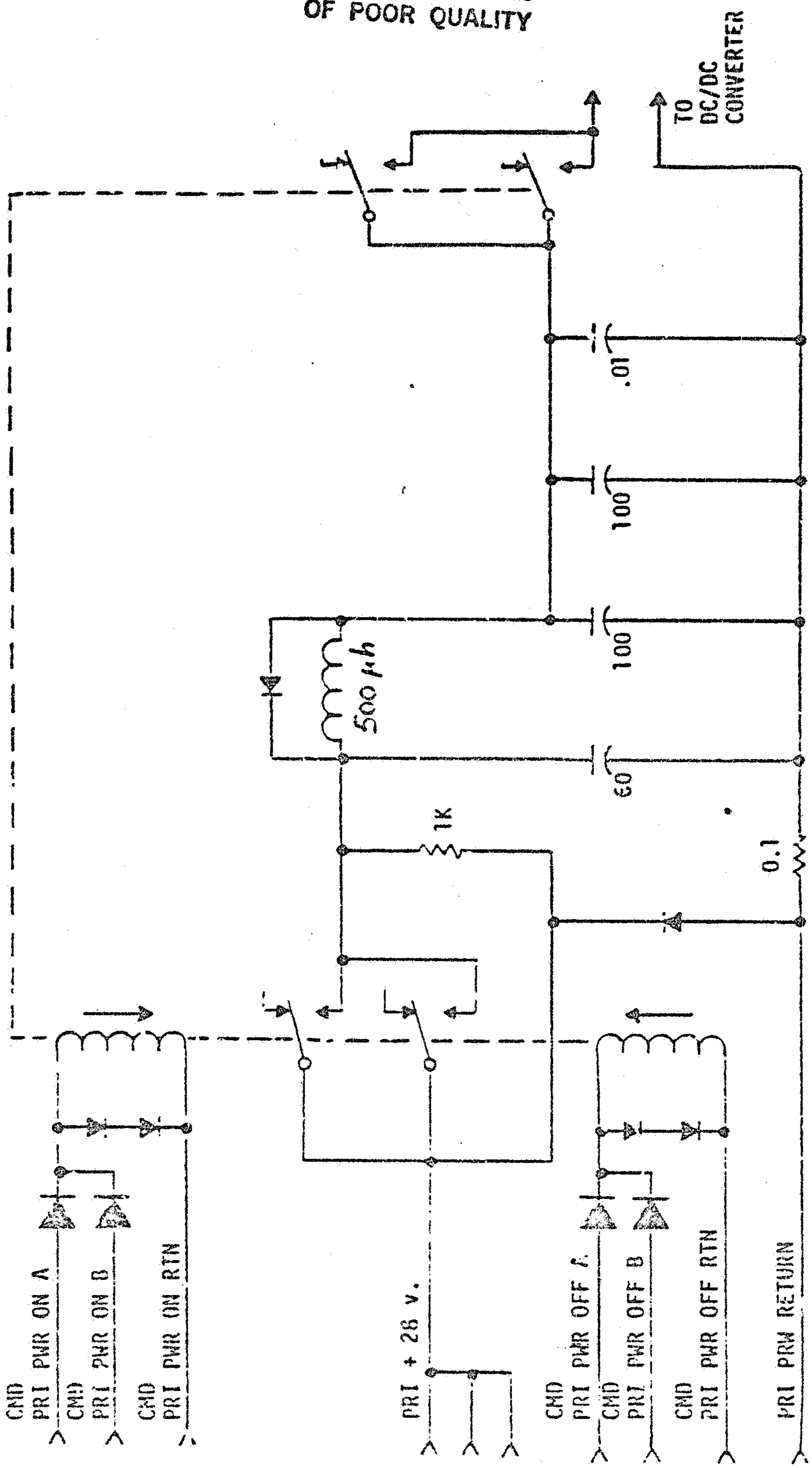

FIGURE 5.6-1 DISCRETE COMMAND INTERFACE

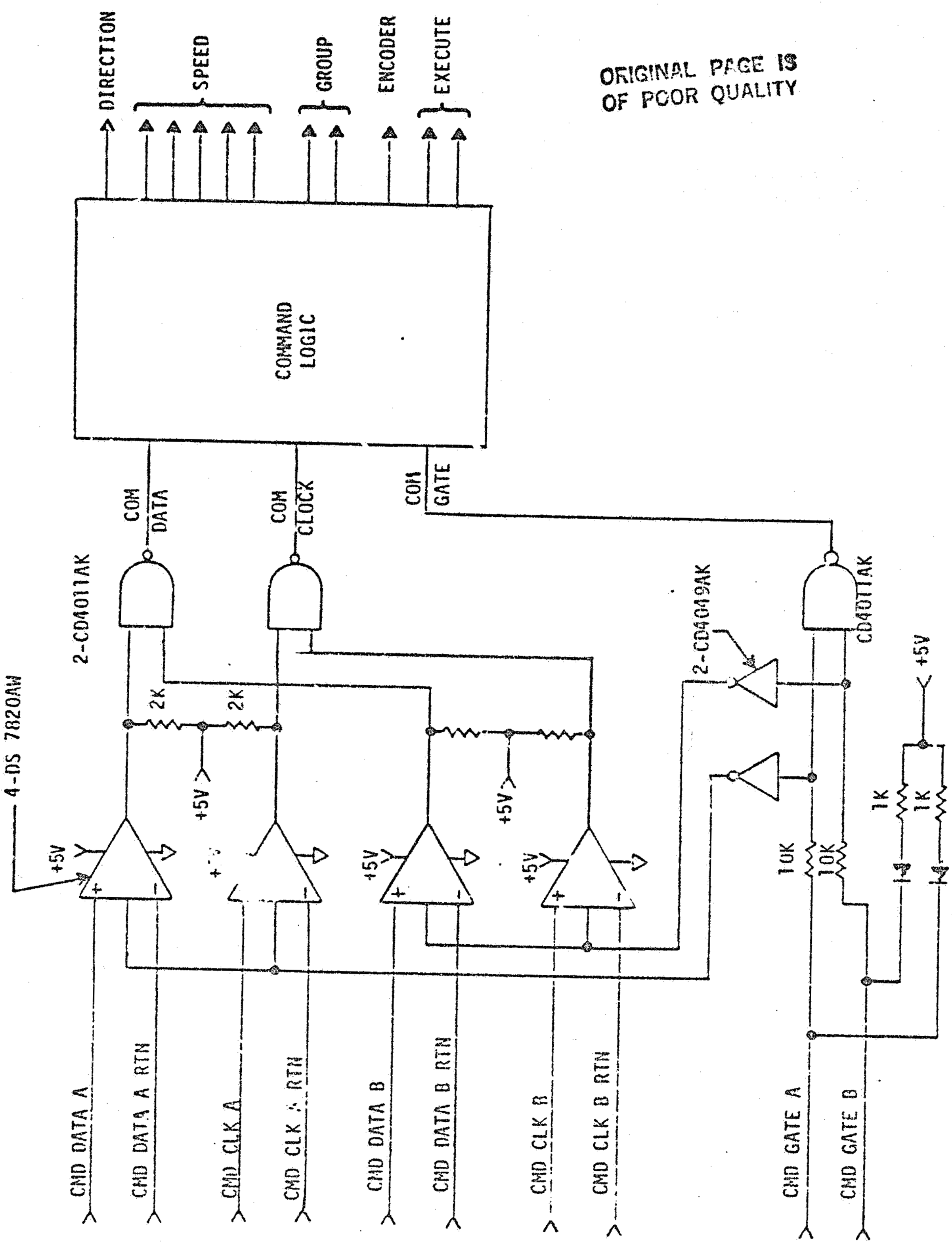

FIGURE 5.6-2 SERIAL COMMAND INTERFACE

5.6.5.5 *PEN
*SEN

These two serial commands are preparatory, and select either the primary or secondary encoder for driving the capstan motor. The encoders control the commutation for the 3-phase 4-pole brushless capstan motor. Selection must be made prior to an execute command. Reference Figure 5.6-2.

5.6.5.6 *STOPX
*RECX
*PBX
*WINDX

Each of these four execute serial commands is a final command, required to place the recorder into a particular mode of operation. Prior to any of these commands, the recorder must have been turned ON and given the proper preparatory commands, as shown in Table 5.6-3, Command Sequences. Reference Figure 5.6-2.

5.6.6 OPERATING RESTRAINTS

5.6.6.1 Command Restraints

1. There is no restraint on command sequencing; that is, the recorder may be commanded directly from any mode to any other mode.

2. Avoid repeated successive motor starts. As a guide, consider no more than 5 starts in any 2 minutes.

3. If the recorder is at ECT, do not execute commands leading to forward tape motion.

4. If the recorder is at BOT, do not execute commands leading to reverse tape motion.

5. Continuous operation of the recorder, especially at high ambient temperatures might cause the internal TU temperature to exceed the specified 40°C limit. This condition should not be allowed to occur.

6. The BOT/EOT sensors are triply redundant using digital sensing as primary, detection of tape windows as secondary and a mechanical brake as tertiary. All sensors outputs are presented as separate telemetry data. If either the secondary or tertiary sensors have ever been actuated, the recorder should not be turned on until a failure or command sequence analysis has been completed. If the tertiary BOT or EOT sensor has been activated, either of the following actions has occurred:

a. Command Sequence and tape position are such that BOT or EOT primary and secondary sensors have been "walked through".

b. A failure has occurred in the primary and secondary BOT or EOT circuits.

7. Tape should be moved end to end during ambient temperature excursions greater than 15°C, though not necessarily in one reeling; i.e., tape should not remain on either reel over a 15°C range.

8. Tape should be reeled end to end (continuously) and set at end-of-tape prior to moving the spacecraft and prior to vibration.

9. The recorder shall not be exposed to primary supply voltages between 1 and 18 volts, except at power-ON/OFF. This voltage range is outside specification and may result in damage to the recorder. If this occurs, turn off the recorder as soon as possible.

10. Avoid interruptions in primary power in the range of 0.5 to 200 ms. If this occurs, turn off the recorder as soon as possible.

11. An interruption of the external clock signal in excess of 0.5 seconds may cause the motor to stop. A Stop Execute, followed by any other appropriate commands, will then restart the motor.

12. The temperature limits, as measured by the recorder internal sensors, are to not exceed the limits given in Table 5.6-5.

13. All recorders should be reeled end-to-end (continuously) prior to setting launch mode. Recorders should be positioned at end-of-tape when launched in a power OFF mode. It can be positioned anywhere when launched while making a recording.

14. Following launch and injection into orbit, each of the recorders shall be given commands to effect the following sequence:

a. Command recorder to Wind to BOT, then to EOT.

b. Command recorder to Wind or Play to BOT.

c. Commence normal orbit use.

The objects of the sequence are:

1) Recover data recorded prior to launch and/or during launch.

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2) Reel the recorders end-to-end to achieve optimum tape stacking prior to orbital use.

15. If a recorder is to be unused for periods in excess of one week in orbit, the following shall apply:

a. Move tape to EOT.

b. Record and Playback end-to-end every three months.

16. Tape use shall be managed to provide relatively uniform distribution of tape wear.

Table 5.6-5. Temperature Limits

Program Phase	Safe Operating Temperature (°C)		Safe Storage Temperature (°C)	
	EU 1)	TU	EU	TU
Spacecraft Test	0 to +40	0 to +40	-10 to +45	0 to +40
Launch	0 to +40	0 to +40	-	-
Orbit	0 to +40	0 to +35	-10 to +45	0 to +35

1. Since the EU temperature is sensed on the heatsink of the power transistor of the energy pump, a temperature rise of 30 to 40°C will be experienced at this point whenever the recorder is in an ON state.

5.7 NBTR Telemetry

The NBTR telemetry consists of 34 analog telemetry points, and serial digital telemetry monitoring 16 functions for each of the two recorders.

Each recorder contains two analog multiplexers, each of which multiplexes 16 analog telemetry signals. The recorder also contains a digital multiplexer, which multiplexes the digital data into 8 words of 8 bits each.

Total Recorder Current and Recorder Servo Error are each available as non-multiplexed analog signals.

5.7.1 TELEMETRY FORMAT LOCATIONS

The locations of the Tape Recorder telemetry points in the Mission Format and in the Engineering Format are given in Figure 5.7-1. All of the telemetry points for both recorders are available in the Mission Format. In the Engineering Format, Analog Multiplexer #2 and Recorder Total Current are omitted because of format space limitations.

In each format, each analog mux is completely sampled 8 times during a major frame as shown by the numbers 1 through 8 to the left of column 79 of the Mission Format, Figure 5.7-1. Similarly, each digital mux is completely sampled 16 times during a major frame as shown by the numbers 1 through 16 to the right of column 12.

Total Recorder Current and Servo Error are each sampled once in each minor frame.

5.7.2 ANALOG AND DIGITAL MULTIPLEXING

A list of the analog telemetry points contained in each analog multiplexer is given in Table 5.7-1. Digital telemetry is multiplexed to eight (8) words as shown in Figure 5.7-2.

The internal analog and digital multiplexing circuits of the recorder are shown in Figure 5.7-3. The major frame sync pulse will set the 4-Bit address counter to the 1111 state, after which the first telemetry gate enable pulse will advance the address counter to the 0000 state.

A list of all digital and analog telemetry points is given in Table 5.7-2.

5.7.3 DIGITAL TELEMETRY

Each digital telemetry monitor is described in the following paragraphs.

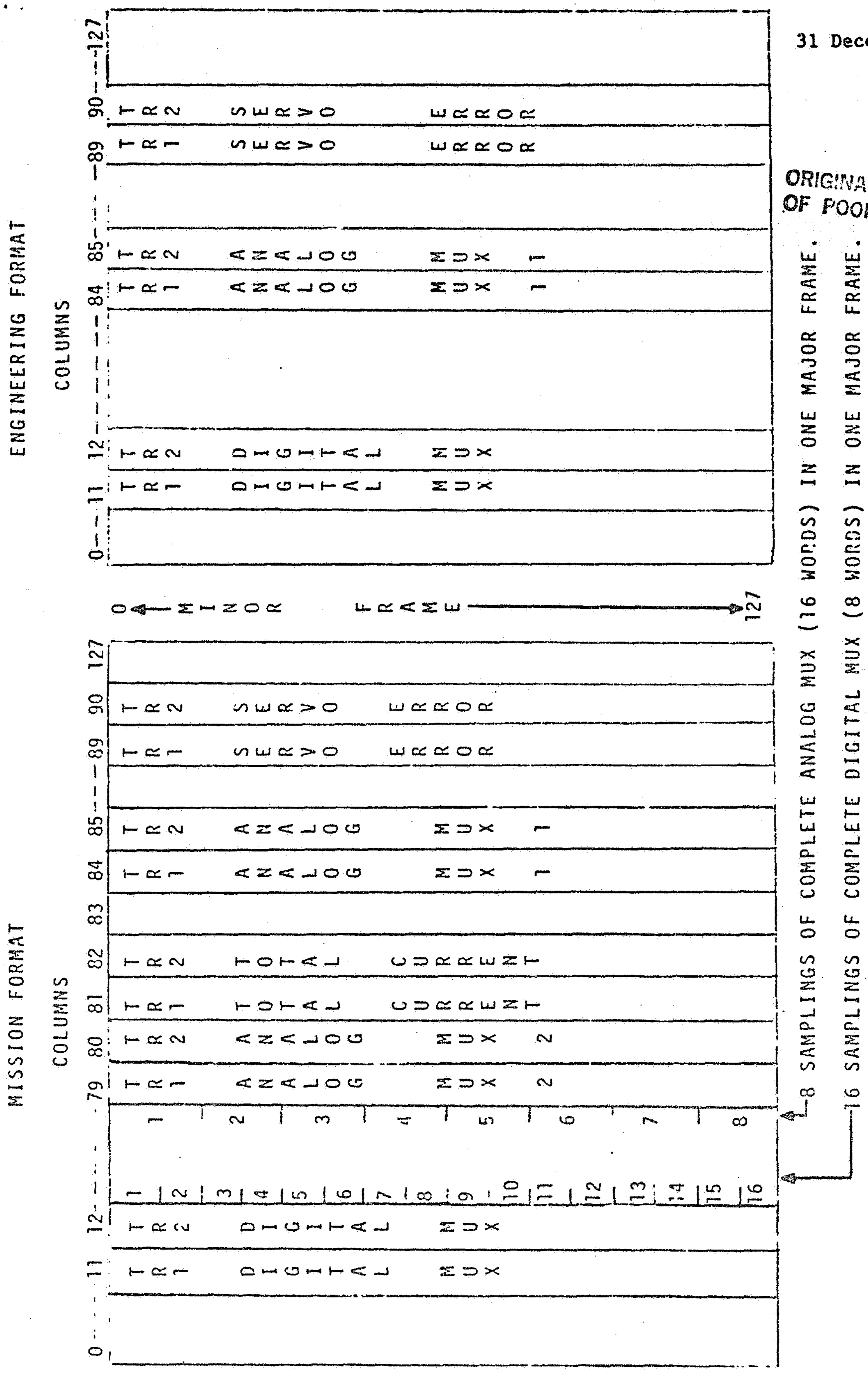

FIGURE 5.7-1 TELEMETRY FORMAT LOCATIONS

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TABLE 5.7-1 MULTIPLEXED ANALOG TELEMETRY

1. Multiplexer No. 1
   a. TU Pressure
   b. Motor Speed
   c. Motor Current
   d. Tachometer Sensor - PRI
   e. +5 Volt Power
   f. SEOT Sensor
   g. Reel Sensor
   h. Encoder Sensor PRI No. 1
   i. Reel Redundant Sensor
   j. SBOT Sensor
   k. Tachometer Sensor SEC
   l. Encoder Sensor PRI No. 2
   m. Encoder Sensor PRI No. 3
   n. Encoder Sensor SEC No. 1
   o. Encoder Sensor SEC No. 2
   p. Encoder Sensor SEC No. 3

2. Multiplexer No. 2
   a. CH 8 Playback Voltage
   b. CH 2 Playback Voltage
   c. CH 7 Playback Voltage
   d. CH 1 Playback Voltage
   e. CH 5 Playback Voltage
   f. CH 6 Playback Voltage
   g. CH 4 Playback Voltage
   h. CH 3 Playback Voltage
   i. Power Supply Voltage, +5V
   j. EU Temperature
   k. TU Temperature
   l. Gnd
   m. Power Supply Voltages, -6
   n. Power Supply Voltages, -12
   o. Power Supply Voltages, +15
   p. Power Supply Voltages, +12

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WORD	MSB							LSB
1	1	1	1	1	1	1	1	1
	MAJOR FRAME SYNC - ALL 1's MSB USED AS INDICATOR OF RECORDER POWER ON.							
2						1=REVERSE 0=FORWARD	0	0
	SELECTED TAPE SPEED					SELECTED DIRECTION	ALWAYS 0	
3	0 = PRI 1 = SEC	0	0	0			0	0
	SELECTED ENCODER	ALWAYS 0			SELECTED GROUP		ALWAYS 0	
4	0	0	0	0	0	0	0	0
	ALWAYS 0							
5				0=FORWARD 1=REVERSE			0	0
	OPERATING MODE			OPERATING DIRECTION	OPERATING GROUP		ALWAYS 0	
6	TBOT	TEOT	0=NOT LOCKED 1=LOCKED	1	SBOT	SEOT	PBOT	PEOT
			SERVO LOCK	ALWAYS 1				
7	LSB 2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7 MSB
	TAPE POSITION							
8	0	1	0	1	0	1	0	0
	FIXED PATTERN						SYNC MARK	

MULTIPLEXED DIGITAL TELEMETRY

FIGURE 5.7-2

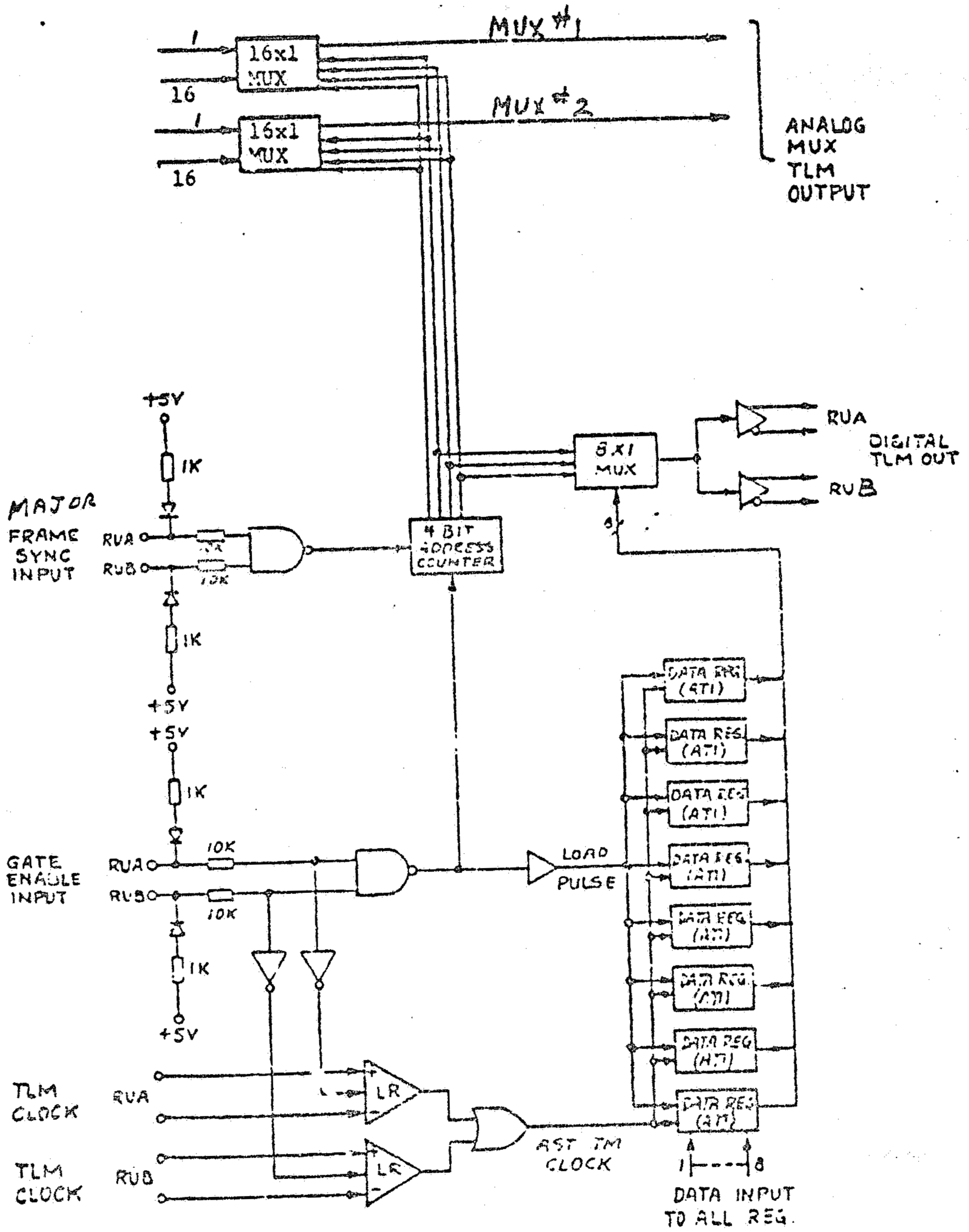

Figure 5.7-3 Multiplexed Telemetry; Analog & Digital

Table 5.7-2. Digital and Telemetry List

[illegible] ID	TELEMETRY NAME SEL = SELECTED OPER = OPERATING	ACRONYM	SIG TYPE	SMPL RATE	MATRIX LOC MISSION COL,ROW	MATRIX LOC ENCR COL,ROW	RIU #-CH	REFERENCE PARAGRAPH
NBTR-01	RECORDER 1 DIGITAL MUX							
	WORD 1							
	SYNC WORD (1,1,1,1,1,1,1,1)	N1SYNC1	S0-7	16	11,00	11,00	01-64	5.7.3.16
	WORD 2							
	TAPE SPEED (SEL.)	N1IPS	S0-4	16	11,01	11,01	01-64	5.7.3.1
	TAPE DIRECTION (SEL.)	N1DIRCD	S-5	16	11,01	11,01	01-64	5.7.3.2
	(NOT USED)(0,C)	---	S6-7	16	11,01	11,01	01-64	5.7.3.16
	WORD 3							
	SERVO ENCODER (SEL.)	N1ENCOD	S-0	16	11,02	11,02	01-64	5.7.3.3
	(NOT USED) (0,0,0)	---	S1-3	16	11,02	11,02	01-64	5.7.3.16
	PB GROUP (SEL.)	N1PBGRP	S4-5	16	11,02	11,02	01-64	5.7.3.4
	(NOT USED) (0,0)	---	S6-7	16	11,02	11,02	01-64	5.7.3.16
	WORD 4							
	(NOT USED) (0,0,0,0,0,0,0,0)	---	S0-7	16	11,03	11,03	01-64	5.7.3.16
	WORD 5							
	OPERATING MODE	N1MODE	S0-2	16	11,04	11,04	01-64	5.7.3.5
	TAPE DIRECTION (OPER.)	N1TPDIR	S-3	16	11,04	11,04	01-64	5.7.3.6
	OPERATING PB GROUP	N1OPGRP	S4-5	16	11,04	11,04	01-64	5.7.3.7
	(NOT USED) (0,0)	---	S6-7	16	11,04	11,04	01-64	5.7.3.16
	WORD 6							
	TERTIARY BOT	N1TBOTS	S-0	16	11,05	11,05	01-64	5.7.3.8
	TERTIARY EOT	N1TEOTS	S-1	16	11,05	11,05	01-64	5.7.3.9
	SERVO LOCK	N1SLOCK	S-2	16	11,05	11,05	01-64	5.7.3.10
	(NOT USED) (1)	---	S-3	16	11,05	11,05	01-64	5.7.3.16
	SECONDARY BOT	N1SBOTS	S-4	16	11,05	11,05	01-64	5.7.3.11
	SECONDARY EOT	N1SEOTS	S-5	16	11,05	11,05	01-64	5.7.3.12
	PRIMARY BOT	N1PBOT	S-6	16	11,05	11,05	01-64	5.7.3.13
	PRIMARY EOT	N1PEOT	S-7	16	11,05	11,05	01-64	5.7.3.14
	WORD 7							
	TAPE POSITION (S0=LSB)	N1POSN	S0-7	16	11,06	11,06	01-64	5.7.3.15

(continued)

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TABLE 5.7-2 (continued)

MSTR ID	TELEMETRY NAME SEL = SELECTED OPER = OPERATING	ACRONYM	SIG TYPE	SMPL RATE	MATRIX LOC MISSION COL,ROW	MATRIX LOC ENGR COL,ROW	RIU #-CH	REFERENCE PARAGRAPH
NBTR-01	RECORDER 1 DIGITAL MUX (con'td.)							
	WORD 8							
	(NOT USED) (0,1,0,1,0,1)	---	S0-5	16	11,07	11,07	01-64	5.7.3.16
	SYNC MARK (0,0)	N1SYNC2	S6-7	16	11,07	11,07	01-64	5.7.3.16
NBTR-03	RECORDER 1 ANALOG MUX 1							
	TV PRESSURE	N1TUPSI	A	8	84,00	84,00	01-69	5.7.4.1
	MOTOR SPEED	N1SPEED	A	8	84,01	84,01	01-69	5.7.4.2
	MOTOR CURRENT	N1MTRI	A	8	84,02	84,02	01-69	5.7.4.3
	TACHOMETER SENSOR - PRI	N1PTACH	A	8	84,03	84,03	01-69	5.7.4.4
	+5V POWER	N1PWR5V	A	8	84,04	84,04	01-69	5.7.4.5
	SECONDARY EOT SENSOR	N1ASEOT	A	8	84,05	84,05	01-69	5.7.4.6
	REEL PRIMARY SENSOR	N1PREEL	A	8	84,06	84,05	01-69	5.7.4.7
	ENCODER SENSOR PRI#1	N1P1ENC	A	8	84,07	84,07	01-69	5.7.4.8
	REEL REDUNDANT SENSOR	N1SREEL	A	8	84,08	84,08	01-69	5.7.4.7
	SECONDARY BOT SENSOR	N1ASBOT	A	8	84,09	84,09	01-69	5.7.4.6
	TACHOMETER SENSOR-SEC.	N1STACH	A	8	84,10	84,10	01-69	5.7.4.4
	ENCODER SENSOR PRI #2	N1P2ENC	A	8	84,11	84,11	01-69	5.7.4.8
	ENCODER SENSOR PRI #3	N1P3ENC	A	8	84,12	84,12	01-69	5.7.4.8
	ENCODER SENSOR SEC #1	N1S1ENC	A	8	84,13	84,13	01-69	5.7.4.8
	ENCODER SENSOR SEC #2	N1S2ENC	A	8	84,14	84,14	01-69	5.7.4.8
	ENCODER SENSOR SEC #3	N1S3ENC	A	8	84,15	84,15	01-69	5.7.4.8
NBTR-05	RECORDER 1 ANALOG MUX 2							
	CHANNEL 8 P/B VOLTAGE	N1PBV8	A	8	79,00	---	01-114	5.7.4.9
	CHANNEL 2 P/B VOLTAGE	N1PBV2	A	8	79,01	---	01-114	5.7.4.9
	CHANNEL 7 P/B VOLTAGE	N1PBV7	A	8	79,02	---	01-114	5.7.4.9
	CHANNEL 1 P/B VOLTAGE	N1PBV1	A	8	79,03	---	01-114	5.7.4.9
	CHANNEL 5 P/B VOLTAGE	N1PBV5	A	8	79,04	---	01-114	5.7.4.9
	CHANNEL 6 P/B VOLTAGE	N1PBV6	A	8	79,05	---	01-114	5.7.4.9
	CHANNEL 4 P/B VOLTAGE	N1PBV4	A	8	79,06	---	01-114	5.7.4.9
	CHANNEL 3 P/B VOLTAGE	N1PBV3	A	8	79,07	---	01-114	5.7.4.9
	+5V POWER SUPPLY VOLTAGE	N1PSP5	A	8	79,08	---	01-114	5.7.4.5
	EU TEMPERATURE	N1EUTMP	A	8	79,09	---	01-114	5.7.4.10
	TU TEMPERATURE	N1TUTMP	A	8	79,10	---	01-114	5.7.4.11
	GROUND	----	A	8	79,11	---	01-114	5.7.4.12
	-6V POWER SUPPLY VOLTAGE	N1PSN6	A	8	79,12	---	01-114	5.7.4.13
	-12V POWER SUPPLY VOLTAGE	N1PSN12	A	8	79,13	---	01-114	5.7.4.13
	+15V POWER SUPPLY VOLTAGE	N1PSP15	A	8	79,14	---	01-114	5.7.4.13
	+12V POWER SUPPLY VOLTAGE	N1P[illegible]	A	8	79,15	---	01-114	5 [illegible] 4.13

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TABLE 5.?-2 (continued)

USER ID	TELEMETRY NAME SEL = SELECTED OPER = OPERATING	ACRONYM	SIG TYPE	SMPL RATE	MATRIX LOC MISSION COL,ROW	MATRIX LOC ENGR COL,ROW	RIU #-CH	REFERENCE PARAGRAPH
NBTR-07	RECORDER 1 SERVO ERROR	N1SVERR	A	128	89,00	89,00	01-90	5.7.4.14
NBTR-09	RECORDER 1 TOTAL CURRENT	N1RECI	A	128	81,00	---	01-68	5.7.4.15
NBTR-02	RECORDER 2 DIGITAL MUX							
	WORD 1							
	SYNC WORD (1,1,1,1,1,1,1,1)	N2SYNC1	S0-7	16	12,00	12,00	01-65	5.7.3.16
	WORD 2							
	TAPE SPEED (SEL)	N2IPS	S0-4	16	12,01	12,01	01-65	5.7.3.1
	TAPE DIRECTION (SEL)	N2DIRCD	S-5	16	12,01	12,01	01-65	5.7.3.2
	(NOT USED) (0,0)	---	S6-7	16	12,01	12,01	01-65	5.7.3.16
	WORD 3							
	SERVO ENCODER (SEL)	N2ENCOD	S-0	16	12,02	12,02	01-65	5.7.3.3
	(NOT USED) (0,0,0)	---	S1-3	16	12,02	12,02	01-65	5.7.3.16
	PB GROUP (SEL)	N2PBGRP	S4-5	16	12,02	12,02	01-65	5.7.3.4
	(NOT USED) (0,0)	---	S6-7	16	12,02	12,02	01-65	5.7.3.16
	WORD 4							
	(NOT USED) (0,0,0,0,0,0,0,0)	---	S0-7	16	12,03	12,03	01-65	5.7.3.16
	WORD 5							
	OPERATING MODE	N2MODE	S0-2	16	12,04	12,04	01-65	5.7.3.5
	TAPE DIRECTION (OPER)	N2TPDIR	S-3	16	12,04	12,04	01-65	5.7.3.6
	OPERATING PB GROUP	N2OPGRP	S4-5	16	12,04	12,04	01-65	5.7.3.7
	(NOT USED) (0,0)	---	S6-7	16	12,04	12,04	01-65	5.7.3.16
	WORD 6							
	TERTIARY BOT	N2TBOTS	S-0	16	12,05	12,05	01-65	5.7.3.8
	TERTIARY EOT	N2TEOTS	S-1	16	12,05	12,05	01-65	5.7.3.9
	SERVO LOCK	N2SLOCK	S-2	16	12,05	12,05	01-65	5.7.3.10
	(NOT USED) (1)	---	S-3	16	12,05	12,05	01-65	5.7.3.16
	SECONDARY EOT	N2SBOTS	S-4	16	12,05	12,05	01-65	5.7.3.11
	SECONDARY EOT	N2SEOTS	S-5	16	12,05	12,05	01-65	5.7.3.12

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TABLE 5.7-2 (continued)

ITEM ID	TELEMETRY NAME SEL = SELECTED OPER = OPERATING	ACRONYM	SIG TYPE	SMPL RATE	MATRIX LOC MISSION COL,ROW	MATRIX LOC FNGR COL,ROW	RIU #-CH	REFERENCE PARAGRAPH
NBTR-02	RECORDER 2 DIGITAL MUX (cont'd.)							
	WORD 6 (cont'd.)							
	PRIMARY BOT	N2PBOT	S-6	16	12,05	12,05	01-65	5.7.3.13
	PRIMARY EOT	N2PEOT	S-7	16	12,05	12,05	01-65	5.7.3.14
	WORD 7							
	TAPE POSITION (SO=LSB)	N2POSN	S0-7	16	12,06	12,06	01-65	5.7.3.15
	WORD 8							
	(NOT USED) (0,1,0,1,0,1)	---	S0-5	16	12,07	12,07	01-65	5.7.3.16
	SYNC MARK (0,0)	N2SYNC2	S6-7	16	12,07	12,07	01-65	5.7.3.16
NBTR-04	RECORDER 2 ANALOG MUX 1							
	TU PRESSURE	N2TUPSI	A	8	85,00	85,00	01-70	5.7.4.1
	MOTOR SPEED	N2SPEED	A	8	85,01	85,01	01-70	5.7.4.2
	MOTOR CURRENT	N2MTRI	A	8	85,02	85,02	01-70	5.7.4.3
	TACHOMETER SENSOR - PRI	N2PTACH	A	8	85,03	85,03	01-70	5.7.4.4
	+5 V POWER	N2PWR5V	A	8	85,04	85,04	01-70	5.7.4.5
	SECONDARY EOT SENSOR	N2ASEOT	A	8	85,05	85,05	01-70	5.7.4.5
	REEL PRIMARY SENSOR	N2PREEL	A	8	85,06	85,06	01-70	5.7.4.7
	ENCODER SENSOR PRI #1	N2P1ENC	A	8	85,07	85,07	01-70	5.7.4.8
	REEL REDUNDANT SENSOR	N2SREEL	A	8	85,08	85,08	01-70	5.7.4.7
	SECONDARY BOT SENSOR	N2ASBOT	A	8	85,09	85,09	01-70	5.7.4.6
	TACHOMETER SENSOR - SEC	N2STACH	A	8	85,10	85,10	01-70	5.7.4.4
	ENCODER SENSOR PRI #2	N2P2ENC	A	8	85,11	85,11	01-70	5.7.4.8
	ENCODER SENSOR PRI #3	N2P3ENC	A	8	85,12	85,12	01-70	5.7.4.8
	ENCODER SENSOR SEC #1	N2S1ENC	A	8	85,13	85,13	01-70	5.7.4.8
	ENCODER SENSOR SEC #2	N2S2ENC	A	8	85,14	85,14	01-70	5.7.4.8
	ENCODER SENSOR SEC #3	N2S3ENC	A	8	85,15	85,15	01-70	5.7.4.8
IBTR-06	RECORDER 2 ANALOG MUX 2							
	CHANNEL 8 P/B VOLTAGE	N2PBV8	A	8	80,00	---	01-117	5.7.4.9
	CHANNEL 2 P/B VOLTAGE	N2PBV2	A	8	80,01	---	01-117	5.7.4.9
	CHANNEL 7 P/B VOLTAGE	N2PBV7	A	8	80,02	---	01-117	5.7.4.9
	CHANNEL 1 P/B VOLTAGE	N2PBV1	A	8	80,03	---	01-117	5.7.4.9
	CHANNEL 5 P/B VOLTAGE	N2PBV5	A	8	80,04	---	01-117	5.7.4.9

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TABLE 5. (continued)

MSMT ID	TELEMETRY NAME SEL - SELECTED OPER = OPERATING	ACRONYM	SIG TYPE	SMPL RATE	MATRIX LOC MISSION COL,ROW	MATRIX LOC ENGR COL,ROW	EIU #-CH	REFERENCE PARAGRAPH
NBTR-06	RECORDER 2 ANALOG MUX 2 (cont'd.)							
	CHANNEL 6 P/B VOLTAGE	N2PBV6	A	8	80,05	---	01-117	5.7.4.9
	CHANNEL 4 P/B VOLTAGE	N2PBV4	A	8	80,06	---	01-117	5.7.4.9
	CHANNEL 3 P/B VOLTAGE	N2PBV3	A	8	80,07	---	01-117	5.7.4.9
	+5V POWER SUPPLY VOLTAGE	N2PSP5	A	8	80,08	---	01-117	5.7.4.5
	EU TEMPERATURE	N2EUTMP	A	8	80,09	---	01-117	5.7.4.10
	TU TEMPERATURE	N2TUTMP	A	8	80,10	---	01-117	5.7.4.11
	GROUND	---	A	8	80,11	---	01-117	5.7.4.12
	-6V POWER SUPPLY VOLTAGE	N2PSN6	A	8	80,12	---	01-117	5.7.4.13
	-12V POWER SUPPLY VOLTAGE	N2PSN12	A	8	80,13	---	01-117	5.7.4.13
	+15V POWER SUPPLY VOLTAGE	N2PSP15	A	8	80,14	---	01-117	5.7.4.13
	+12V POWER SUPPLY VOLTAGE	N2PSP12	A	8	80,15	---	01-117	5.7.4.13
NBTR-08	RECORDER 2 SERVO ERROR	N2SVERR	A	128	90,00	90,00	01-67	5.7.4.14
NBTR-10	RECORDER 2 TOTAL CURRENT	N2RECI	A	128	82,00	---	01-71	5.7.4.15

5.7.3.1 Tape Speed, Selected

Five bits (bits S0 to S4) of Word 2 indicate the tape speed selected by the last speed command. The telemetry bits for each of the four (4) allowed speeds of Landsat-D are shown below.

Mode	Tape Speed (inches/second)	Telemetry Bits S0	S1	S2	S3	S4
Record	0.418	0	1	1	1	0
PB 128 KBPS	6.693	0	1	0	1	0
PB 256 KBPS	13.386	1	0	0	1	0
Wind	33	See Note Below				

NOTE: Since no new speed is commanded when entering the Wind mode, the speed telemetry bits continue to indicate the speed that had been commanded for the previous mode.

5.7.3.2 Tape Direction, Selected

One bit (bit S5) of Word 2 indicates the tape direction selected by the last direction command. A logic 1 indicates reverse (EOT to BOT) direction; logic 0 indicates forward (BOT to EOT) direction.

5.7.3.3 Servo Encoder, Selected

One bit (bit S0) of Word 3 indicates the servo encoder selected. Logic 0 indicates primary encoder; logic 1 indicates secondary encoder. The selection determines which set of LED/photo transistors is used for motor commutation. Figure 5.7-4 and 5.7-5 show the arrangement of LED's and phototransistors in forming the commutator.

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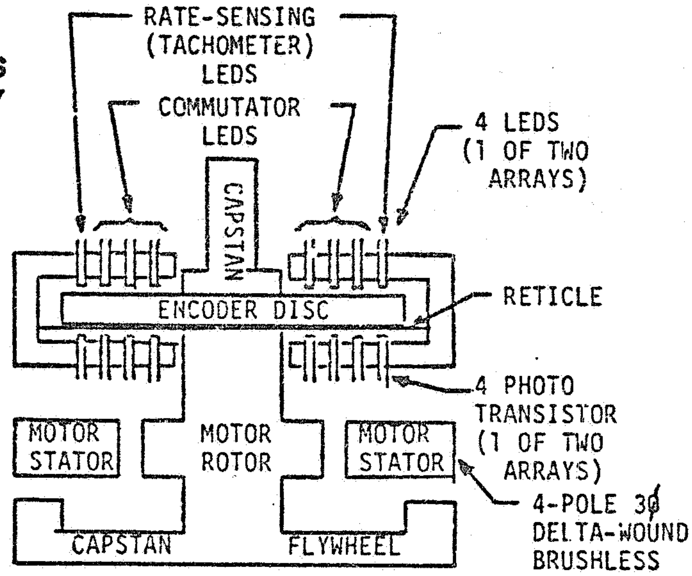
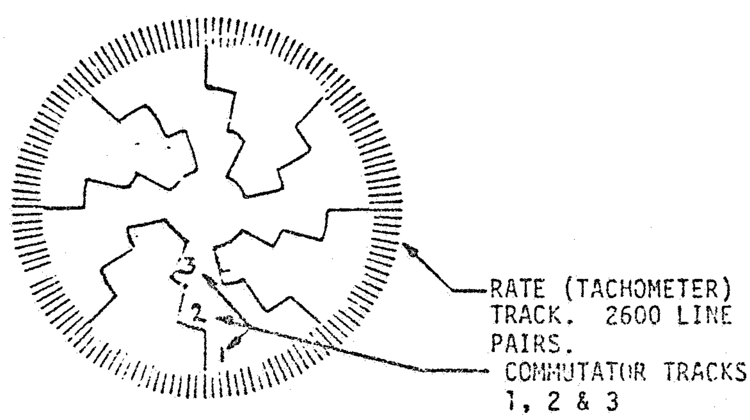


NOTE: THERE IS A PASSIVE HYSTERESIS BRAKE.

CAPSTAN-MOTOR ASSEMBLY DETAILS



ENCODER DISC DETAIL

FIGURE 5.7-4 SERVO ENCODER DETAILS

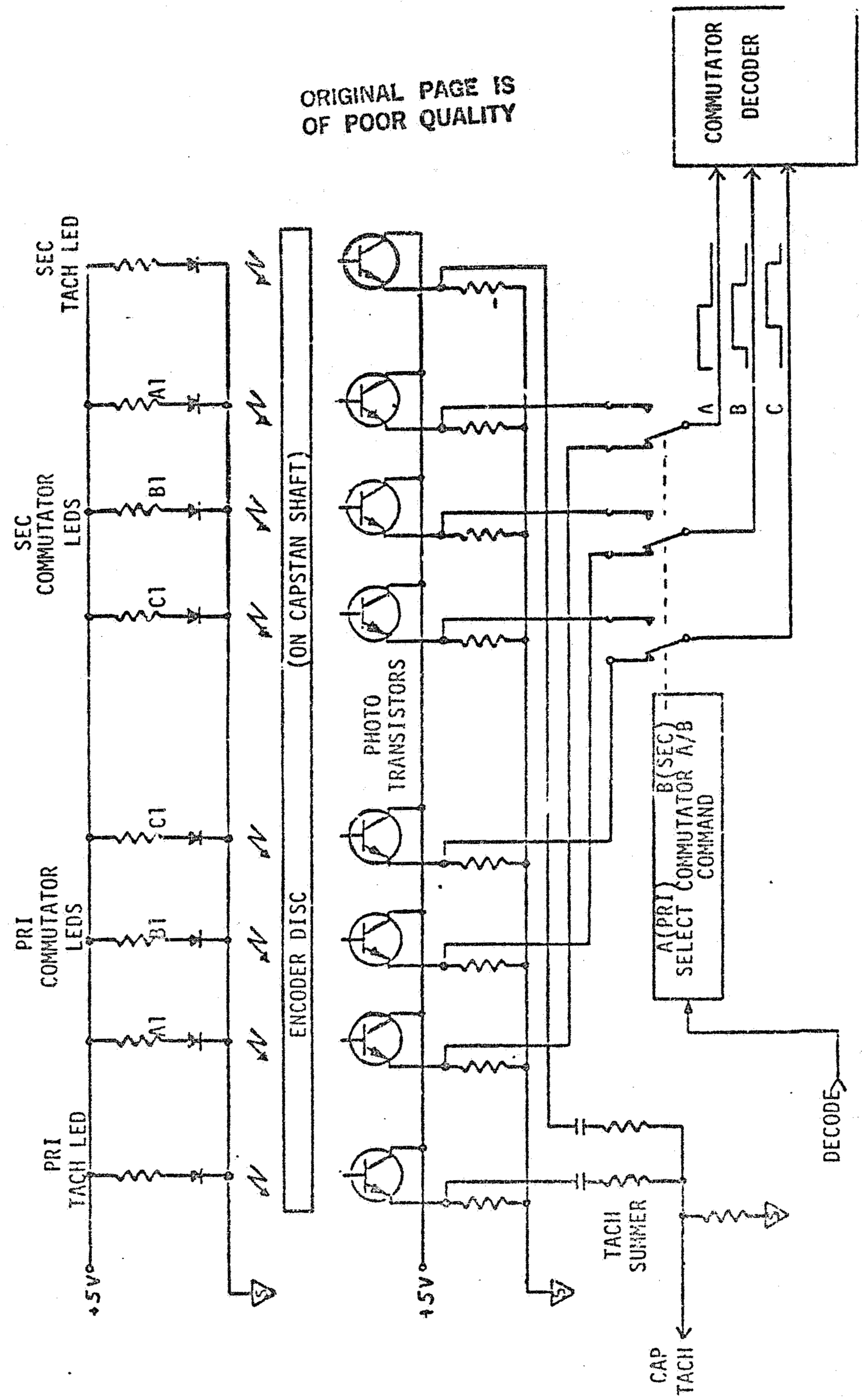


FIGURE 5.7-5 SERVO ENCODER DETAILS

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5.7.3.4 PB Group, Selected

Two bits (bits S4 and S5) of Word 3 indicate which group (pair) of tracks has been selected for data recovery during playback.

Group	Tracks Used	Telemetry Bits S4	S5
A	1,2	0	0
B	3,4	1	0
C	5,6	0	1
D	7,8	1	1

The bits will change immediately after a group select (intermediate) command is received.

5.7.3.5 Operating Mode

Three bits (bits S0 to S2) of Word 5 indicate the recorder present operating mode, as shown in the table below:

	Telemetry Bits		
Mode	S0	S1	S2
Stop	0	0	0
Record	1	1	0
Playback	0	0	1
Wind	1	0	1

If the recorder reaches EOT or BOT during record, playback, or wind, the recorder will revert to standby (stop) and the bits will go to all zeros.

Bits will change to indicate the operating mode only after the appropriate execute command has been received.

5.7.3.6 Tape Direction, Operating

One bit (bit S3) of Word 5 indicates the present operating mode. A logic 0 indicates forward (BOT to EOT); a logic 1 indicates reverse (EOT to BOT).

If the recorder reaches BOT or EOT, the bit will remain in its current state.

The bit is unaffected by a select direction command and changes only after an execute command.

5.7.3.7 Operating Group

Two bits (bits S4 and S5) of Word 5 indicate the current operating group as follows:

Group	Tracks Used	Telemetry Bits S4	Telemetry Bits S5
A	1,2	0	0
B	3,4	0	1
C	5,6	1	0
D	7,8	1	1

If the recorder reaches EOT or BOT, the bits will not change.

The bits are unaffected by a select group (intermediate) command, but change only following an execute command.

5.7.3.8 Tertiary BOT

One bit (bit S0) of Word 6 indicates the state of the tertiary BOT microswitch. A logic 1 indicates the switch is closed and the recorder is at tertiary BOT. A logic 0 indicates the swtich is open and the recorder is not at tertiary BOT. Figure 5.7-6 shows the layout of the tertiary microswitch and brake.

5.7.3.9 Tertiary EOT

One bit (bit S1) of Word 6 indicates the state of the tertiary EOT microswitch. A logic 1 indicates the switch is closed and the recorder is at tertiary EOT. A logic 0 indicates the switch is open and the recorder is not at tertiary EOT. Figure 5.7-6 shows the layout of the tertiary microswitch and brake.

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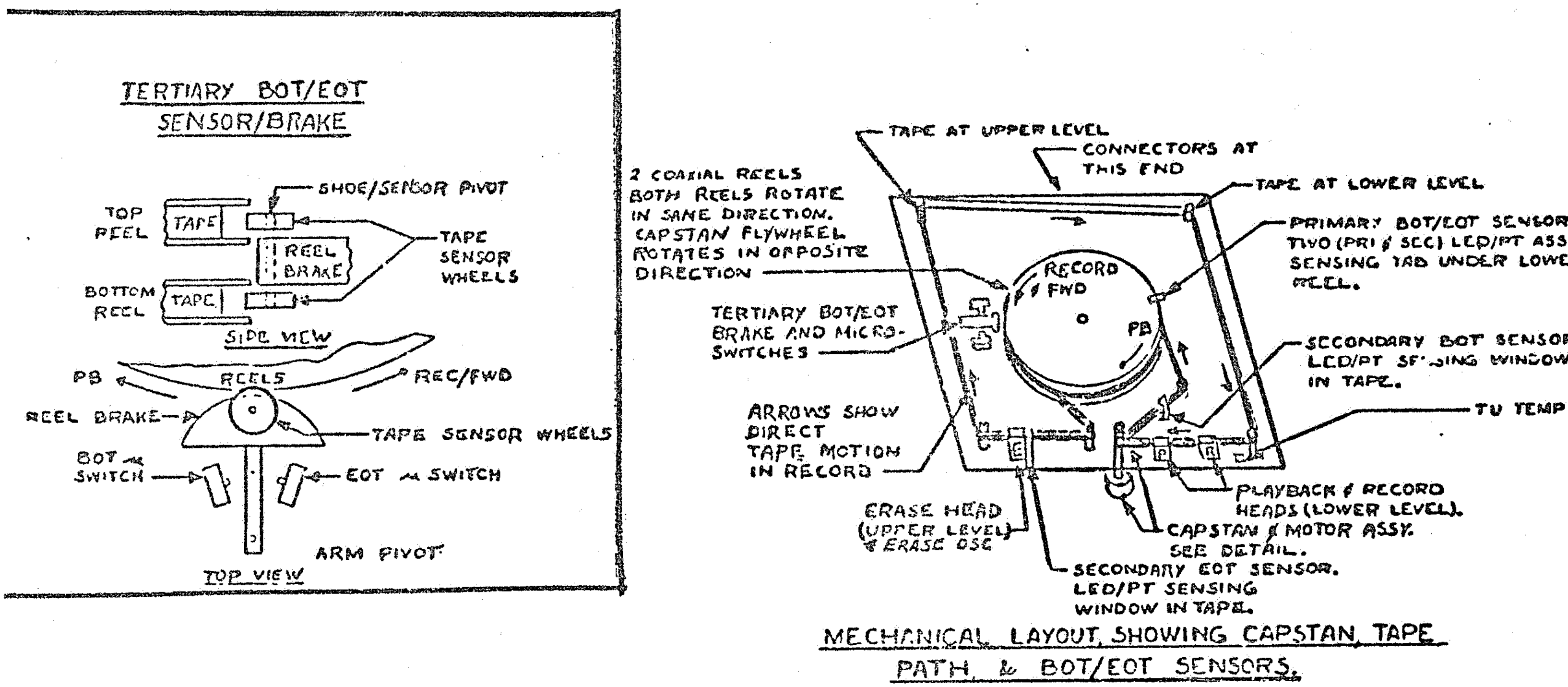

FIGURE 5.7-6 LAYOUT OF TAPE DRIVE, MONITORING AND BRAKING

5.7.3.10 Servo Lock

One bit (bit S2) of Word 6 indicates the lock state of the servo phase locked loop which compares the capstan tachometer pulses to the input clock during RECORD. During playback, the clock derived from the playback output signal is compared to an internal crystal oscillator.

A logic 1 indicates that the servo PLL is locked, and tape is moving at the correct speed. A logic 0 indicates that the servo PLL is not locked, and tape is therefore not moving at the synchronous speed.

5.7.3.11 Secondary BOT

One bit (bit S4) of Word 6 indicates the state of the secondary BOT sensor (phototransistor). A logic 1 indicates that the sensor is illuminated. A logic 0 indicates that the sensor is not illuminated. Since the sensor is illuminated for only a short time (several micro-seconds) it is likely that it won't be observed at secondary BOT. Figure 5.7-6 shows the location of the secondary BOT sensor.

5.7.3.12 Secondary EOT

One bit (bit S5) of Word 6 indicates the state of the secondary EOT sensor (phototransistor). A logic 1 indicates that the sensor is illuminated. A logic 0 indicates that the sensor is not illuminated. Since the sensor is illuminated for only a short time (several microseconds), it is likely that it won't be observed at secondary EOT. Figure 5.7-6 shows the layout of the secondary EOT sensor.

5.7.3.13 Primary BOT

One bit (bit S6) of Word 6 indicates the state of the primary BOT sensor (capstan tachometer pulses per one lower reel rotation). A logic 1 indicates that the number of capstan tachometer pulses fell below a preset number on three successive rotations of the lower reel, and that the tape is therefore at BOT. A logic 0 indicates that the tape is not at BOT. See Figure 5.7-7.

5.7.3.14 Primary EOT

One bit (bit S7) of Word 6 indicates the state of the primary EOT sensor (capstan tachometer pulses per one lower reel rotation). A logic 1 indicates that the number of capstan tachometer pulses exceeded a preset number on three successive rotations of the lower reel, and that the tape is therefore at EOT. A logic 0 indicates that the tape is not at EOT. See Figure 5.7-7.

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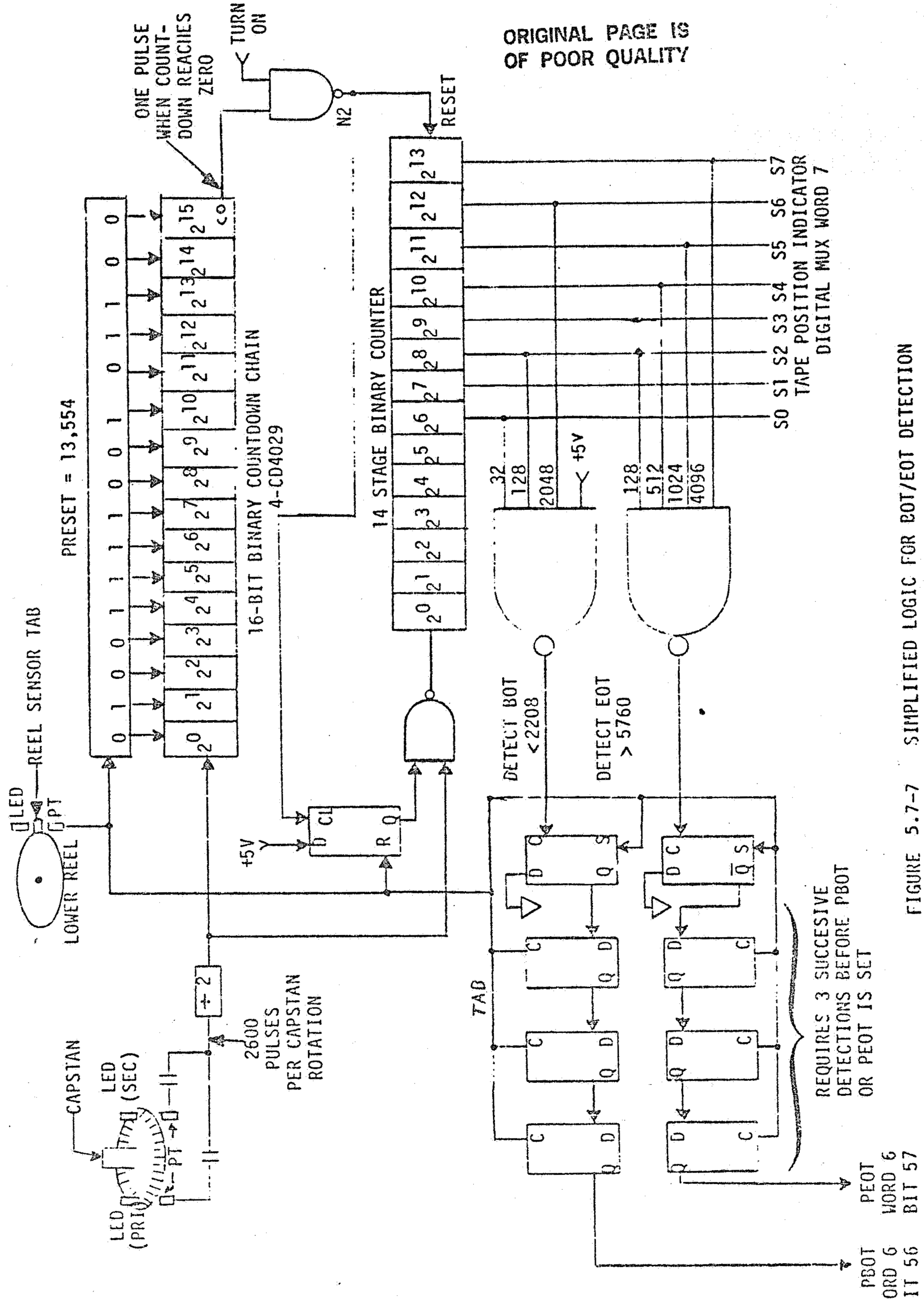

FIGURE 5.7-7 SIMPLIFIED LOGIC FOR BOT/EOT DETECTION AND TAPE POSITION INDICATOR

5.7.3.15 Tape Position

Eight bits (bits S0-7) of Word 7 indicate the tape position. Preset values of 69 and 180 indicate BOT and EOT respectively. Between these two values, 111 counts is equivalent to 255 minutes of RECORD, or typically 2.3 minutes per count. The first bit (S0) represents the LSB.

5.7.3.16 Sync Bits and Unused Bits, Power ON/OFF

Of a possible 64 bits (8 words X 8 bits per word), 30 bits are used actively for the telemetry points described in the preceding paragraphs and 34 bits are fixed bits labeled either as sync bits or as unused bits. The first bit of the first word of the digital mux is used as an indication of recorder power ON (logic 1).

5.7.4 ANALOG TELEMETRY

Each analog telemetry monitor is described in the following paragraphs.

5.7.4.1 TU Pressure

Transport Unit pressure is measured by a sensor placed under the motor board. The sensor consists of a diaphragm separating an enclosed evacuated chamber from the atmosphere of the (sealed) transport unit. The diaphragm moves the arm of a potentiometer in response to the differential pressure between the transport and the evacuated chamber. The pressure monitor is valid only during playback.

5.7.4.2 Motor Speed

Motor speed telemetry is derived from the capstan tachometer. the telemetry voltage is linear with respect to the motor speed.

Typical Values:

Recorder Mode	Tape Speed IPS	Motor Speed Telemetry (V)
Record	0.418	0.5
PB 128 KBPS	6.693	1.4
PB 256 KBPS	13.386	2.3
Wind	33	5.0

5.7.4.3 Motor Current

Motor current telemetry is derived from the voltage drop across a resistor in series with the motor winding circuit. The current is relatively constant (5.1 volts) for tape speeds above 2 inches per second.

5.7.4.4 Tachometer Sensor (Primary and Secondary)

The output of the capstan tachometer phototransistor is monitored to assess the operating state of the tachometer sensors. The phototransistor receives light from the LED, through the encoder disc outer track of 2600 line pairs, as shown in Figure 5.7-4.

The analog output voltage is inversely proportional to the capstan speed. Typical output values are:

Recorder Mode	Tape Speed IPS	Tachometer Sensor (volts)
Record	0.418	2.6
PB 128 KBPS	6.693	2.2
PB 256 KBPS	13.386	1.6
Wind	33	0.1

5.7.4.5 +5 Volt Power

+5 Volt Power telemetry is derived from measurement of the direct output of the +5 volt secondary voltage supply.

The telemetry is linear with respect to supply voltage, and is 5.0 volts for a supply output of 5 volts, and 0 telemetry volts for 0 supply volts.

5.7.4.6 SEOT, SOBT Sensors

The SEOT and SBOT sensors are phototransistors, which receive light from LED's through tape windows (cleared portions of the tape) at BOT and EOT. The sensors normally receive no light and the telemetry is normally at 0 to 0.7 volts. At EOT or BOT there is a short (5 millisecond) pulse.

5.7.4.7 Reel Sensor, Primary and Redundant

The reel sensors are contributors to both the Primary BOT/EOT sensing and to the tape position indicators, as shown in Figure 5.7-7. The tab on the lower reel of the recorder interrupts the flow of light between the LED and phototransistor of each of two redundant sensor pairs, located to the right of the reels in Figure 5.7-6.

The reel sensor telemetry represents the current in the phototransistor and is typically 5 volts except when the tab interrupts the light from the LED, when it falls to near zero volts.

5.7.4.8 Encoder Sensor; #1, #2, #3 Primary and #1, #2, #3 Secondary

The encoder disc attached to the motor and capstan contains commutator tracks (Figure 5.7-4) that interrupt the light flow from 6 LED's to 6 phototransistors. The signals from the phototransistors (signals A, B, C of Figure 5.7-5) are used to control the excitation of the 3 phase motor.

The encoder sensor telemetry represents the currents in the 6 phototransistors, and is the average of the lighted/not lighted values. At low tape speeds, ripple voltages become apparent. The normal average voltage is 2.5 volts at high speeds to 3.0 volts at low speeds.

5.7.4.9 Playback Voltage, Channels 1 through 8

The playback voltage telemetry is derived from the peak-detected analog playback signal, conditioned to the telemetry voltage range. The telemetry voltage ranges from 0.4 volts to 2.0 volts.

5.7.4.10 EU Temperature

EU temperature is derived from a thermistor mounted at the power transistor in the power supply.

5.7.4.11 TU Temperature

TU temperature is derived from a thermistor mounted on the top of the tape deck near the record/playback head.

5.7.4.12 Ground

The ground telemetry supplies a 0 volt analog signal, and should therefore result in a zero volt signal in ground processing.

5.7.4.13 Power Supply Voltage, -6, -12, +15, +12, and +5 Volts

These telemetry points are the outputs of the secondary supplies, conditioned to the telemetry range.

The typical telemetry voltage for the nominal, nominal +1 volt, and nominal -1 volt output voltage are given below.

	-6 V	-12 V	+15 V	+12 V	+5 V
Nominal +1 V	(-5) 3.2	(-11) 2.4	(+16) 3.75	(+13) 3.4	(+6) 3.0
Nominal	(-6) 2.2	(-12) 1.4	(+15) 3.5	(+12) 3.1	(+5) 2.5
Nominal -1 V	(-7) 1.2	(-13) 0.4	(+14) 3.25	(+11) 2.3	(+4) 2.0

5.7.4.14 Servo Error

An analog signal is derived from within the servo loop that can be used to assess the health of the servo system. The servo error signal is a function of motor speed and varies from nominal depending on parameters such as bearing friction, tape tension, etc. Typical values are shown below:

Recorder Mode	Tape Speed IPS	Telemetry Volts
Record	0.418	0.7
PB 128 KBPS	6.693	1.3
PB 256 KBPS	13.386	1.7
Wind	33	3.7

5.7.4.15 Recorder Total Current

An analog signal is derived by measuring the voltage developed across a 0.1 resistor in series with the return of the primary voltage input to the recorder. The voltage is conditioned to telemetry range by a CA3130 amplifier, which is powered continuously by primary input voltage.

Typical operating values are shown below:

Mode	Input Current (Amps)	Telemetry (Volts)
Standby	.085	0.7
Record	.429	2.9
Playback	.768	5.2
Wind	.429	2.9

5.7.5 TELEMETRY INTERFACE CIRCUITS

The interface circuits for the multiplexed analog telemetry as shown in Figure 5.7-8.

The non-multiplexed analog telemetry interface circuit for the servo error is shown in Figure 5.7-9.

The interface circuits for the multiplexed digital telemetry are shown in Figure 5.7-10.

The non-multiplexed analog telemetry interface circuit for the recorder input current is shown in Figure 5.7-11.

5.7.6 ANALOG TELEMETRY CALIBRATION

For information regarding calibration curves for the telemetered functions, see Appendix A.5.

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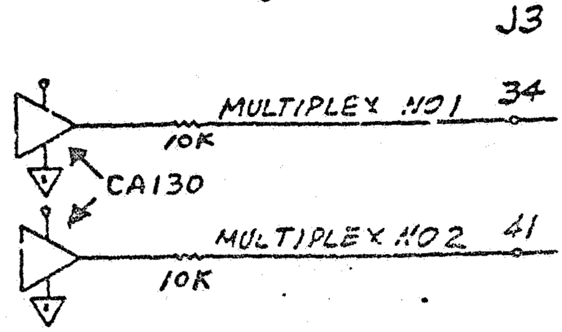
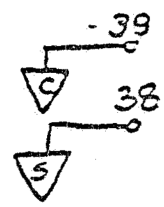


FIGURE 5.7-8 MULTIPLEXED ANALOG TELEMETRY INTERFACE



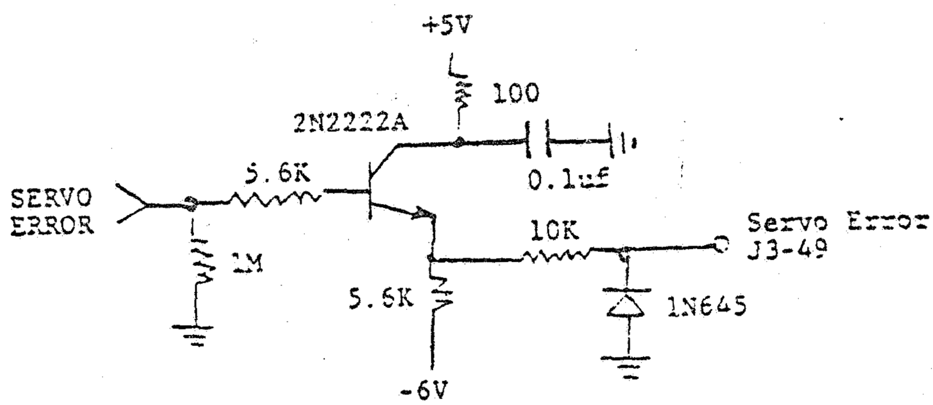


FIGURE 5.7-9 DETAILS OF SERVO ERROR TELEMETRY OUTPUT CIRCUITRY

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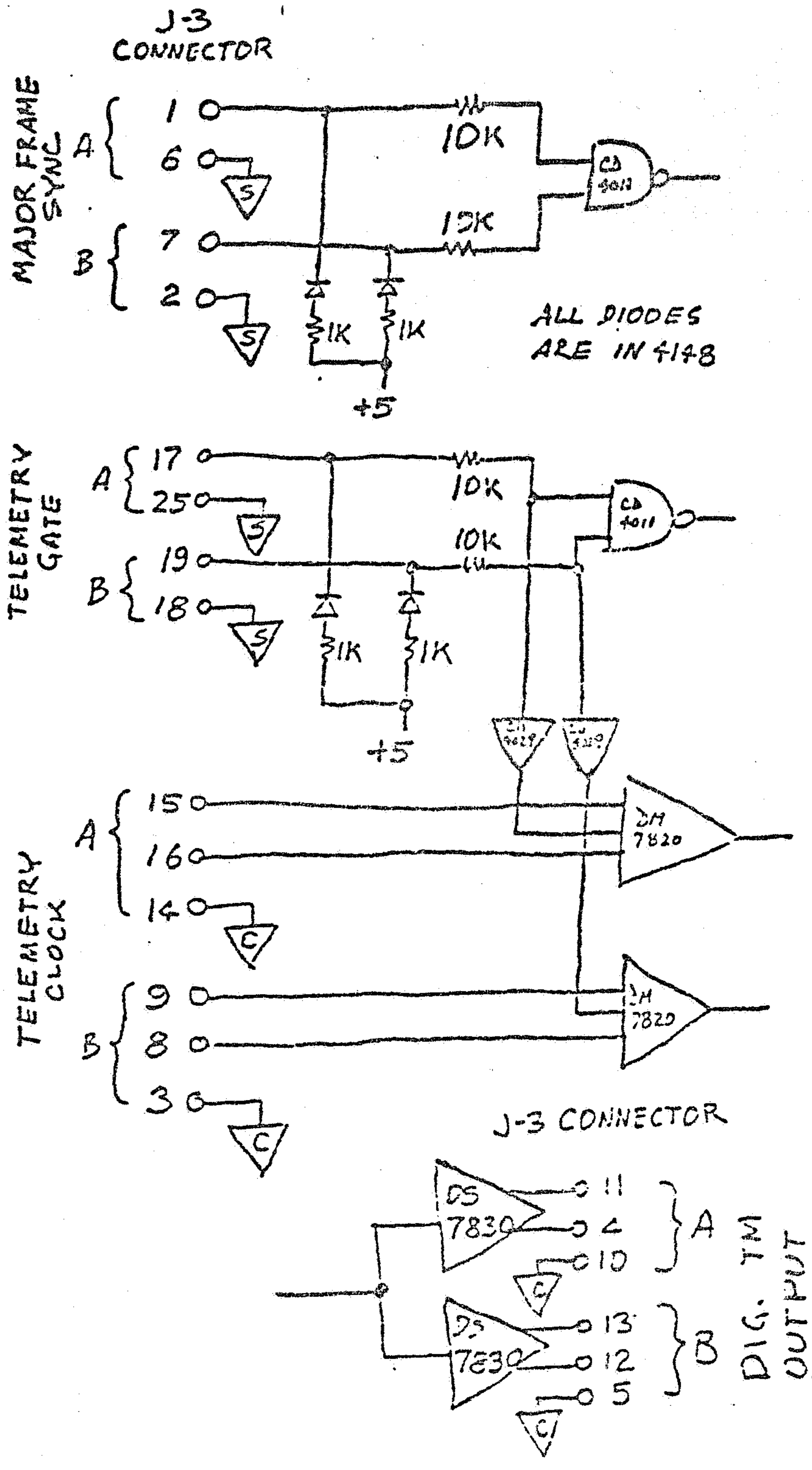

FIGURE 5.7-10 DETAILS OF DIGITAL TELEMETRY INTERFACE

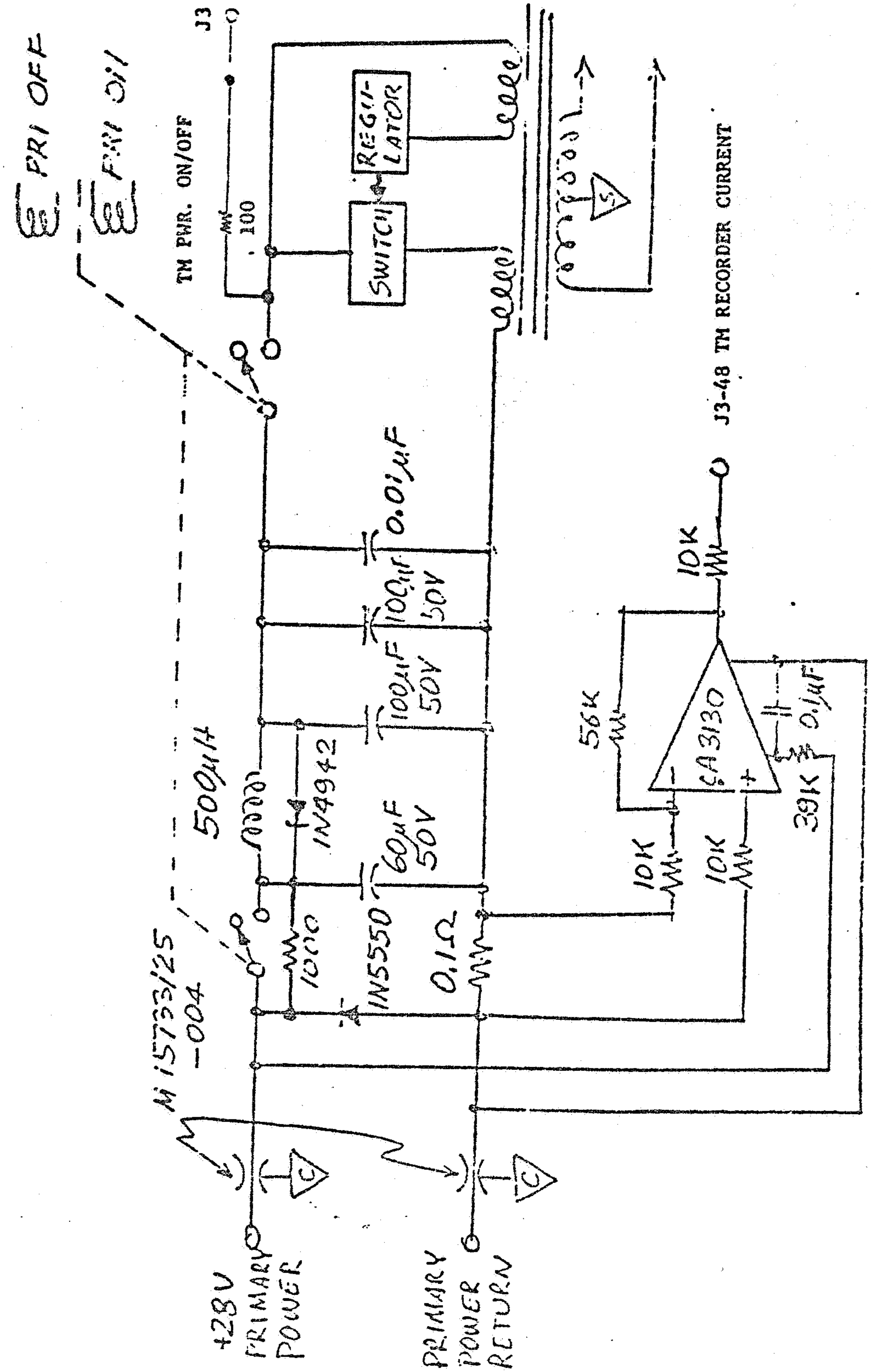

FIGURE 5.7-11. PRIMARY POWER INPUT CIRCUIT

6.0 ON-BOARD COMPUTER

SECTION 6.0

ON-BOARD COMPUTER (OBC)

The On-Board Computer (OBC), NASA Standard Spacecraft Computer (NSSC-1), is a component of the C&DH subsystem. The NSSC-1 used on the multimission modular spacecraft is a general purpose programmable digital computer utilizing an 18-bit word. The Central Processor Module (CPM), contains a conventional CPU, (Central Processing Unit), two's complement arithmetic and an Input-Output with 16 Direct Memory Access (DMA) channels and 16 priority interrupts. The CPU is a double length accumulator, single index register type with 55 single word instructions.

The OBC memory is made up of eight memories and each memory is divided into two banks of 4096 18-bit words. There are 16 memory banks numbered 0-15.

The OBC flight executive technical description is in S-700-5, MMS Flight Executive User's Guide.

6.1 OBC STINT FUNCTIONAL DESCRIPTION

The On Board Computer performs the following functions:

1. Performs on-board computations
2. Provides realtime control for Landsat-D subsystems.
3. Stores commands for subsystems and executes them at specified times.
4. Performs telemetry formatting.

The STINT (STACC Interface) provides all communications to and from the OBC.

Figure 6.1-1 shows a block diagram of the STINT OBC configuration used aboard Landsat-D. The OBC is defined to be the redundant CPMs (Central Processor Modules) and eight memories. Four memories are accessed by the LOWER MEMORY BUS and four are accessed by the UPPER MEMORY BUS. Either CPM can access memory on either memory bus. The Landsat-D flight software requires the use of all eight memories.

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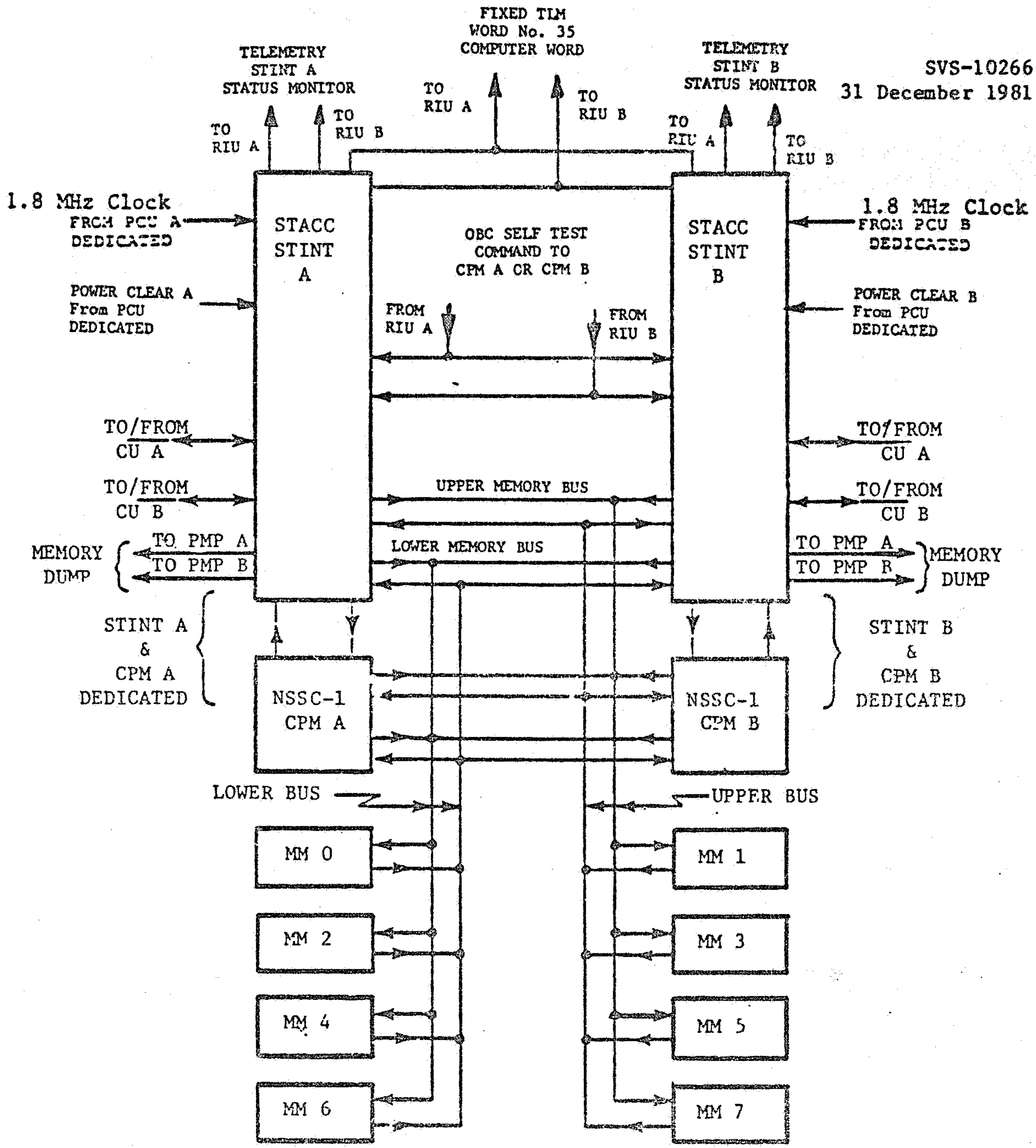

Figure 6.1-1. STACC STINT - OBC Block Diagram

STINT A and CPM A are dedicated, and are powered by dedicate Power Supply A. STINT B and CPM B are dedicated, and are powered by dedicated Power Supply B. The STINT CPM pair is selected by commanding ON the appropriate power supply.

Power Supply A or Power Supply B must not be commanded ON without first commanding the other power supply OFF.

The C&DH Power Control Unit (PCU) contains the power supplies, the 1.8 MHz OBC clocks and the power clear modules. The PCU contains redundant 1.8 MHz Xtal oscillators and redundant power clear modules. Oscillator A is dedicated to STINT OBC A, and oscillator B is dedicated to STINT OBC B. Power clear A is dedicated to STINT A, and power clear B is dedicated to STINT B.

6.1.1 OBC STINT POWER SUPPLIES

Figure 6.1-2 shows the power distribution to the STINT OBC and the ACRONYM for the commands that select the options. Power supply A is dedicated to 1.8 MHz oscillator A, Power Clear A, Computer Failure Detector A, STINT A and CPM A. Power Supply B is dedicated to same units on the "B" side. The A or B side is selected by turning on the corresponding power supply.

The Landsat-D flight software uses the complete eight memories and the memory is not redundant. The two memory po‑‑r select switches must be set to power the memory from the power supply that will be turned ON.

6.1.1.1 Power Clear Unit

The PCU contains redundant power clear circuits. Power Clear A is dedicated to Power Supply A and Power Clear B is dedicated to Power Supply B. The Power Clear circuit is used to send the halt signal to the OBC via the STINT. And when the signal is received, the CLEAR NSSC will be executed to HALT the OBC.

6.1.1.2 OBC STINT Power Fault Conditions

The OBC power supplies have circuits that monitor the output voltage and current and sets up fault conditions for undervoltage, overvoltage and overcurrent. The fault conditions oeprate trip circuits.

The overcurrent and undervoltage faults cause the trip circuit to latch, and the DC/DC converter voltages are turned OFF and remain OFF until restored by appropriate commands. To restore the voltage, the power supply is turned off by sending the Power Supply OFF command followed by the Power Supply ON command. If the fault has cleared, the operation of the power supply is restored.

The overvoltage fault does not latch the trip circuit, and when the fault is removed, the power is restored without sending any commands.

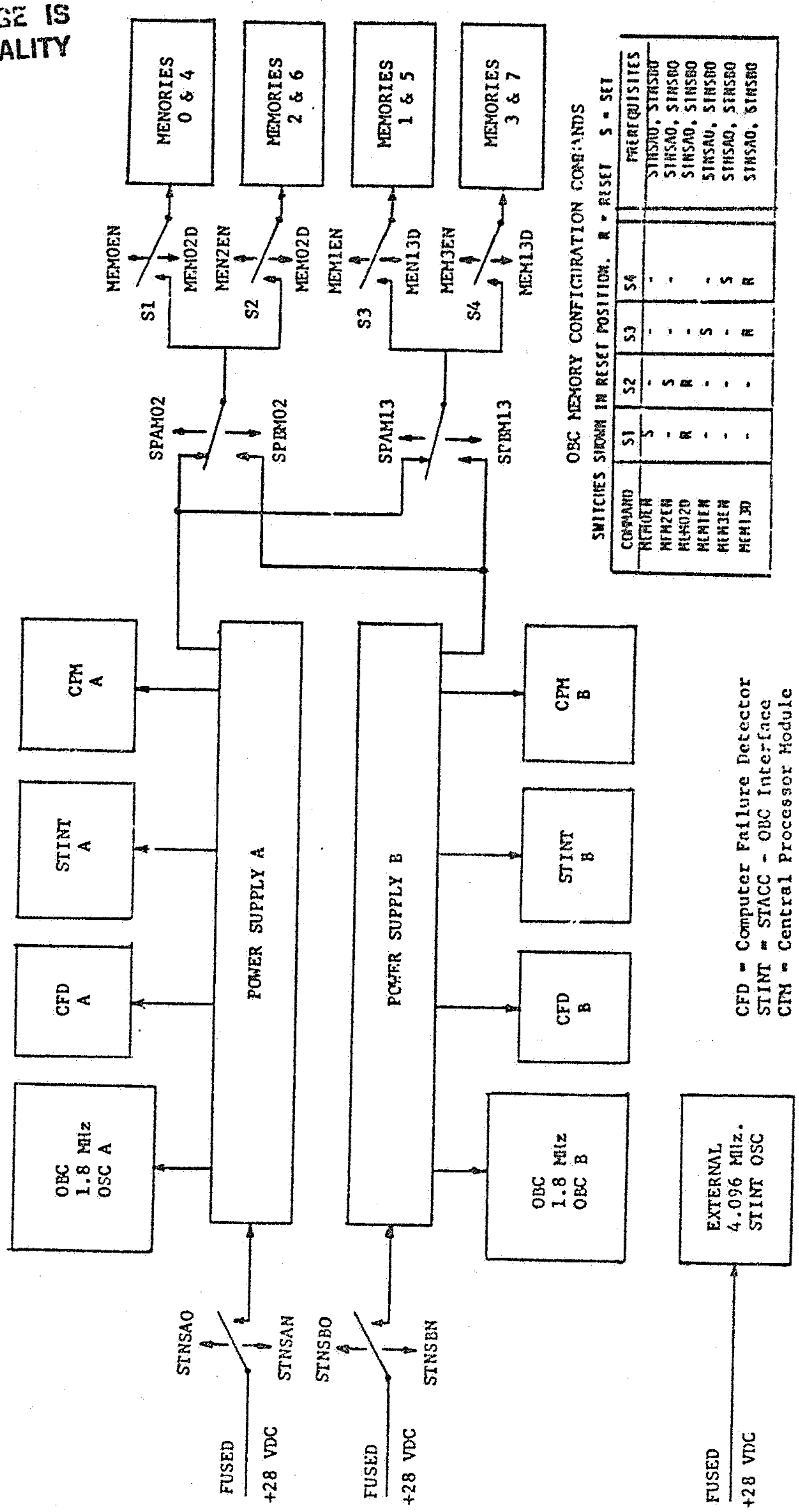

Figure 6.1-2. STINT OBC Power Distribution and Command Acronyms

In all three cases (overvoltage, overcurrent and undervoltage), the Power Clear halts the OBC and the OBC CLEAR NSSC, and INITIATE NSSC preceeded by CFD DISABLE commands must be sent to start the OBC. The Computer Failure Detector (CFD) must be disabled to prevent it from halting the OBC before the OBC can start the OBC Self Test routine.

6.1.1.3 OBC STINT Start Up

The OBC STINT is controlled by discrete commands addressed to RIU 1. The command sequence to power up the OBC STINT is as follows:

1. STINT A AND NSSC A OFF turns off the A side

2. STINT B AND NSSC B OFF turns off the B side

3. ENABLE MEMORY 0 (0 and 4)
   ENABLE MEMORY 2 (2 and 6)
   ENABLE MEMORY 1 (1 and 5)
   ENABLE MEMORY 3 (3 and 7)

   Enables the eight memories.

4. SELECT POWER SUPPLY A MEMORY 0 AND 2, SELECT POWER SUPPLY A MEMORY 1 AND 3 enables the memory to be powered from Power Supply A.

5. STINT A and NSSC A ON

   Turns on the power to STINT A and OBC A and starts OBC functioning in the hardware control mode.

6. DISABLE COMPUTER FAILURE DETECTOR A disables the CFD located in the PCU (Power Control Unit).

7. INITIATE NSSC - Word for computer command starts OBC execution in the software control mode.

8. Initiate the software routines (Processors) that generate the OBC test commands.

9. ENABLE COMPUTER FAILURE DETECTOR A - Enables the CFD and the OBC will halt anytime the CFD fails to receive three consecutive COMPUTER A 1 SECOND TEST discrete commands.

Note that both Power Supply A and B must be OFF for at least 60 seconds before the memory select commands are sent. And both Power Supply A and B must not be ON concurrently.

6.1.2 OBC STINT DATA FLOW

Figure 6.1-3 shows a simplified block diagram of the CU (STACC Central Unit), the STINT, the CPM and the OBC memory. The diagram shows the direction of the data/signal flow between the various units. STINT CPM are dedicated and data flows to the side that is powered ON. The CU STINT units are cross strapped and either CU A or CU B can be used with the STINT CPM that is turned ON. The OBC memory is not redundant.

6.1.2.1 STINT-CU

Each STINT interfaces with both CUs (Figure 6.1-3). The active CU provides sync, enable, clock, data and address signals to both STINTS simultaneously. This provides for four basic computer functions:

1. Transfer of forward link stored commands (or data) to the memories.
2. Telemetry format control and computer data requests from the OBC
3. Stored commands issued from the OBC and
4. Return of computer requested data to the OBC and monitoring of return link data by the OBC.

The CU decodes the forward link commands and the ones for the OBC are transferred to the STINT. OBC telemetry requests and the "stored commands" are transferred from the STINT to the CU. The telemetry request by the OBC is transferred from the CU to the STINT.

6.1.2.2 STINT-OBC

Data transfer between the STINT-OBC is a dedicated transfer. Included in the signals to the OBC are the various CU commands plus the power clear and oscillator signals from the PCU. Signals to the STINT include acknowledgements and various timing functions.

6.1.2.3 STINT and OBC to Memory

The STINT and OBC provide separate upper and lower bus input and outputs. See Figure 6.1-1. Data to a memory bus is obtained in parallel (only one OBC-STINT pair is active), driving all memories on the bus in parallel. The alternate memory bus is fed similarly. Addressing of the memories is provided by the OBC while data is provided by either STINT or OBC.

Output data from the memories to the STINT-OBC have a similiar configuration. Memories on a given bus are parallel and feed the parallel combination of 2 OBCs and 2 STINTs.

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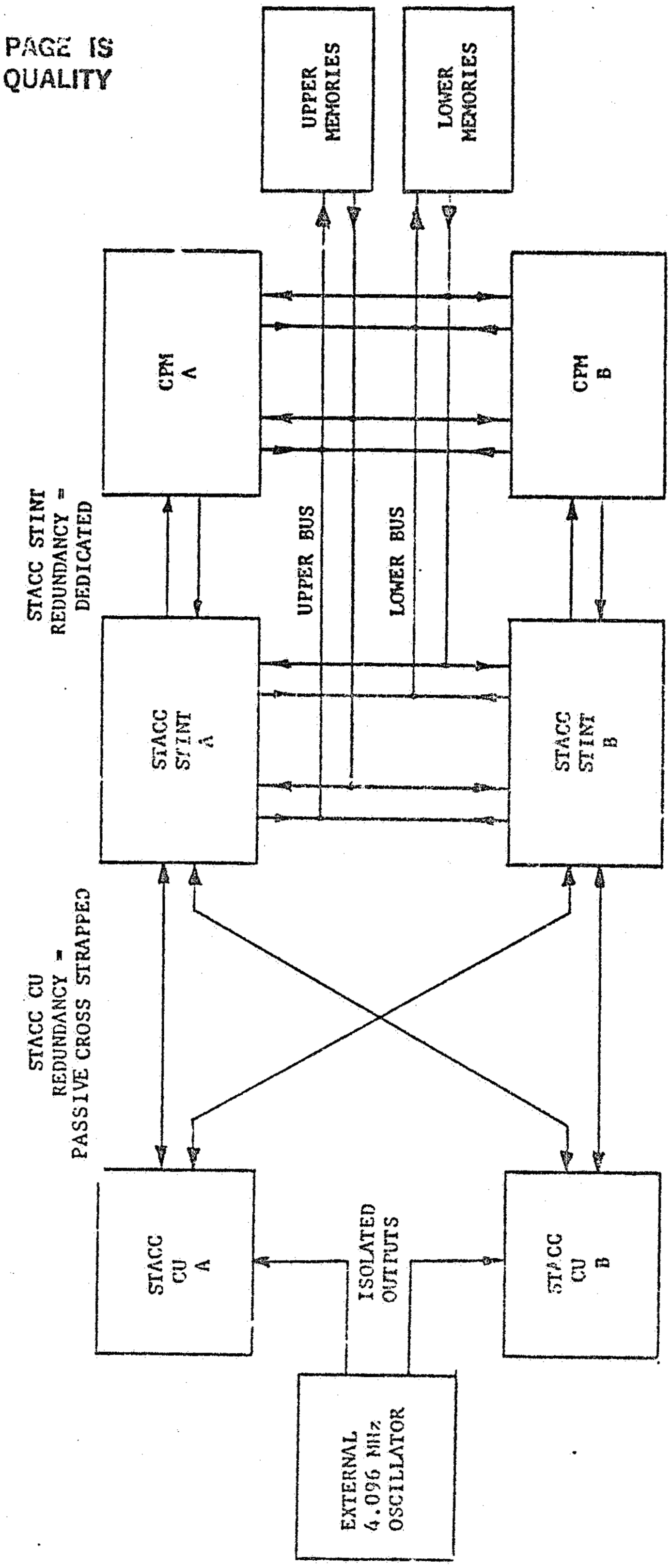

Figure 6.1-3. OBC-STINT Simplified Block Diagram

LSD-WPC-263

6.1.2.4 STINT-PMP

Each STINT supplies memory dump data to the redundant PMPs at the command selectable rate of 32 Kbps or 1 Kbps. Additionally, it provides both a 1X and 2X clock.

6.1.2.5 STINT-PCU

The 1.8 MHz OBC clock and OBC clear are supplied from the PCU. These are dedicated and, associated with the respectrive A and B power supplies. In the absence of either proper voltage to the computer (PCU power clear circuit) or a 1 second self check signal from the computer (before 3 seconds have elapsed) (PCU Computer Failure Detector) the PCU output circuit will provide a ground path and cause the computer to halt. The Computer Failure Detector (CFD) must initially be disabled (by command) in order to start the computer. Once halted, the recurrances of 1 second self check signals will not start the computer. The CFD must be disabled then re-enabled after the processor that sends the OBC Self Test commands once per second is initialized.

6.2 PERFORMANCE CAPABILITIES

The OBC performance capabilities are summarized in Table 6.2-1.

Table 6.2-1. OBC Capability Summary

Function	Capability	Landsat-D Implementation
Word Length	18 Bits	Same
Instruction Word	18 Bits	Same
Data Flow	Parallel	Same
Data Type	Fixed Point Fraction 2's Complement	Same
No. of Instructions	55	Same
Add Time	5.0 Microseconds	Same
Multiply Time	38 Microseconds	Same
Divide Time	75 Microseconds	Same
Clock Rate	800 kHz	Same
No. of Index Registers	One	Same
Operations per Sec.	200K	Same
Indirect Addressing	Load and Store	Same
Accumulator	Double Length	Same
Interrupts	16 Multilevel	Same
Memory Access	Direct, 100K words Per Channel I/O Rate	Same
OBC Memories	4 to 8	8
NSSC-1 Downlink Telemetry Rates	1 or 32 kbps By Command	Same

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6.3 STINT/OBC MODES OF OPERATION

The STINT/OBC are dedicated devices in that STINT A is connected to OBC A. The same is true of the B side. The first level of operating modes therefore is ON or OFF (no power). The modes are summarized as follows:

1. ON/OFF
2. Hardware Controlled (Load or Dump)
3. Software Controlled (Operating System)

The MMS OBC Flight Executive Technical Description, S-700-56B covers the commands for the modes of STINT-NSSC operation.

6.3.1 ON/OFF MODE

The ON Mode is used after the Power (A or B) for memory and memories enable commands are issued. Power A corresponds to STINT A and OBC A. The Computer Failure Detectors in the PCU must be disabled until the OBC is started since 1 second computer self check pulses will begin with OBC initiation. This mode (ON) is used after the STINT-OBC (NSSC) is turned OFF for a few seconds prior to any reconfiguration of the on-line memories. Also, if the PCU protection trip circuit is activated by temporary bus voltage interruption, the OBC-STINT will be shutdown. To restart, the STINT-OBC must be powered OFF then ON, the Computer Failure disabled, the OBC started by a Computer word comand as above.

6.3.2 HARDWARE CONTROLLED MODE

The OBC is controlled by Serial Magnitude commands that are identified as "Computer Word" commands. The OBC command CLEAR NSSC halts the execution of the Flight Software and activates the hardware Controlled Mode. The OBC stops sending the COMPUTER 1 SECOND TEST command and, unless disabled, the CFD causes the spacecraft to transfer to Safehold Mode.

The Hardware Mode acts as a "loader" program. In this mode, the commands can: (1) Select a (4K) fixed memory bank, (2) load fixed bank or (3) dump a fix memory bank. And process the INITIATE NSSC command that starts the execution in the Software Controlled Mode.

6.3.3 SOFTWARE CONTROLLED MODE

The Software Controlled Mode is the mode used when the spacecraft is on orbit. The operation of the OBC is controlled by the Flight Executive Software. While in the Software Mode, commands to the OBC are in the form of Executive Requests. They are uploaded as "Computer Words". An Executive Request creates a software interrupt and the request is processed upon receipt. The Flight Executive is a multi-task operating system. and the executive request is processed as a task and the software interrupt does not HALT the OBC.

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A software memory dump can be made without halting the OBC whereas a hardware memory dump requires the OBC first be halted.

The Executive Request commands are described in detail in the Data Format control Book, Volume III (SVS-10124).

The Software Controlled Mode can execute "stored commands". The stored command execution time is specified by an associated "time tag" command and the stored command is executed when the OBC clock equals the time specified in the time tag.

6.4 OBC/STINT CONSTRAINTS

1. Two operational constraints are imposed in the OBC-STINT operation, both PCU power supplies must be OFF before memory reconfiguration (Power Supply Select and Memory ENABLE/DISABLE) and only one of the two power supplies should be ON at a time.

2. Switching the OBC/STINT can cause garbage to appear on the Multiple Data Bus (MDB) if both power supplies are not commanded OFF first.

6.5 OBC/STINT REDUNDANCY

Active Cross Strapping: Active cross strapping is when redundant units X-A and X-B are cross strapped to redundant units Y-A and Y-B and both X-A and X-B are active. Unit Y-A or unit Y-B can select data from either X-A or X-B as required.

Passive Cross Strapping: Passive cross strapping is when redundant units X-A and X-B are cross strapped to redundant units Y-A and Y-B, and unit Y-A or Y-B can receive data from X-A or X-B depending upon which unit X-A or X-B is turned on.

Dedicated Redundant Units: Dedicated redundancy is when units X-A and Y-A are hardwired and X-B and Y-B are also hardwired. Unit X is dedicated to unit Y.

Figure 6.1-3 shows the CU STINT OBC redundant units. STINT A or STINT B can transfer data to or from CU A or CU B depending upon which CU is powered. The redundant CUs are passively cross strapped to the redundant STINTs.

STINT A is hardwired to CPM A and STINT B is hardwired to CPM B. The STINT CPM pair that is powered communicates with the active CU. The STINT and CPM are dedicated redundant units.

6.6 OBC COMMANDING

6.6.1 OBC STINT COMMANDS

The OBC STINT power supplies and the OBC hardware configuration are controlled by the C&DH Discrete Commands addressed to RIU 1.

The commands are described in detail in the Data Format Control Book, Volume III, SVS-10124.

Commands for the OBC are uploaded in the Serial Magnitude Command format with function code that identifies the command as a "computer word" command. A "computer word" command can be either a hardware command or a software command.

The CLEAR NSSC command halts the operation of the flight executive and starts the OBC operating in the Hardware Controlled Mode. ~~Once~~ the CLEAR NSSC command has been processed, the OBC can now accept the hardware commands.

Commands for the OBC software are called Executive Requests and are processed when the OBC is in the Software Controlled Mode; i.e., the OBC Flight Executive.

6.6.1.1 Memory Configuration Commands

The full complement of eight memories can be configured by enable/disable commands by which the memories are enabled in pairs and disabled in groups of four. As indicated in the table shown in Figure 6.1-2, the prerequisite for any memory enable/disable command is that both OBC/STINT power supplies must be off to prevent damage to the memories or relays. The memory configuration commands are listed below and depicted in Figure 6.1-2.

The memory configuration commands and the telemetry verifications are as follows:

Command Acronym	Command Description	Telemetry Verification
MEM02D	DISABLE MEMORY 0 and disables memories 0, 2, 4 and 6	CMEM0FD=0
MEM13D	DISABLE MEMORY 1 and 3 disables memories 1, 3, 5 and 7	CMEM1FD=0
MEM1EN	ENABLE MEMORY 1 enables memories 1 and 5	CMEM1FD=1
MEM3EN	ENABLE MEMORY 3 enables memories 3 and 7	CMEM3FD=1

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MEM0EN	ENABLE MEMORY 0 enables memories 0 and 4	CMEM0FD=1
MEM2EN	ENABLE MEMORY 2 enables memories 2 and 6	CMLM2FD=1

6.6.1.2 Computer Failure Detection Commands

Each STINT CPM pair has its own failure detection circuit which is powered by the dedicated power supply. The circuit checks that a computer 1 second command has been received from the OBC via this RIU A or B within the last three seconds. If either condition is not satisfied, the failure detection circuit sends a signal to the Power clear circuit and the Power clear sends a signal to the STINT which halts the computer. The circuitry can be enabled/disabled by command. It must be disabled in order to start the computer because a halted computer does not generate the 1 second commands used by the failure detection circuit. The commands associated with the failure detection circuits are listed below. Telemetry verifications for the enable/disable functions are obtained from the monitors CCFDAED and CCFDBED. The only verification of the 1 second commands is that the OBC has not halted.

OBC A	OBC B	Failure Detection	Telemetry Verification	
CPFDDA	CPFDDB	Disable	CCFDAED=0	CCFDBED=0
CPFDEA	CPFDEB	Enable	CCFDAED=1	CCFDBED=1
CA1SEC	SB1SEC	(From operating OBC)	None	None

6.6.2 COMPUTER WORD COMMANDS

C&DH Serial Magnitude Commands for the OBC have a "Computer Word" function code. These commands are decoded by the STACC Central Unit and sent directly to the OBC via the STINT.

6.6.2.1 OBC Hardware Commands

A "Computer Word" command can be either an OBC hardware command or an executive request command. The hardware commands are processed when the OBC is in the Hardware Controlled Mode. The Hardware Controlled Mode is used to load or dump the OBC memory contents.

Table 6.6-1 contains a list of the OBC hardware commands and a description of each command.

Table 6.6-1. OBC Hardware Commands

	OBC COMMANDS	DESCRIPTION	MEMORY LENGTH WORD	GROUND COMMAND REQUIREMENTS	REMARKS
1.	Clear OBC (NSSC)	Halts the OBC	N/A	Unique Hardware Command to OBC	No Change to Memory; Most registers set = Ø; Bank Ø is selected. Disable CIO in PCU first
2.	Initiate OBC (NSSC)	Begin execution of EXEC from initial start	N/A	Unique Hardware Command to OBC. Should always be preceded by Clear	If S/W needs other than fixed bank Ø, select fixed bank first. Enable CFD in PCU afterwards
3.	Select Fixed Bank	Selects a given bank as the fixed bank	N/A	Unique Hardware Command to OBC	Usually Ø for EXEC System processing otherwise select new fixed band for EXEC, LOAD, or DUMP
4.	Load Fixed Bank	Load/Reload program segemtns	1 to 4096	Send: CLEAR, SELECT FIXED BANK and series of LOAD FIXED BANK COMMANDS (3 to 4098 total) plus — Any Failure: BAP register points to next addr & telemetry Command Counter points to command that failed Continuing Cmds auto. places data in next correction address in SELECTED FIXED Bank.	Send: CLEAR SELECT FIXED BANK & Initiate commands.
5	Dump Fixed Bank	Entire logical bank is dumped. Dumps band 4 times. Begin at FFFØ	4096	Send: CLEAR, SELECT FIXED BANK, DUMP FIXED BANK Plus	Same as Above
1.	Executive Request Command Formats:	Various Commands acted upon by Software	Varies	Varies	Varies
2.	Software Load	Loads data in Memory	1 to 4096	Multiple commands following EXEC request Command	Inhibit Memory Checksum first. See Executive Request Cmd #1)

Table 6.6-2. Executive Request Commands

	OBC COMMANDS	DESCRIPTION	INPUT LENGTH WORDS	GROUND COMMAND REQUIREMENTS	REMARKS
1.	SOFTWARE MEMORY LOAD	Loads Memory under Software Control concurrent with execution of flight software	1 to 4096	EXEC REQ CODE = 01 with number locations, Start addr., & Data (SOFTWARE MEMORY LOAD) commands (type 7, see table 7-14)	Must send new memory checksum and put in System Table 13 afterwards then enable Memory Checksum.
2.	SOFTWARE DUMP	Dumps consecutive addresses of memory concurrent with exec of flight software. Sent 4 times	0 to 4096 (56 to 4096 effectively)	EXEC REQ CODE = 02 with number locations, Start Address. Short dumps increased to 56 words.	Area dump may be garbage if Application Processors are storing data. May need to inhibit processor(s) execution momentarily.
3.	LOAD STORED COMMANDS (Absolute)	Load commands in the stored command buffer (See #5 below for time tags)	2/delayed command	EXEC REQ CODE = 03 with number of commands, start location (Relative location in buffer) followed by the "N" number of stored commands (delayed command format-function code ØØ).	Send stored commands first, then send time tagged commands second. May need to inhibit ATCP temporarily then reenable or LOAD STORED COMMAND POINTER below.
4.	INHIBIT & RESTART SCHEDULER TABLE PROCESSING	Executive Schedules Tables Processing is inhibited immediately or restarted at the major frame sync.	N/A	EXEC REQ CODE = Ø4 with operand of 1 = inhibit Ø = restart	No second operand inhibit = immediate effect restart = delayed by up to one major frame for synch of scheduler Table with telemetry & S/C clock
5.	LOAD TIME TAGS FOR STORED COMMANDS (Absolute or Psuedo Ops)	Loads Absolute time tags loaded in companion buffer to stored commands above Tag associated with delayed command purily by relative position in buffer for use by ATCP	2/time tagged command	EXEC REQ CODE = 05 with either absolute time tag ro Psuedo Ops (high order 9 bits) and operand (if necessary in law order 18 bits). Psuedo Ops — Operand (if applicable) Ø = Realtime Command — 18 bits = law order bits of OBS clock to send this cmd. 1 = Jump — 16 bits = jump to relative command (position) in the buffer. 2. No OP — N/A = skips to next command 3. Halt — N/A = inhibits ATCP execution 4. Predefined Block — 16 bits = relative block to be processed. 5. Activate an RTS — 16 bits = sequence number of RTS to be activated.	Psuedo-Ops can be added to the high order 9 bits in which case the low order bits have different meanings or not used (N/A). Psuedo-Ops code 6 and 7 are not used

Table 6.6-2. Executive Request Commands

	OBC COMMANDS	DESCRIPTION	MEMORY LENGTH WORDS	GROUND COMMAND REQUIREMENTS	REMARKS
6.	DUMP A SYSTEM TABLE	Dumps a system table by number (no address needed)	56 to varies	EXEC REQ CODE = Ø6 with table number. No 2nd operand	Short tables are increased to 56 words to software dump the table.
7.	LOAD A SYSTEM TABLE	Loads a system table without the absolute address using table number only	1 or more	EXEC REQ CODE = Ø7 with table number, number of words in table, series of SOFTWARE MEMORY LOAD commands (type 7 in table 7-14)	Can change just the first part of a table and leaves remainder of table unchanged. If number of words in greater than actual table length, the entire request is ignored and result put in status buffer.
8.	LOAD A TABLE OF ADDRESSES TO CONTROL TELEMETRY FORMAT	Loads list of RIU addresses Main Frame or Subcom (See DFCB Vol III for RIU Address Formats).	120 (for minor frame 768 for subcom)	EXEC REQ CODE = Ø8 with indicator 1 = subcom Ø is Main Frame, series of 120 or 768 SOFTWARE LOAD COMMANDS (type 7 in table 7-14) 120 minor frame words excludes fixed words (0-3 & 64-67)	Can't send while OBC controlling telemetry format: System refused to act on request if OBC is in control of format & indicates error in status buffer report.
9.	PROCESSOR CONTROL	Controls a processor to: 1 = Request Execution 2 = Inhibit Execution 4 = Reenable Execution 10_8 = Inhibit Sending Commands 20_8 = Reenable Sending Commands 40_8 = Reinitialize Self	N/A	EXEC REQ CODE = Ø9 with processor number located in PCT table in operand, second operand function to perform in its f_{20} - f_{25} Action remains in effect until changed by ground or another processor	Can have multiple ac ons but must not be contrad.:tary. Req Exec = Executes 1 time based on priority Inhibited = Remains in effect until changed by Ground or another Processor Reenable = Same as above Inhibit/Reenable Sending Cmds = takes effect next time Processor restarted or started Initialize = Effective next time Processor starts from begin; not in the middle of its execution.
10.	LOAD STORED COMMAND POINTER	Restarts Absolute time Command Processing at new starting point in command buffer.	N/A	EXEC REQ CODE = 10 plus relative command number to start with in command buffer processing in 2nd operand. 1st operand is ignored. Note: location is a relative command number and not an address.	Processor is initialized & Reenabled if previously inhibited.
11.	INHIBIT MEMORY CHECK	Inhibits memory to prevent executive falsely reporting memory errors while doing a software load	N/A	EXEC REQ CODE = 11 No operands used	Processor MEMCK must be re-enabled after the load. A new checksum must be calculated by OCC and put into System Table 13 before MEMCK is reenabled.

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Table 6.6-2. Executive Request Commands

	OBC COMMAND	DESCRIPTION	MEMORY LENGTH WORDS	GROUND COMMAND REQUIREMENTS	REMARKS
12.	CHANGE CONTROL OF TELEMETRY FORMAT	Transfers Control of telemetry format among ROM 1, ROM 2, or OBC	N/A	EXEC REQ CODE = 12, Operand: 1 = ROM 1 - Engineering Format 2 - ROM 2 - Missing Format 3 = OBC - Ground No second operand	If OBC is to control: Must have loaded tables via Request Code 8 avove first.
13.	ZERO REPORTS IN OBC CONTRIBUTION TO TELEMETRY	Zero's/Clears reports in OBC that must be acknowledged by OCC	Varies	EXEC REQ CODE = 13 with I.D. of report to be zeroed (256 = zero all reports)	The OBC contribution to telemetry is zeroed after the ground acknowledges the report.
14.	DUMP AND RESET STATUS BUFFER	Dumps or Resets the Status Buffer	Varies	EXEC REQ CODE = 14 with operand: 1 = dump Ø = reinitialize the buffer no 2nd operand	If dumped, the status buffer must be reinitialized to allow new reports to be stored.
15.	DUMP STORED COMMAND BUFFER (Absolute)	Dumps stored command buffer used by ATCP.	56 or more	EXEC REQ CODE = 15 operand field is ignored no 2nd operand	Dump repeated 4 times minimum 56 words/dump
16.	LOAD A PREDEFINED BLOCK OF COMMANDS	Loads a predefined block of commands in a buffer - SPREBUF	32	EXEC REQ CODE = 16 with serial number of block to be loaded (which identifies the location the block is going to be stored into) plus 16 Delayed Commands (function ØØ for bits R_1 and R_2) See DFCR Vol III, Command, must be transmitted.	16 delayed commands are stored. No time tags used. First command must be a discrete command.
17.	DUMP BUFFER OF PREDEFINED BLOCKS OF COMMANDS	Initiates a software dump of the entire memory area containing the blocks of commands.	56 or more	EXEC REQ CODE = 17, no operands No 2nd operand	Get all blocks of SPREBUF in the dump
18.	RESERVE SPACE FOR A RELATIVE TIME SEQUENCE (RTS)	Sets aside space in the RTS Buffer	Varies: A cmd = 4 wds (2 wds for cmd & 2 wds for the relative time	EXEC REQ CODE = 18 with operand = identification number and second operand = maximum number of commands the RTS will ever have in it. (Not words).	Values are stored in the index entry to show the limits of the area set aside (or number of commands). A new request for less space is ignored. A new request for more space is reserved and old space is abandoned
19.	LOAD COMMANDS FOR AN RTS	Loads commands into space previously reserved for an RTS	Varies: 2 words per command	EXEC REQ CODE = 19 with serial number of RTS to be loaded, number of commands to be loaded plus commands in delayed command format (Function Code R_1 & R_2 = ØØ).	Number of commands (in RTS) must not exceed space reserved. Need "times" for each command (See item 20 below).

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Table 6.6-2. Executive Request Commands

	OBC COMMAND	DESCRIPTION	MEMORY LENGTH WORDS	GROUND COMMAND REQUIREMENTS	REMARKS
20.	LOAD COUNTS FOR AN RTS (time in terms of Processor execution times)	Loads "times" associated with commands in the RTS above.	Varies: 2 words per command	EXEC REQ CODE = 20 with serial number of RTS to be loaded, number of counts (times) to be loaded plus sequence of counts, (software load format or as in time tags for absolute time commands). Count = zero: the command is executed at the same time as its processor.	Number of commands above determine number of "time" tags commands needed. Processor RTCP frequency execution interval is Scheduler Table dependent (mission unique).
21.	DUMP AN RTS OR RTS INDEX	Dump the contents of the RTS (sequence)or the RTS index (number of commands in the RTS is stored in the index)	Varies Minimum 56 words dumped	EXEC REQ CODE = 21 with the operand = serial number of the RTS sequence wanted If operand = 7777 octal, the index of the RTS is dumped.	All space for the RTS will be dumped regardless of the number of commands stored some space may be empty.
22.	CLEAR THE RTS BUFFER	Clears all memory space reserved for the RTS's. Space must be reserved (both commands and times must be loaded).	N/A	EXEC REQ CODE = 22 and no operand used No 2nd operand	When RTS's are abandoned, eventually, a new RTS will overflow the memory space alotted for this buffer
23.	CONTROL AN RTS	Ground can activate, halt, inhibit or reenable an RTS	N/A	EXEC REQ CODE = 23 with serial number of the RTS & function code as follows: 1 = activate (starts at beginning) 2 = inhibit (if active - goes to end then inhibited) 4 = reenable (if halted - starts at beginning) 10 = halt (immediately halts in sequence)	Any noncontradictory set of bits can be used
24.	CHANGE THE TELEMETRY BIT RATE	Changes the telemetry bit rate via the Executive on a major frame beginning	N/A	EXEC REQ CODE = 24 with operand: 0 = 1 KBPS * 1 = 2 KBPS 2 = 4 KBPS 3 = 8 KBPS * 4 = 16 KBPS 5 = 32 KBPS 6 = 64 KBPS No 2nd operand	Codes express the rate in kilobits/second as a power of 2 word 3 of telemetry shows the new rate
25.	DUMP TELEMETRY FORMAT TABLES	Dumps a telemetry format table	120 or 768	EXEC REQ CODE = 25 with operand: 0 = dump minor frame 1 = dump subcom No 2nd operand	Previously loaded (request code = 8) minor frame and subcom tables.

6.6.2.2 OBC Software Commands

Commands for the OBC software are Computer Word commands in the form of Executive Requests. Executive Request commands are processed when the OBC is in the Software Controlled Mode which is the normal mode for on-orbit operation. An Executive Request generates a software interrupt and is processed when received by the OBC. Executive requests differ from hardware command in that executive requests can be processed without halting the OBC.

Table 6.6-2 contains a list of the Executive Request commands and a description of each command.

6.6.2.3 COIL Command Procedures

The OBC hardware and software commands are uploaded in the C&DH Serial Magnitude Command format. These commands are generated by the COIL (Computer Operator Interface Language) program. The Landsat-D Ground Segment Control and Simulation COIL Users Guide describes the COIL procedures needed to upload the OBC commands. The COIL command names are not the same as the names used in the Data Format Control Book and care must be exercised to avoid confusion.

The "/OBC" COIL directive is used to send commands that control the hardware and software operation of the flight computer (OBC). Mnemonic formats described in the following paragraphs may cause more than one command to be sent depending upon the operation to be performed.

General Format: (Different formats exist depending on the function to be performed)

1. To initiate a hardware load of the selected fixed bank:

   /OBC LOAD, HDW, source

   where:

   source is the file containing the load data

   *bank number was previously entered by the

   /OBC, FIXB, banknumber' directive.

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2. To initiate a software memory load:

   /OBC LOAD, SFT, source

   where:

   source = file containing load data

3. To initiate a table load of an OBC flight executive table.

   ´/OBC, LOAD, TBL, Table number

   where:

   Table number - the number of OBC system table to load

4. To initiate a hardware dump of the selected fixed bank:

   /OBC DUMP, HDW, destination

   where:

   Destination is the file to receive and store the raw dump.

5. To initiate an OBC software dump:

   /OBC DUMP, SFT, START LOC (OCTAL), NUMBER WORDS (DEC)

   where:

   destination = file in which to store dump.

6. To initiate an OBC flight executive table dump:

   /OBC DUMP, TBL, ´table number´

   where:

   ´table number´ is the table to be dumped.

7. To initiate an OBC status buffer dump.

   /OBC DUMP, SBF, destination

   where:

   destination is the file to contain the raw dump.

8. To reset the flight computer hardware:

/OBC, RESET

9. To select the OBC Fixed Bank for a memory load/dump and/or the software system execution:

/OBC FIXB, bank number

where:

"bank number" is the selected fixed bank (0-15).

10. to initiate and start the OBC flight software:

/OBC, START

11. To clear the OBC status buffer:

/OBC, CLEAR

12. To control the execution of an OBC applications processor:

/OBC, PCNTL, processor ID, function code

where:

processor ID = the software processor identification number (0-63)

function code = octal representation of the function desired (0-777777)

13. To patch OBC memory locations:

/OBC, PATCH, absolute address, data

where:

absolute address = (0-65535)

data = 18 bit value to load into address (octal)

14. To initialize of restart schedule table processing:

/OBC, SCHTAB, function

where:

function = 'RESTART' to restart scheduler table processing

'INITIALIZE' to initia.ize scheduler table processing

15. To inhibit OBC memory checking:

/OBC, INHMFM

16. To change control of the telemetry format:

/OBC, TMCNTL, source

where:

Source = 'ROM1' Engineering Format
'ROM2' Mission Format
'OBC' Special

17. To zero reports in OBC contribution to telemetry:

/OBC, TMZERO, Report Number

where:

Report number = 0 - 256 decimal

Note: 256 = zero all reports

18. Change the telemetry bit rate:

/OBC, TMBITR, bit rate in Kbps

where:

bit rate in Kbps = 1
2
4
8
16
32
64

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6.7 OBC STINT TELEMETRY

The OBC STINT telemetry gives the status of the hardware. Table 6.7-1 defines the telemetry points and the acronyms used by the ground segment to identify the specific telemetry points.

Telemetry is described in detail in the Data Format Control Book, Volume III, SVS-10123.

Once every second the OBC sends an OBC Self Test command via RIU-1 to itself. It also sends a Computer A/B 1-second Test command to the Computer Failure Detector A/B located in the C&DH Power Control Unit. If the failure detections are enabled and the command is not received for three consecutive commands, the OBC will be halt . The fact that the OBC has not been halted indicates that the OBC is operating in the Software Controlled Mode.

Table 6.7-1. OBC-STINT Status Telemetry

```
User ID C/DH-26 Bilevel word 160:

     STACC STINT A, NSSC A
          CSTOBCA=0      OFF
                 =1      ON

     COMPUTER FAILURE DET A
          CCFDAED=0      DISABLED
                 =1      ENABLED

     STACC STINT B, NSSC B
          CSTOBCB=0      OFF
                 =1      ON

     COMPUTER FAILURE DET B
          CCFDBED=0      DISABLED
                 =1      ENABLED

     PWR SUPPLY FOR MEM 1, 3, 5 and 7
          CPWRM13=0      POWER SUPPLY A
                 =1      POWER SUPPLY B

     PWR SUPPLY FOR MEM 02, 4, and 6
          CPWRM02=0      POWER SUPPLY A
                 =1      POWER SUPPLY B

User ID C/DH-27 Bilevel word 170:

     MEM 1 and 5
          CMEM1ED=0      DISABLED
                 =1      ENABLED

     MEM 2 and 6
          CMEM2ED=0      DISABLED
                 =1      ENABLED

     MEM 3 and 7
          CMEM3ED=0      DISABLED
                 =1      ENABLED

     MEM 0 and 4
          CMEM0ED=0      DISABLED
                         ENABLED
```

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Table 6.7-1. OBC-STINT Status Telemetry

User ID C/DH-12 Serial digital

OBC DUMP MEMORY BANK ID, STINT A:

CADMPID=0	MEM BANK 15
=1	MEM BANK 14
=2	MEM BANK 13
=3	MEM BANK 12
=4	MEM BANK 11
=5	MEM BANK 10
=6	MEM BANK 9
=7	MEM BANK 8
=8	MEM BANK 7
=9	MEM BANK 6
=10	MEM BANK 5
=11	MEM BANK 4
=12	MEM BANK 3
=13	MEM BANK 2
=14	MEM BANK 1
=15	MEM BANK 0

TYPE DUMP, STINT A

CADMPHS=0	SOFTWARE DUMP
=1	HARDWARE DUMP
=2	Not Used
=3	NO DUMP

User ID C/DH-13 Serial digital

OBC DUMP MEMORY BANK ID, STINT B

CBDMPID=0	MEM BANK 15
=1	MEM BANK 14
=2	MEM BANK 13
=3	MEM BANK 12
=4	MEM BANK 11
=5	MEM BANK 10
=6	MEM BANK 9
=7	MEM BANK 8
=8	MEM BANK 7
=9	MEM BANK 6
=10	MEM BANK 5
=11	MEM BANK 4
=12	MEM BANK 3
=13	MEM BANK 2

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Table 6.7-1. OBC-STINT Status Telemetry

=14	MEM BANK 1
=15	MEM BANK 0
TYPE DUMP, STINT B	
CBDMPHS=0	SOFTWARE DUMP
=1	HARDWARE DUMP
=2	Not Used
=3	NO DUMP

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7.0 PROPULSION MODULE SUBSYSTEM

7.0 PMS

SECTION 7.0

PROPULSION MODULE SUBSYSTEM

Orbit adjust and attitude control capability for the Landsat-D is provided by the PM-1A Propulsion Module Subsystem of the three axis stabilized Multimission Modular Spacecraft (MMS).

The PM-1A Propulsion Module Subsystem which consists of the PM1 and Auxiliary Tank Kit is used in conjunction with a Modular Power Subsystem (MPS), a Modular Attitude Control System (MACS), a Communication and Data Handling Module (C&DH) and a Signal Conditioning and Control Unit (SC&CU) to form the MMS. The MMS is adaptable to various types of missions ranging from a near-earth, circular orbit to geosynchronous orbits. For the Landsat-D application a circular, sun synchronous orbit will be employed.

7.1 PM-1A FUNCTIONAL DESCRIPTION

The PM-1A consists of a Propulsion Module (PM-1A), an Auxiliary Tank Kit (ATK) and full lines that together have a maximum hydrazine propellant capacity of 517.20 lbs. and 3.2 lbs of nitrogen pressurant. 510 lbs. of the propellant are usable; approximately 7.2 lbs. are needed to fill the lines to the thrusters.

The PM-1A Propulsion Module subsystem provides orbit adjust thrusters integrated with attitude control thrusters. The attitude control thrusters are also used for initial and backup attitude acquisition, and for reaction wheel momentum unloading. The design is a mass expulsion hydrazine subsystem using nitrogen pressurant in a blowdown mode as illustrated in Figure 7.1-1. The propellant and pressurant for both the attitude control and translation thrusters are stored in four spherical tanks each containing an elastomeric positive expulsion diaphragm which separates the pressurant from the propellant and retains propellant at the outlet ports. Component contaminate damage is eliminated by location of a high capacity filter in the feed line to the thruster manifolds. ATK contains approximately 345 lbs. of propellant whereas the three PM-1 tanks contain 167 lbs. of propellant. Blowdown ratio of the ATK is 6-to-1; the three PM-1 tank ratio is 3-to-1.

The thrusters are divided into two component sets, each capable of performing all mission functions, and are mounted in four Rocket Engine Modules (REM's). The general layout of the primary and backup REM's and the thrusters in each REM is illustrated in Figure 7.1-2.

Each REM, groups three 0.2 lbf attitude control thrusters and one 5 lbf translation thruster into one basic unit. The translation thrusters are used for orbit adjusts. The ACS thrusters are for attitude control only. The thrust levels drop as propellant is expended. Latch valves are used to provide malfunction protection.

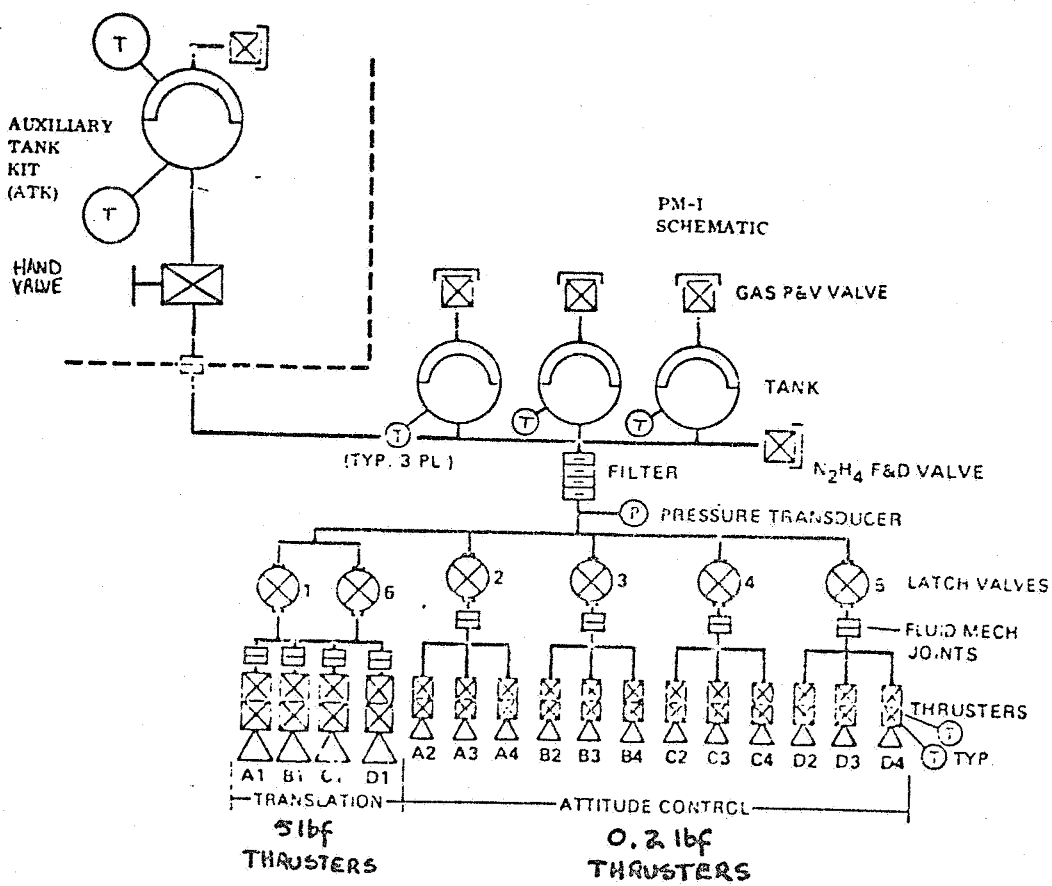

Figure 7.1-1. PM-1A System Schematic

PROPULSION MODULE (BOTTOM VIEW) LOOKING FORWARD TOWARD PAYLOAD

- X, Y, Z ARE MACS CONTROL AXES

REMS A & C BACKUP, B & D PRIMARY

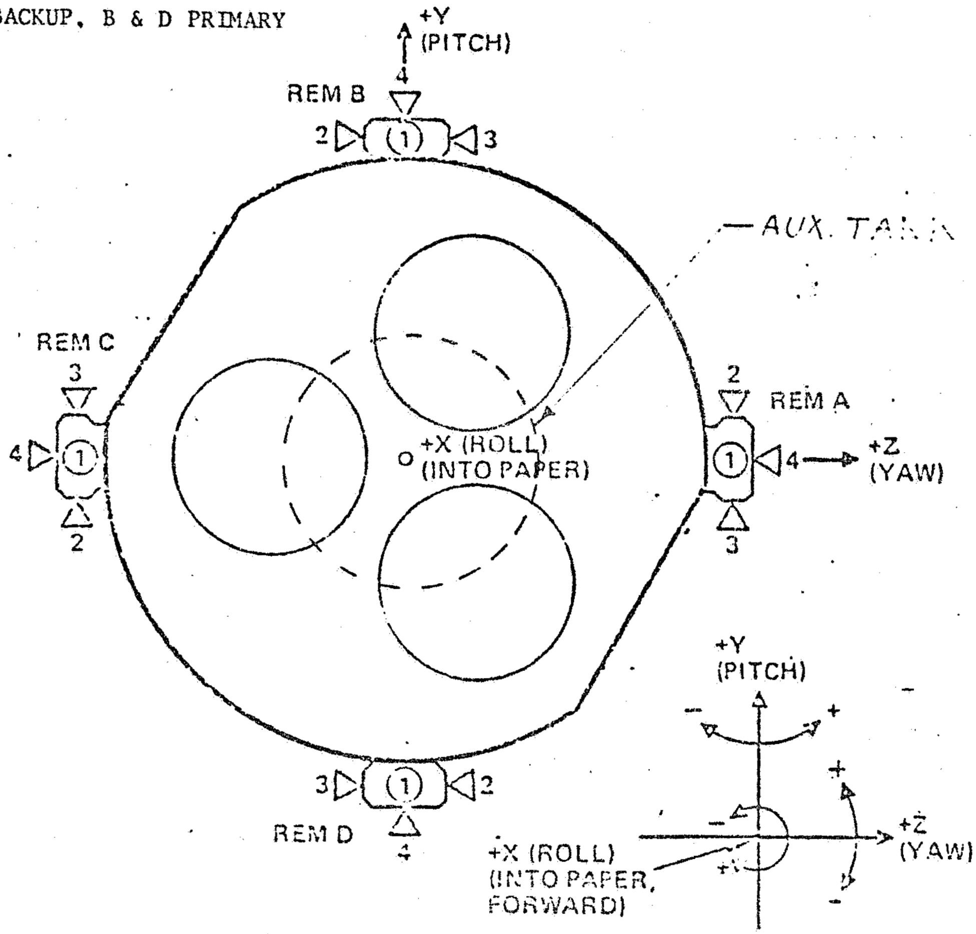

Figure 7.1-2. PM-1A Propulsion Module - Aft View

The Propulsion Module is required to 1) decode, route and properly execute the various commands; 2) supply the required thrust levels and durations in the proper directions; 3) collect, encode and route the required telemetry back to the spacecraft; 4) provide mechanical support during launch, operation and retrieval; and 5) maintain a tightly controlled thermal environment. These functions are accomplished by using the following hardware.

1. Commands with the exception of the ATK, are routed from the interface connector to one of two redundant remote interface units (RIU) which decodes the commands and routes them to the appropriate input of one of the two redundant Propulsion Module Electronic (PME) units. A simplified block diagram of the Remote Interface Unit (RIU) is shown in Figure 7.1-3.

2. The PME takes the commands, operates upon them and drives the required relays and valves. Operation of the appropriate valves allows hydrazine to flow from the tanks to the required thrusters where it is catalytically decomposed to provide thrust. Sixteen thrusters are provided with four in each of the four Rocket Engine Modules (REM). Two of the REM's are redundant to the other two.

3. Telemetry, with the exception of the ATK, signals are routed back from the relays and valves through the PME, where they are combined. From the PME the telemetry signals are routed to the RIU where they are encoded after which they are routed through the interface connector to the spacecraft.

   In addition to the telemetry signals above, subsystem pressure and various module temperatures are also telemetered. The commands and telemetry necessary for the operation of the PM-1A Propulsion Module are listed in Paragraphs 7.6 and 7.7, respectively.

4. Power, telemetry and command, and electrical interface requirements for the Auxiliary Tank Kit (ATK) are handled by the Signal Conditioning and Control Unit (SC&CU).

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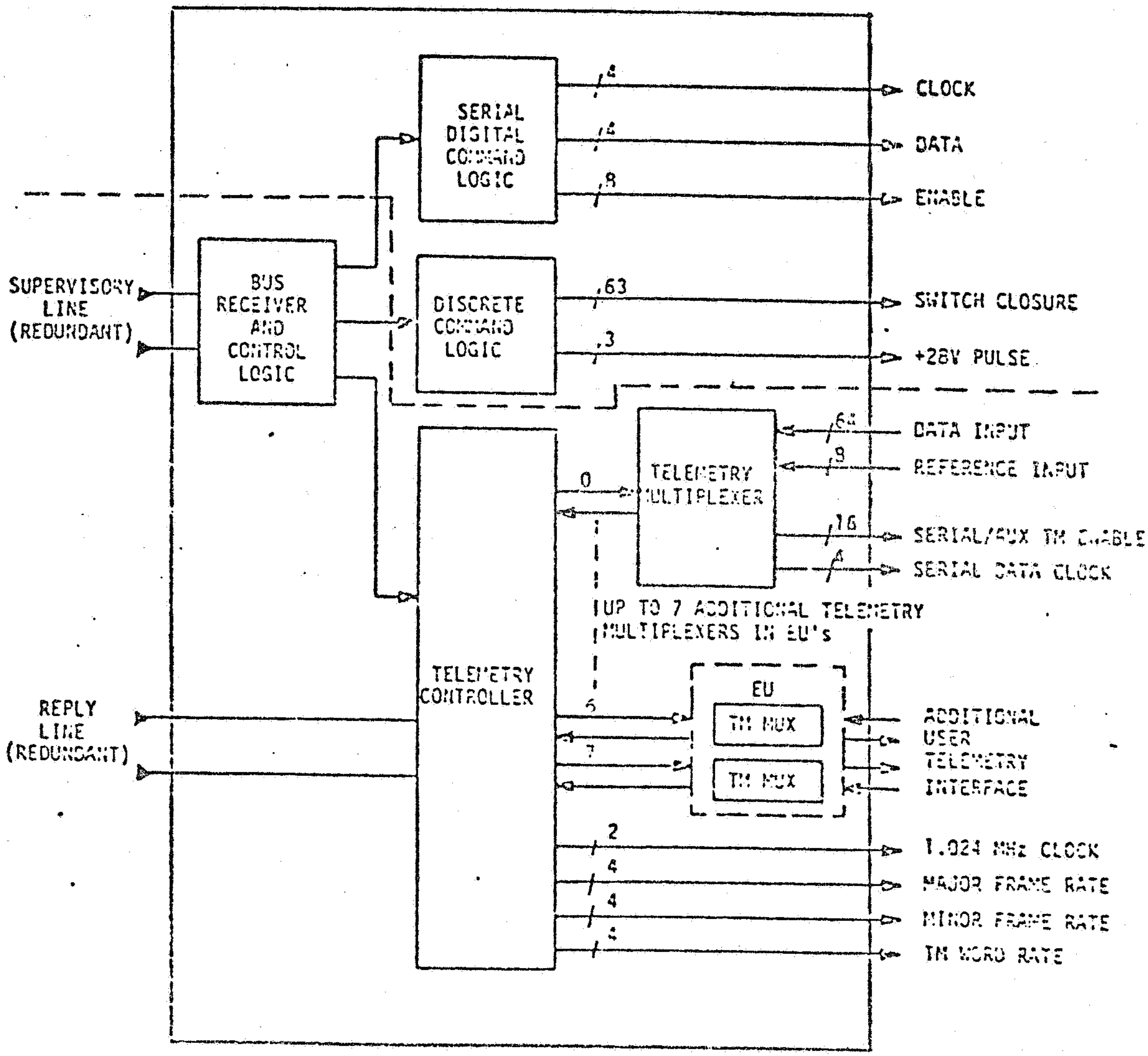

Figure 7.1-3. RIU Simplified Block Diagram

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Each PM-1A Propulsion Module uses two Propulsion Module Electronics (PME) units. Both PME's are identical, and can react to commands that are issued from either RIU.

Each PME unit contains command buffers and power switches to drive thruster and latch valves for attitude control and translation. Relays for heater control are included in each PME. The primary heater controll is in PME-A, and the redundant heater control is in PME-B. Each unit also contains telemetry circuits to give status indications, and a small dc/dc converter to provide isolated power for signal processing. Every valve used in the PM-1A module can be driven from either PME, or from both, simultaneously. To avoid ASCS hardline command problems in the safehold mode, PME-A should be used with ACE-A and PME-B with ACE-B.

Each PME unit for the PM-1A weighs less than 13.5 pounds, occupies less than 80 square inches of shelf space, and has a volume of approximately 480 cubic inches. The average power dissipation of each unit is less than 4 watts.

One of the main functions of the PME is to stretch the incoming 6 ms discrete commands, for the attitude control thrusters, into 40 ms pulse outputs, 100 ms pulse pulse outputs, or 280 ms pulse outputs. The 280 ms pulse duration will primarily be utilized on Landsat-D. During orbit adjust and normal operation of the spacecraft, the OBC will "refresh" the ACS commands every 256 ms and 512 ms, respectively. A block diagram of the PM-1A attitude control electronics is shown in Figure 7.1-4. The 6 ms discrete commands for the translations thruster firings are stretched to 1 second. For Landsat-D, the OBC will "refresh" the thruster commands every 256 ms during orbit adjust. The translation thrusters are not employed during normal operation. Both types of discrete stretchers (ACS and translation thrusters) can be extended before the stretch time is completed in order to obtain continuous firing of the thrusters. Refer to Paragraph 7.3 for a discussion of OBC thruster control logic.

REMs which are opposite each other on the shelf are generally activated as a pair to accomplish ± roll, ± pitch, and ± yaw corrections. One of the REM pairs is called the "Primary Set" for Landsat-D (REMs B and D), and can be used for all attitude control maneuvers. The A-C REM's comprise the back-up set. Table 7.1-1 identifies the specific thrusters which are activated to perform all six attitude control maneuvers.

Table 7.1-1. Attitude Control Thruster Assignments for Landsat-D

	+ ROLL	- ROLL	+ PITCH	- PITCH	+ YAW	- YAW
Back-Up	A2, C2	A3, C3	C4	A4	A2, C3	A3, C2
Primary	B2, D2	B3, D3	B2, D3	B3, D2	B4	D4

Translation maneuvers, for orbit changes, are normally performed with all 5-pound thrusters operating. Capability exists to fire only two of the four 5-pound thrusters for translation, but this mode would normally be used only in case of malfunction.

For translation thrust operation, the incoming 6 ms command is stretched to 1 second and (normally) all four thrusters are fired. Unequal moment arms to the Spacecraft cg, or unequal thruster outputs can produce unwanted attitude control errors. An OFF-pulsing to control pitch and yaw disturbances during translation maneuvers capability is included in the 5 pound thruster driver circuitry. This OFF-pulsing feature will OFF-pulse ONE five pounder during normal translation maneuvers, and OFF pulse both five pounders when a back-up mode is being used. The 0.2 lb. thrusters are normally disabled during a translation maneuver. If the ±P, R or Y disturbances exceed specified limits, the 5 lb. thrusters will be disabled and the 0.2 lb. thrusters enabled until the disturbance is eliminated. At that time the translation maneuver can be resumed.

7.2 PM-1A SUBSYSTEM PERFORMANCE CAPABILITIES

Table 7.2-1. Propulsion Module Subsystem Summary

Function	Characteristics
Power Supply	
Two different internal supplies are generated from the spacecraft for internal PME use.	12.5V + 1V, -0V
One low voltage supply which is referenced to signal ground is a nominal 12.5V supply, used for integrated circuit power, telemetry voltage/power source, ACS and hardwire interface circuitry and for input command buffer circuitry.	
The other low voltage supply is referenced to the spacecraft power input bus, providing a 12 volt supply below the incoming power bus and is only used by the photo couplers.	
Heater Controls	
Sixteen commands are allocated to the control of 10 flight heaters. These commands are configured for primary and redundant heater circuits for 4 REMs and 2 shelf heater to maintain temperature control of the PM-1A Propulsion Module elements	5 watts (per each REM) Heater resistance sized for 20% below normal at low line voltage, making the resistance equal to: E^2/P, where $E=22V$, and $P=6$ watts $R_{min} = \frac{484}{6} = 680.$ ohms $I_{max} = \frac{35V}{R_{min}} = 433.9$ mA (374 mA at 28V)
A functional diagram (Figure 7.2-1) and a command matrix (Table 7.2-2) illustrate this approach.	
Heater power for each REM will be controlled by one of two thermostats for each heater set.	

Table 7.2-1. Propulsion Module Subsystem Summary

	Close	0.015 sec
A cross section of the 5.0 lbf thruster is shown in Figure 7.2-2.	Internal leakage	0.5 s.c.c./hr GN_2
	External leakage	1×10^{-6} scc/sec He
	Weight	0.60 lb
	Coil resistance (each)	78.4 ohms at 70°F
0.2 lbf Thruster Valve Parameters		
Used to overcome unwanted attitude control errors	Supply Pressure	350 psig (maximum)
	Proof Pressure	600 psig
	Burst Pressure	1600 psig
	Flow rate	0.0020 lb/sec
The 0.2 lbf thruster valve is a scaled down version of the 5 lbf thruster valve pictured in Figure 7.2-3 with one difference; the inlet feed tube enters the filter housing of the upstream valve radially rather than axially.	Pressure Drop	10 psid
	Power at 28 VDC	10W
	Supply Voltage	18 to 45 Vdc
	Pull in Voltage (max)	17 VDC
	Drop out voltage	2 min, 10 max Vdc
	Internal Leakage	0.5 scc/hr, GN_2
	External Leakage	1×10^{-6} scc/sec, He
	Weight	0.20 lb
	Coil Resistance (Each Coil)	157 ohms at 70°F
Latch Valve Performance Characteristics		
The latch valve has a single poppet, seat, and actuator and is magnetically latched in either the open or closed position following a signal to either the opening or closing coil. The valve will remain latched without power. A microswitch located in the housing of the valve indicates its position. Figure 7.2-4 shows a cross section of this valve and Figure 7.2-5 shows a block diagram of the latch valve controls.	Supply pressure	350 psig
	Proof pressure	600 psig
	Burst pressure	1600 psig
	Flow rate design point	0.025 lb/sec
	Pressure drop at design point	3.5 psid
	Power (minimum 20 ms)	8W
	Supply voltage	18-35 Vdc
	Internal leakage	0.5 scc GN_2/hr
	External leakage	1×10^{-6} scc GHe/sec
	Reverse relief pres.	100 psi max
	Weight	0.60 lb
	Inlet tube	0.250 by 0.020 in wall
	Outlet tube	0.250 by 0.020 in wall

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Table 7.2-1. Propulsion Module Subsystem Summary

Shelf Heater	20 watts 1736 mA - Maximum Value	
ATK Heaters		
Flight Heaters		
All ATK flight heaters and control circuits will be powered from the 22-35 Vdc spacecraft bus.		
The SC&CU provides bus protection and power control circuitry for four ATK heaters, two of which shall contain thermostat bypass capability.		
Shuttle Survival/Servicing Heaters		
Separate heaters will provide safe temperatures in the ATK during resupply operations when the spacecraft power is turned off. These heaters will be electrically isolated from the flight heater circuits and will be thermostatically controlled.	28V $\pm$ 4 Volts	
5.0 lbf Thruster Valve Parameters		
The 5 pound thruster driver circuitry incorporates an OFF-pulsing capability.	Supply pressure	350 psig (maximum)
	Proof pressure	800 psig
	Burst pressure	1600 psig
	Flow rate	0.025 lb/sec
	Pressure drop	28 psid
	Power at 28 Vdc	20W
This OFF-pulsing feature will OFF-pulse one five pounder during normal translation maneuvers, and both five pounders when a back-up mode is being used.	Supply voltage	18 to 45 Vdc
	Pull in voltage (max)	17.0 Vdc
	Dropout voltage	2.0 Vdc min 10.0 Vdc max
	Response 70°F at 28 Vdc	
	Open	0.010 sec

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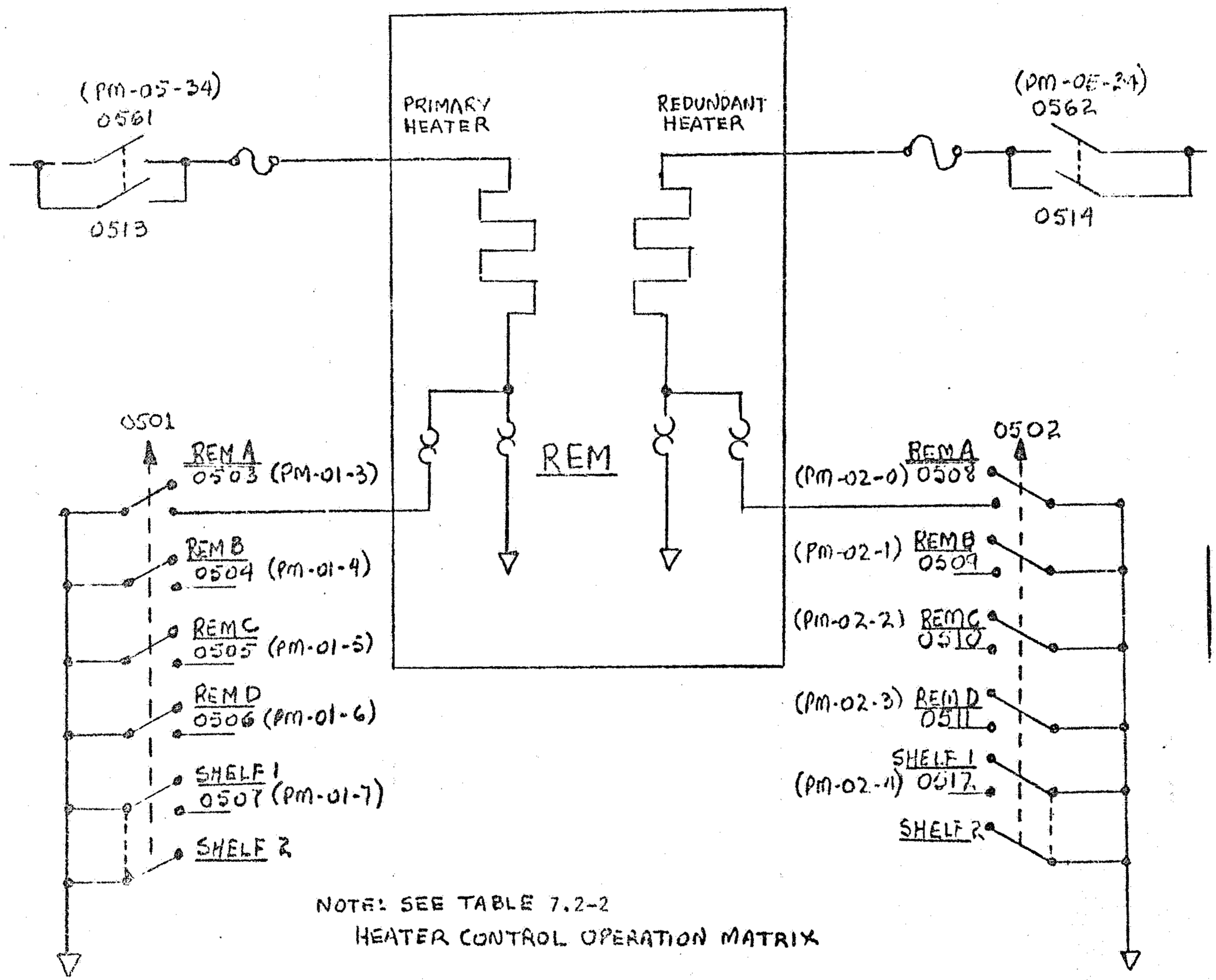

Figure 7.2-1. Functional Diagram - Heater Controls

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Table 7.2-2. PM-1A Heater Control Operation Matrix

FUNCTION	COMMAND NUMBER															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	61	62
BUS ENABLE PRIM ON													X			
OFF															X	
REDUN ON														X		
OFF																X
REM A PRIM AUTO MODE	X															
MANUAL MODE			X													
REDUN AUTO MODE		X														
MANUAL MODE								X								
REM B PRIM AUTO MODE	X															
MANUAL MODE				X												
REDUN AUTO MODE		X														
MANUAL MODE									X							
REM C PRIM AUTO MODE	X															
MANUAL MODE					X											
REDUN AUTO MODE		X														
MANUAL MODE										X						
REM D PRIM AUTO MODE	X															
MANUAL MODE						X										
REDUN AUTO MODE		X														
MANUAL MODE											X					
SHELF PRIM AUTO MODE	X															
MANUAL MODE							X									
REDUN AUTO MODE		X														
MANUAL MODE												X				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	61	62

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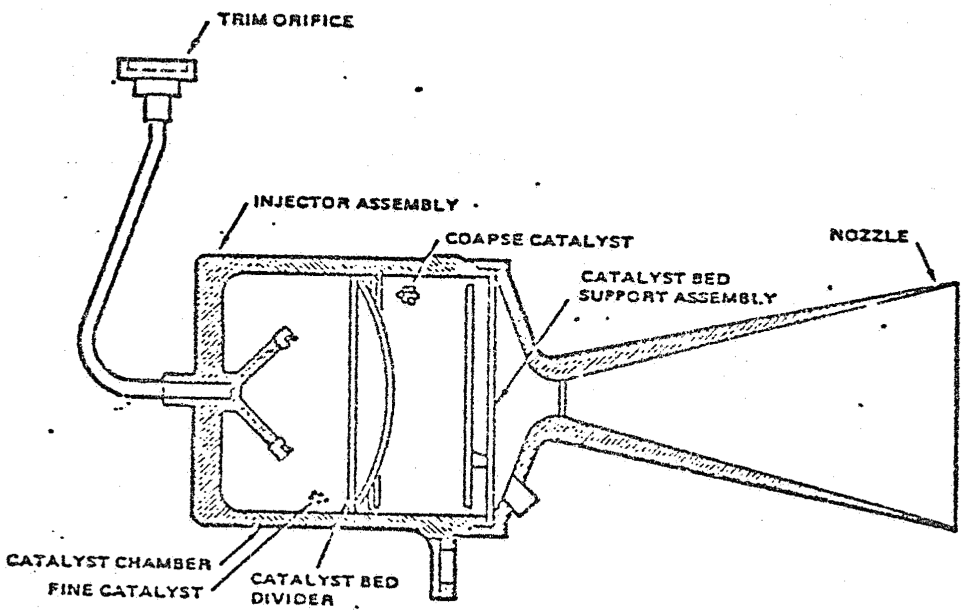

Figure 7.2-2. 5 lbf Thruster

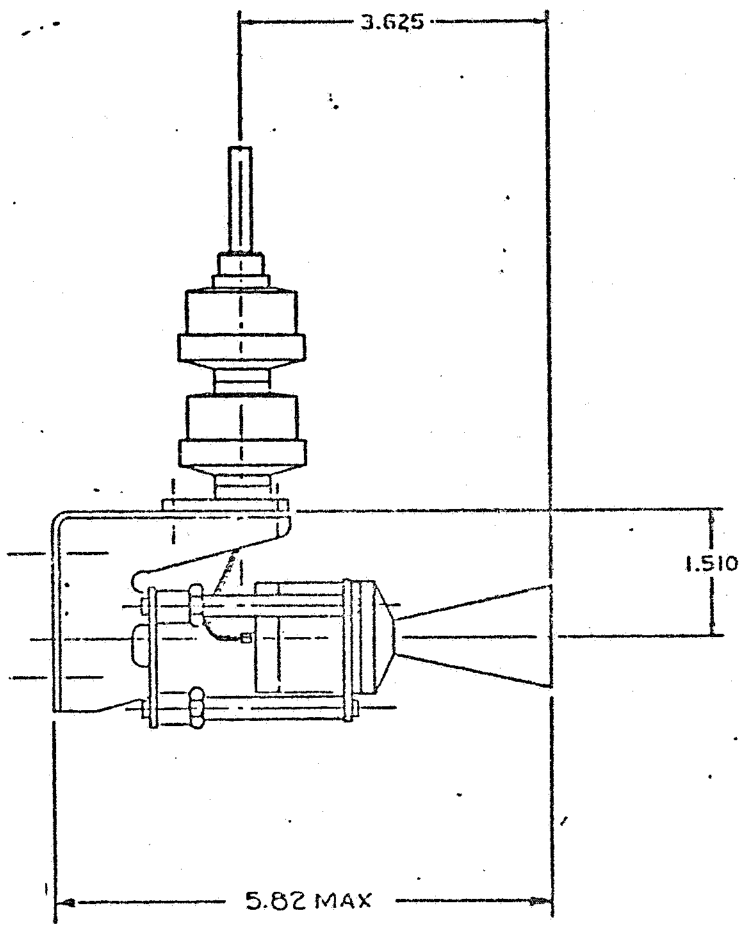

Figure 7.2-3. 5 lbf Thruster Valve

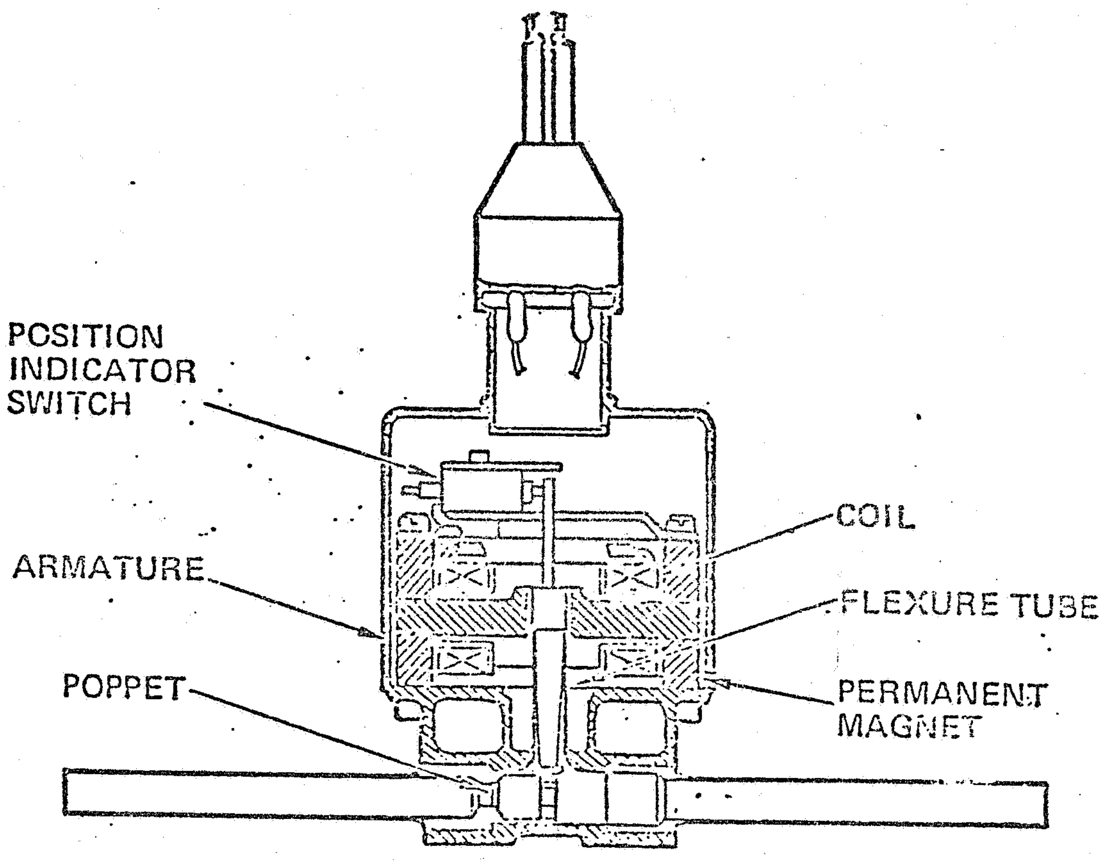

Figure 7.2-4. Latch Valve Cross Section

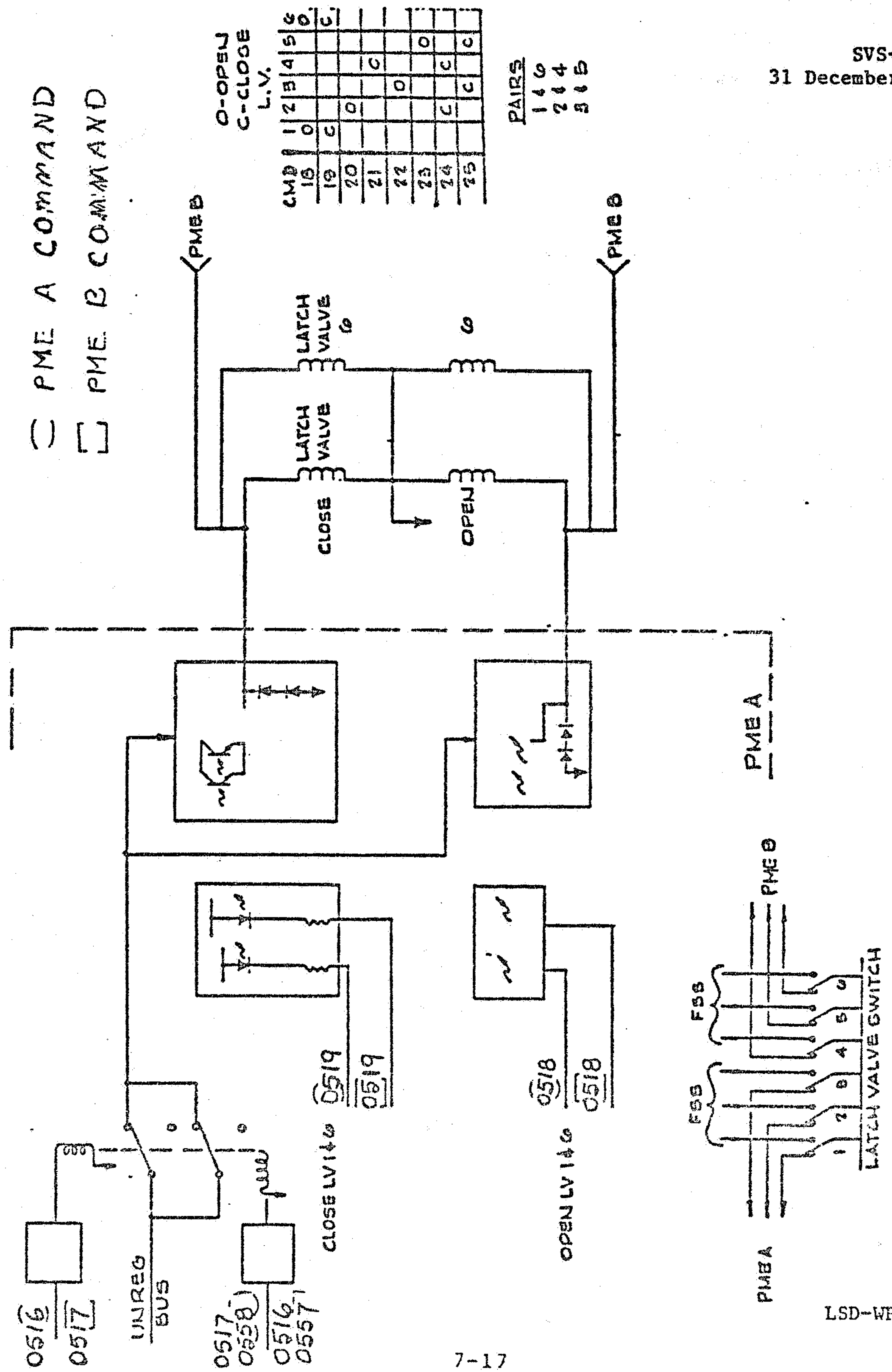

Figure 7.2-5. Block Diagram - Latch Valve Controls

7.3 PM-1A SUBSYSTEM MODES OF OPERATION

The following describes the built-in orbit adjust thruster selection logic. The OBC software for the Attitude Control System provides torque axis input signals to the PM-1A logic every 756 milliseconds, integrates the total translation thruster firing time commanded for all translation thrusters, and disables firing of all translation thrusters on the 756ms cycle when the integrated firing time equals or exceeds the commanded value.

Figure 7.3-1 is a simplified diagram of the portion of the PM-1A electronics that controls the translation thrusters and shows the drivers for the four translation thrusters designated as A1, B1, C1, and D1. When enabled by appropriate commands, the thruster valves are opened when light from light emitting diodes (LED) strikes the photo diodes in the optical couplers designated for each thruster. If the appropriate propellant latch valves are open, the engine fires.

Figure 7.3-2 shows that thrusters B1 and D1 or A1 and C1 are enabled in pairs by connecting either or both pairs to either of two redundant Propulsion Module electronics (PME) power supplies. For simplicity only PME-A is shown.

The plus and minus yaw and pitch signals entering at the bottom of Figure 7.3-2 are generated by the OBC attitude control software which controls the firing of the 0.2 lbf attitude controls thrusters. These lines are tied to the control of the translation thrusters in the PM-1A electronics. Each of these lines short circuits the light emitting diode which actuates the thruster producing the undesired torque. Since only one axis is commanded each ACS cycle, only one translation thruster (the one with the largest error) will be off-pulsed at a time. However, if either thruster pair is not enabled, the two diodes shown provide ground to a relay which ties all the torque command lines together for translation thruster control so that both translation thrusters, in a pair, will be off-pulsed for any torque command if only one pair is enabled. Thus, if either pair of translation thrusters is enabled, either zero or two thrusters will be firing each 256 ms command cycle; if both pairs are enabled, either 3 or 4 thrusters will be firing each 256 ms command cycle.

The command interface for the orbit adjust thrusters has been established through the attitude control software to simplify utilization of the propulsion module built-in logic. In addition to PM-1A configuration commands which specify the PME side to be utilized, the latch valve positions, and which thruster pair to use (either or both), the only thruster maneuver magnitude command required is total thruster-seconds for the burn, and a maximum elapsed time after which to disable all translation thrusters. Start time and attitude data are of course also required.

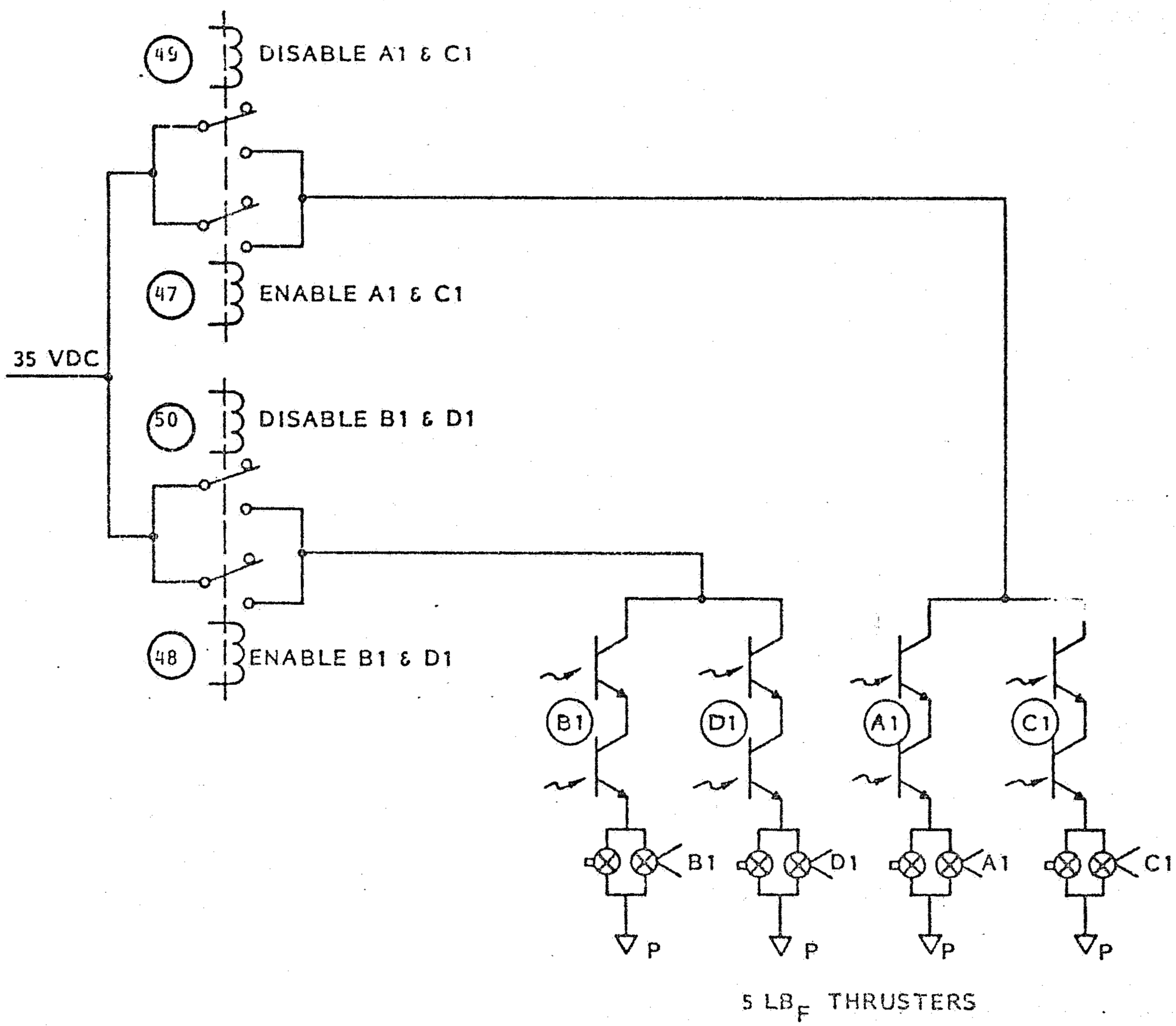

Figure 7.3-1. PM-1 Simplified Schematic Translation Controls

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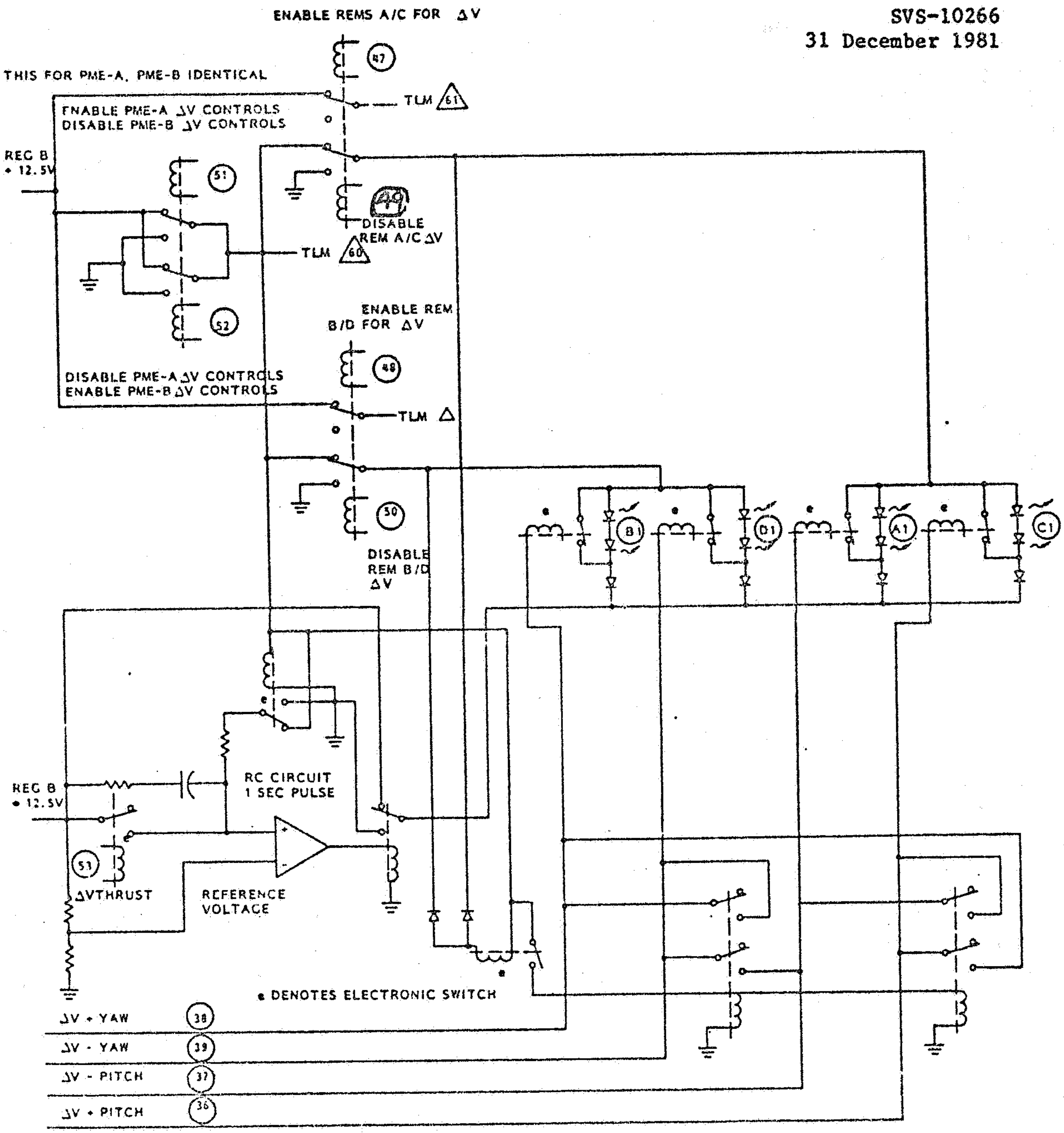

Figure 7.3-2. PM-1 Simplified Schematic

7.4 PROPULSION MODULE SUBSYSTEM CONSTRAINTS

7.4.1 PM-1A INITIALIZATION CONSTRAINTS

The sequence of commands required to enable a PME for attitude control is:

1. PME A/B ENABLE
2. SELECT PULSE WIDTH 40/100/280 ms
3. ENABLE REM'S A,C/B,D
4. ENABLE LATCH VALVE DRIVERS A/B
5. OPEN APPROPRIATE LATCH VALVES

7.4.2 PM-1A TELEMETRY CONSTRAINTS

All telemetry indications of any off PME should be totally ignored because they are unpredictable.

7.4.3 PM-1A COMMAND CONSTRAINTS

1. If a SAFE HOLD entry occurs with ACS rates >.25 degrees per second and the ACS REMs are not enabled, enabling must be ground commanded.

2. Following Coarse Sun Acquisition, the commands below should be sent to disable all thruster banks:

1	PRIMARY HTRS ON, AUTO MODE, MANUAL MODE OFF
19	CLOSE LATCH VALVES 1 & 6
24	CLOSE LATCH VALVES 2 & 4
25	CLOSE LATCH VALVES 3 & 5
29	DISABLE PME-A ATTITUDE CONTROLS
30	DISABLE PME-B ATTITUDE CONTROLS
49	DISABLE REMs A/C FOR TRANSLATION CONTROL
50	DISABLE REMs B/D FOR TRANSLATION CONTROL

7.4.4 PM-1A TEMPERATURE CONSTRAINTS

1. There is no specified limit for the catalyst bed which typically runs between 1200-1500°F during firing.

2. The PM non-firing temperature limits are:

Component	Temperature Limit(°F)
0.2 Pound Thruster:(1)	
Catalyst Bed	80 to 185
Valve(2)	80 to 185
5.0 Pound Thruster:(1)	
Catalyst Bed	20 to 185
Valve(2)	50 to 185
All other PM Components: (Tanks, Lines, Latch Valves)	50 to 140
Electronics	
PME's	32 to 104
RIU's	32 to 104
Maximum Tank-Tank Differential	10

(1) Excludes firing temperature. Heaters are thermostatically controlled and left on throughout the mission.

(2) 250°F limit during firing and soakback.

7.4.5 PM-1A PRESSURE CONSTRAINTS

Thruster valves must not be opened below closed latch valves such as to drain the hydrazine from the line(s) between the latch valve(s) and the thrusters because of potential problems when the lines are refilled. (i.e., potential damage to the latch valves and thrusters)

7.4.6 PM-1A VIEWING CONSTRAINTS

TBD

7.4.7 PM-1A OPERATING MODE CONSTRAINTS

1. The 280 millisecond thruster pulse time must be selected for orbit adjusts.

2. Attitude Control REMs A/C or B/D must be enabled during initial attitude acquisition or backup momentum dump.

3. Translation control REMs A/C and B/D must be enabled during orbit adjust.

4. All Attitude Control and translational REMs must be disabled during normal operation.

5. MACS safehold enable signals are not cross-strapped; i.e., the safehold enable signal from ACE-A goes to PME-A and the safehold enable signal from ACE-B goes to PME-B. Therefore, PME-A should be used with ACE-A, PME-B with ACE-B.

7.4.8 PM SAFE HOLD CONSTRAINTS

All thrusters should be disabled during Safe Hold Mode if all magnetic torquers are operational. Thrusters should only be enabled by ground command.

7.5 PM-1A SUBSYSTEM REDUNDANCY

The PM-1A provides a high degree of redundancy for propellant leakage above the latch valves. The translation thrusters utilized for all orbit adjusts are configured in two independent systems of 2 thrusters each, and either pair may be utilized. Either pair may be operated from either of two sets of Propulsion Module electronics (PME).

7.5.1 PME RELIABILITY

The PME design is based primarily upon a unit redundancy approach, with cross strapping on input and output. Figure 7.5-1 illustrates this approach.

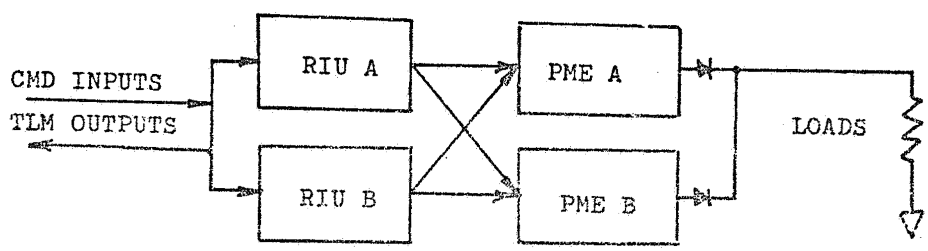

Figure 7.5-1. PM Reliability

Higher levels of redundancy exist within each PME, which allow portions of a PME to be disabled wihtout impeding the operation of the remainder of that PME.

To preclude problems, if the S/C goes into safehold mode, operate RIUA with PMEA and RIUB with PME-B.

7.5.2 CROSS STRAPPING/REDUNDANCY

Cross strapping or redundant inputs have been provided for all electrical functions whose loss could result in a mission failure or out-of-tolerance performance. Figures 7.5-2, 7.5-3 and 7.5-4 show the techniques used. Note that TLM channels 16-31 are not cross-strapped.

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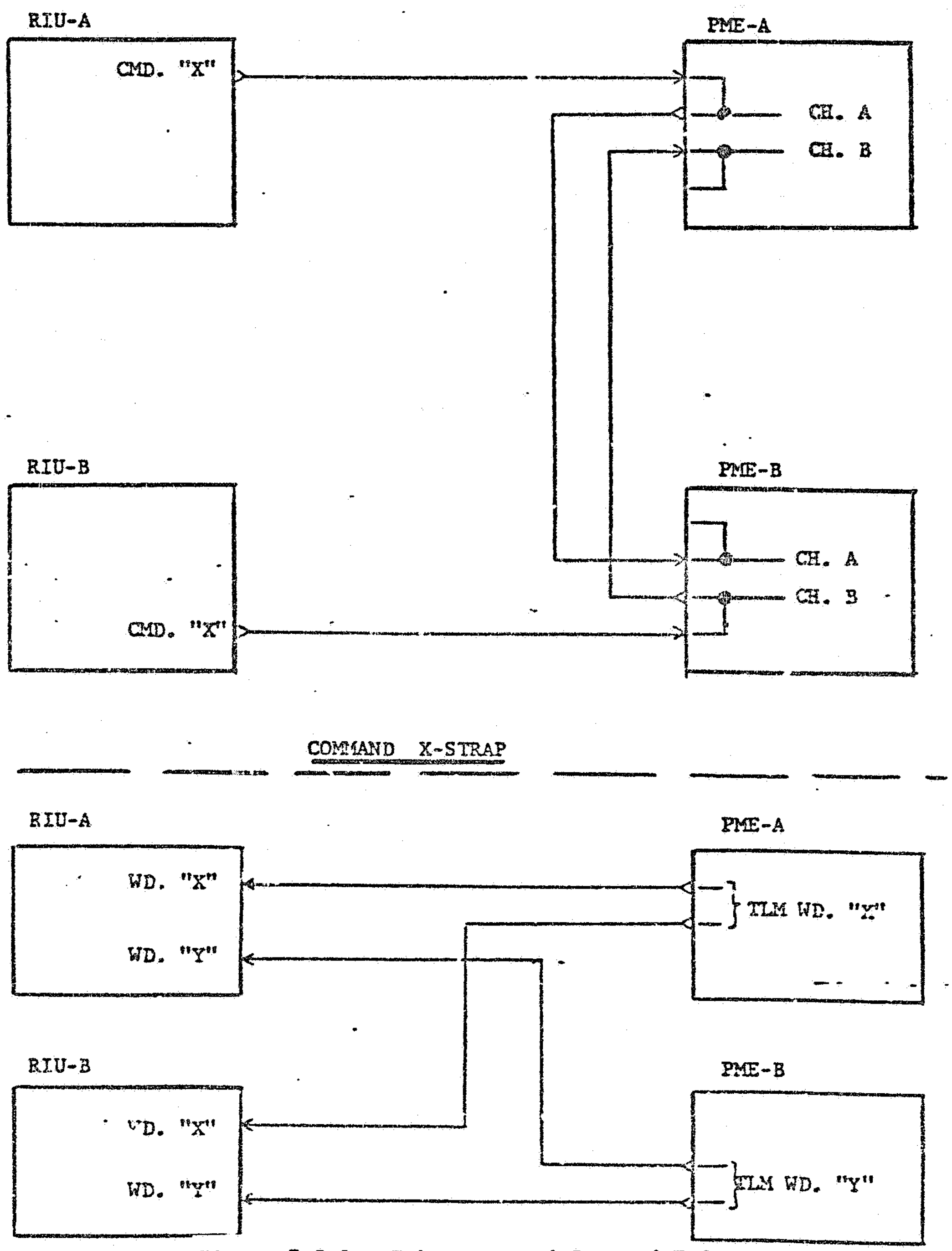

Figure 7.5-2. Telemetry and Command X-Strap

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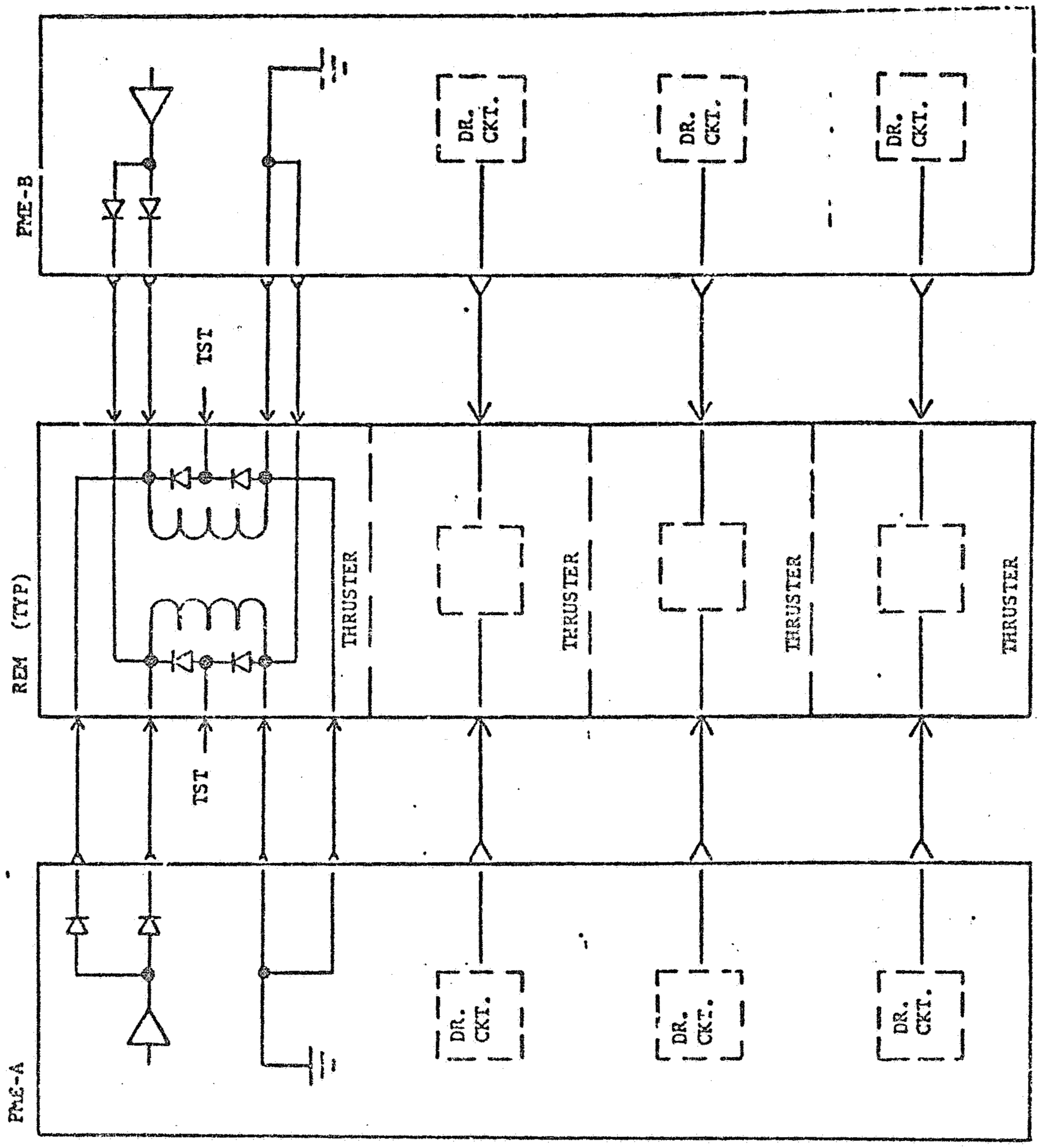

Figure 7.5-3. Thruster X-Strap

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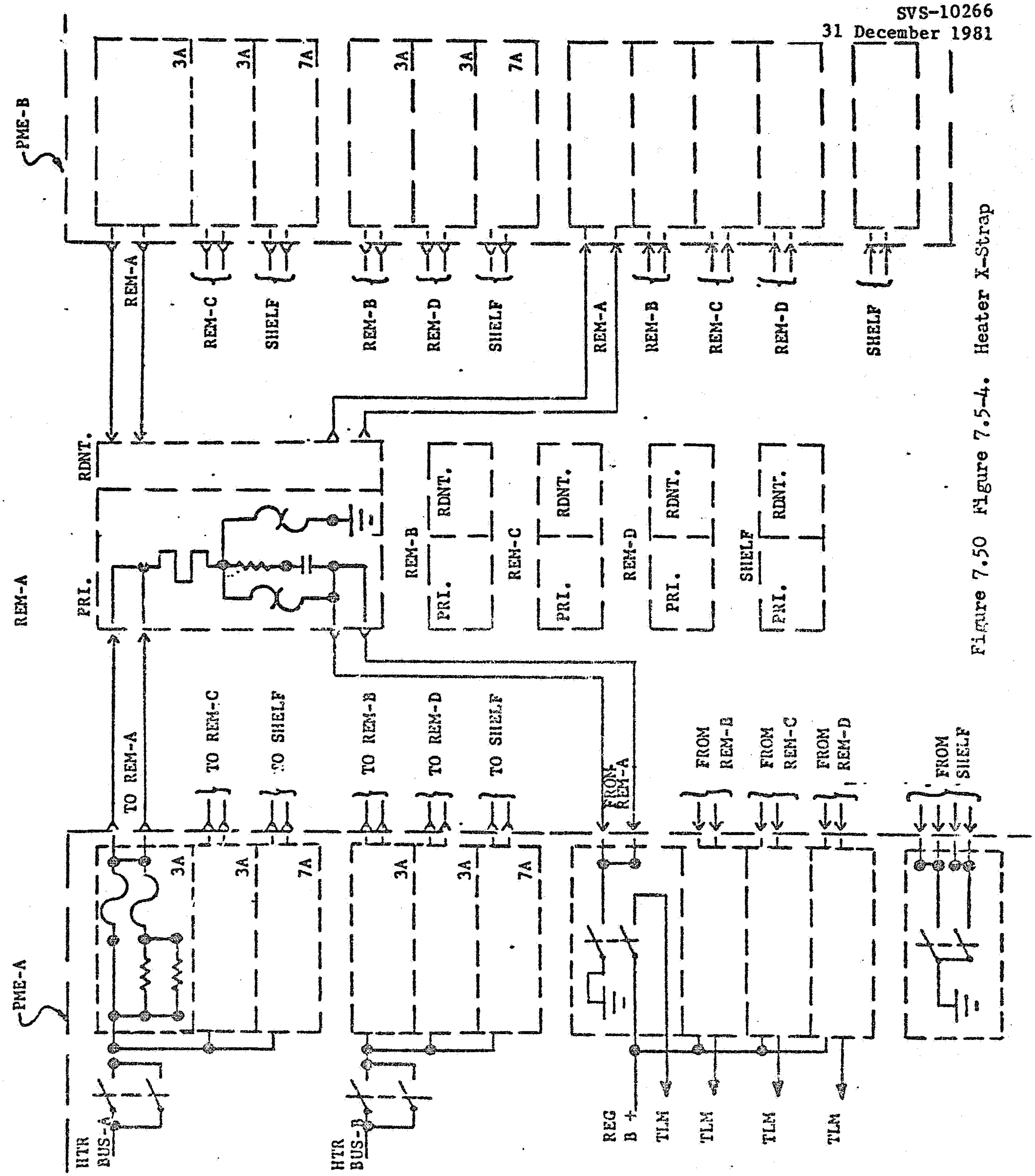

Figure 7.50 Figure 7.5-4. Heater X-Strap

Figure 7.5-1 shows a redundancy for PMEs that is consistent with the plan for RIU failure. This plan suggests that a failure of RIUA results in disabling that RIU and PME-A enabling RIUB and PME-B.

For each PME function shown in Figure 7.5-2, a failure of one PME will require that function to be disabled in that PME, and the same function enabled in the other PME.

One further level of redundancy exists in the PME's for the attitude control section, which reflects the redundancy that exists for REM operation. Table 7.1-1 showed a primary and back-up set of thrusters for each attitude control maneuver. The PME attitude control driver outputs can be guided to either the primary set of thrusters (REMs B & D) or to the back-up set of thrusters (REMs A & C), for each of the attitude control operations. Each PME set of attitude control electronics can therefore be used to operate valves in an operational REM in case of a valve or thruster failure in its counterpart REM.

With REM's B and D primary and REM's A and C back-up, total redundancy is provided for performing station acquisition and orbit adjust maneuvers and concurrent transverse axis pitch/yaw attitude control using the 5 lbf thrusters. The 0.2 lbf thrusters provide a redundant capability to execute roll and pitch/yaw torque commands for all attitude control functions as required.

Redundancy also exists for attitude control outputs and translation outputs through use of series redundant drivers. Each thruster driver contains 2 transitor switches in series. A single failure can prevent an output from that driver, but no single failure can open a thruster valve continuously. Since each PME contains drivers for each thruster valve, the series redundancy in each PME thruster driver circuit provides "quad" redundant capabilities for these important loads.

The Propulsion Module (PM-1A) incorporates effective redundancy in all mission critical areas. Single point failure modes which might cause mission failures are essentially eliminated except for some low predicted frequency failure modes where redundancy is impractical.

7.6 PROPULSION MODULE COMMANDS

Operation of the propulsion module is controlled utilizing a total of 58 commands. Of these, 57 are discrete commands and 1 is a serial message command word. The serial message command controls 12 functions.

The commands are listed in Tables 7.6-1 and 7.6-2 for discrete and serial magnitude commands respectively, and are described in Paragraph 7.6.1. Command sequences and restraints are provided in Paragraph 7.6.2 and 7.6.3. Functional schematics of command operation appear in Paragraph 7.6.4.

7.6.1 COMMAND DESCRIPTIONS

7.6.1.1 RIU Selection Commands

RIU 5 SELF STANDBY 1
RIU 5 SELF STANDBY 2

The selection of RIU 5A or 5B is controlled by these two discrete commands. The functional schematic for these commands is illustrated in Figure 7.6-1. The operation of these commands is identical for RIU A and B.

RIU 5 SELF STANDBY 1 to RIU A enables a pulse to one side of a latching relay, closing it, connecting RIU internal signal grounds to external signal grounds. In this configuration the RIU is in STANDBY 1 mode as evidenced by PM bilevel telemetry, ZMATENF = 1. RIU 5 SELF STANDBY 2 to RIU A elevates RIU A to the STANDBY 1 mode, enabling its use for command and telemetry. In addition, this command enables a pulse to RIU B, turning it off. This prevents both RIU's from being on simultaneously. The telemetry verification that RIU A is in the STANDBY 2 mode is indicated by PM bilevel ZRIUSBA = 0.

The complement to this series of commands is to send the same commands to RIU B, resulting in RIU B being on in the STANDBY 2 mode and RIU A OFF. The telemetry verification that RIU B is in the STANDBY 2 mode is indicated by PM bilevel ZRIUSBA = 1.

Table 7.6-1. Propulsion Module Discrete Command List

Command	Acronym	RIU Channel	Complement CMD Acronym	Verification TLM Acronym	Reference Paragraph
RIU 5 SELF STANDBY 1	RIU5EN	05-00	RIU5EN	ZMATENF	7.6.1.1
RIU 5 SELF STANDBY 2	RIU5STD2	05-63	RIU5STD2	ZRIUSBA	7.6.1.1
ENABLE PME-A LATCH VALVE DRIVERS	PLVDREN	05-16	PLVDRDIS	ZLVDVRS	7.6.1.2
DISABLE PME-A LATCH VALVE DRIVERS	PLVDRDIS	05-57	PLVDREN	ZLVDVRS	7.6.1.2
ENABLE PME-B LATCH VALVE DRIVERS	RLVDREN	05-17	RLVDRDIS	ZLVDVRS	7.6.1.2
DISABLE PME-B LATCH VALVE DRIVERS	RLVDRDIS	05-58	RLVDREN	ZLVDVRS	7.6.1.2
OPEN LATCH VALVES 1 AND 6	LV1A6OPN	05-18	LV1A6CL	ZLV123,ZLV456	7.6.1.3
OPEN LATCH VALVE 2	LV2OPN	05-20	LV2A4CL	ZLV123	7.6.1.3
OPEN LATCH VALVE 3	LV3OPN	05-22	LV3A5CL	ZLV123	7.6.1.3
OPEN LATCH VALVE 4	LV4OPN	05-21	LV2A4CL	ZLV456	7.6.1.3
OPEN LATCH VALVE 5	LV5OPN	05-23	LV3A5CL	ZLV456	7.6.1.3
CLOSE LATCH VALVE 1 AND 6	LV1A6CL	05-19	LV1A6OPN	ZLV123,ZLV456	7.6.1.3
CLOSE LATCH VALVE 2 AND 4	LV2A4CL	05-24	LV2OPN,LV4OPN	ZLV123,ZLV456	7.6.1.3
CLOSE LATCH VALVE 3 AND 5	LV3A5CL	05-25	LV3OPN,LV5OPN	ZLV123,ZLV456	7.6.1.3
ENABLE PME-A ATTITUDE CONTROL	APACEN	05-27	APACDIS	ZEABATC	7.6.1.4
DISABLE PME-A ATTITUDE CONTROL	APACDIS	05-29	APACEN	ZEABATC	7.6.1.4
ENABLE PME-B ATTITUDE CONTROL	BPACEN	05-28	BPACDIS	ZEABATC	7.6.1.4
DISABLE PME-B ATTITUDE CONTROL	BPACDIS	05-30	BPACEN	ZEABATC	7.6.1.4
SELECT 40 MSEC PULSE WIDTH	40PWSEL	05-31	100PWSEL,280PWSEL	ZEAPULS,ZEBPULS	7.6.1.5
SELECT 100 MSEC PULSE WIDTH	100PWSEL	05-32	40PWSEL,280PWSEL	ZEAPULS,ZEBPULS	7.6.1.5
SELECT 280 MSEC PULSE WIDTH	280PWSEL	05-33	40PWSEL,100PWSEL	ZEAPULS,ZEBPULS	7.6.1.5
+ROLL TORQUE COMMAND	PXTQCMD	05-34	N/A	ZEAPGEN,ZEBPGEN	7.6.1.6
-ROLL TORQUE COMMAND	NXTQCMD	05-35	N/A	ZEANGEN,ZEBNGEN	7.6.1.6
+PITCH TORQUE COMMAND	PYTQCMD	05-36	N/A	ZEAPGEN,ZEBPGEN	7.6.1.6
-PITCH TORQUE COMMAND	NYTQCMD	05-37	N/A	ZEANGEN,ZEBNGEN	7.6.1.6
+YAW TORQUE COMMAND	PZTQCMD	05-38	N/A	ZEAPGEN,ZEBPGEN	7.6.1.6
-YAW TORQUE COMMAND	NZTQCMD	05-39	N/A	ZEANGEN,ZEBNGEN	7.6.1.6
ENA REM A/C DIS REM B/D FOR +ROLL	PXREMEN	05-40	BDREMEN	ZEAPATC,ZEBPATC	7.6.1.7
ENA REM A/C DIS REM B/D FOR -ROLL	NXREMEN	05-41	BDREMEN	ZEANATC,ZEBNATC	7.6.1.7
ENA REM A/C DIS REM B/D FOR +PITCH	PYREMEN	05-42	BDREMEN	ZEAPATC,ZEBPATC	7.6.1.7
ENA REM A/C DIS REM B/D FOR -PITCH	NYREMEN	05-43	BDREMEN	ZEANATC,ZEBNATC	7.6.1.7
ENA REM A/C DIS REM B/D FOR +YAW	PZREMEN	05-44	BDREMEN	ZEAPATC,ZEBPATC	7.6.1.7
ENA REM A/C DIS REM B/D FOR -YAW	NZREMEN	05-45	BDREMEN	ZEANATC,ZEBNATC	7.6.1.7
ENA REM B/D FOR ATT CONTROL DIS REM A/C	BDREMEN	05-46	PXREMEN,NXREMEN PYREMEN,NYREMEN PZREMEN,NZREMEN	ZEAPATC,ZEANATC ZEBPATC,ZEBNATC	7.6.1.7
ENA PME-A FOR TRANS CONTROL DIS PME-B	PMEATREN	05-51	PMEBTREN	ZEABTRS	7.6.1.8
ENA PME-B FOR TRANS CONTROL DIS PME-A	PMEBTREN	05-52	PMEATREN	ZEABTRS	7.6.1.8
ENABLE REM A/C FOR TRANSLATION CONTROL	RMACEN	05-47	RMACDIS	ZEARMTC,ZEBRMTC	7.6.1.9

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Table 7.6-1. Propulsion Module Discrete Command List

Command	Acronym	RIU Channel	Complement CMD Acronym	Verification TLM Acronym	Reference Paragraph
DISABLE REM A/C FOR TRANSLATION CONTROL	RMACDIS	05-49	RMACEN	ZEARMTC,ZEBRMTC	7.6.1.9
ENABLE REM B/D FOR TRANSLATION CONTROL	RMBDEN	05-48	RMBDDIS	ZEARMTC,ZEBRMTC	7.6.1.9
DISABLE REM B/D FOR TRANSLATION CONTROL	RMBDDIS	05-50	RMBDEN	ZEARMTC,ZEBRMTC	7.6.1.9
TRANSLATION THRUST COMMAND	TRTHCMD	05-53	N/A	ZRMACTC,ZRMBDTC	7.6.1.10
ENABLE PRIMARY HEATER BUS	PHTREN	05-13	PHTRDIS	ZHTRBUS	7.6.1.11
DISABLE PRIMARY HEATER BUS	PHTRDIS	05-61	PHTREN	ZHTRBUS	7.6.1.11
ENABLE REDUNDANT HEATER BUS	RHTREN	05-14	RHTRDIS	ZHTRBUS	7.6.1.11
DISABLE REDUNDANT HEATER BUS	RHTRDIS	05-62	RHTREN	ZHTRBUS	7.6.1.11
PRIMARY HEATERS ON AUTO MODE MANUAL MODE OFF	PHTRAUON	05-01	PAHTONMM,PBHTONMM PCHTONMM,PDHTONMM PSHTONMM	ZRMAPRHT,ZRMBPRHT ZRMCPRHT,ZRMDPRHT ZSHFPRHT	7.6.1.12
REM A PRIMARY HEATERS ON MANUAL MODE	PAHTONMM	05-03	PHTRAUON	ZRMAPRHT	7.6.1.12
REM B PRIMARY HEATERS ON MANUAL MODE	PBHTONMM	05-04	PHTRAUON	ZRMBPRHT	7.6.1.12
REM C PRIMARY HEATERS ON MANUAL MODE	PCHTONMM	05-05	PHTRAUON	ZRMCPRHT	7.6.1.12
REM D PRIMARY HEATERS ON MANUAL MODE	PDHTONMM	05-06	PHTRAUON	ZRMDPRHT	7.6.1.12
SHELF PRIMARY HEATERS ON MANUAL MODE	PSHTOMM	05-07	PHTRAUON	ZSHFPRHT	7.6.1.12
REDUNDANT HEATERS ON AUTO MODE MANUAL MODE OFF	RHTRONAM	05-02	RAHTONMM,RBHTONMM RCHTONMM,RDHTONMM RSHTONMM	ZRMABUHT,ZRMBBUHT ZRMCBUHT,ZRMDBUHT ZSHFBUHT	7.6.1.12
REM A REDUNDANT HEATERS ON MANUAL MODE	RAHTONMM	05-08	RHTRONAM	ZRMABUHT	7.6.1.12
REM B REDUNDANT HEATERS ON MANUAL MODE	RBHTONMM	05-09	RHTRONAM	ZRMBBUHT	7.6.1.12
REM C REDUNDANT HEATERS ON MANUAL MODE	RCHTONMM	05-10	RHTRONAM	ZRMCBUHT	7.6.1.12
REM D REDUNDANT HEATERS ON MANUAL MODE	RDHTONMM	05-11	RHTRONAM	ZRMDBUHT	7.6.1.12
SHELF REDUNDANT HEATERS ON MANUAL MODE	RSHTONMM	05-12	RHTRONAM	ZSHFBUHT	7.6.1.12

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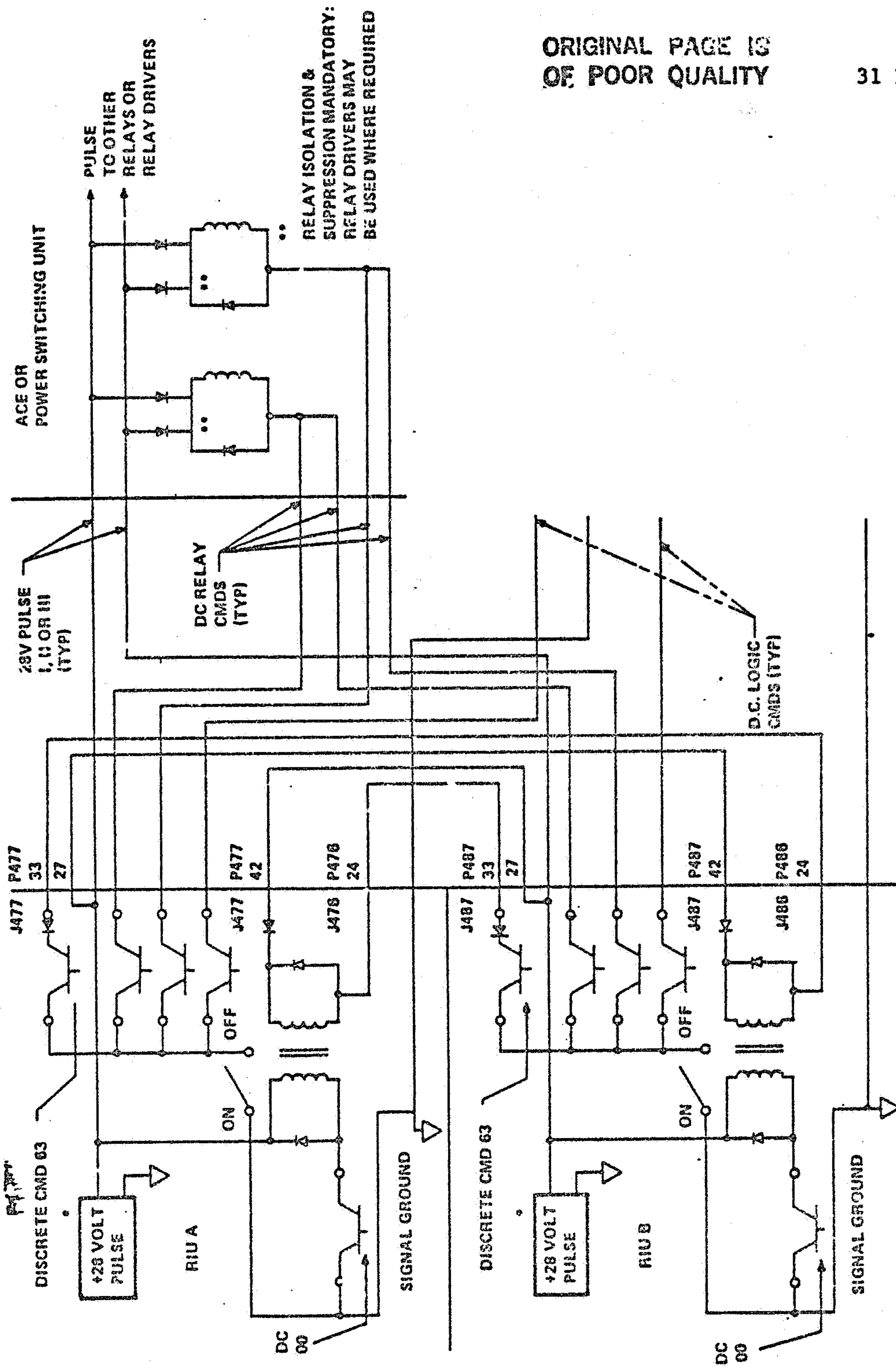
Table 7.6-2. Propulsion Module Serial Magnitude Command List

Command	Acronym	RIU Channel	Serial Bits (Hexi)	Complement CMD Acronym	Verification TLM Acronym	Reference Paragraph
ATK PRIMARY TANK HEATER ENABLE	PTKHTEN	04-70	1C7E	PTKHTDIS	ZPRTKHT	7.6.1.13
ATK PRIMARY TANK HEATER DISABLE	PTKHTDIS	04-70	2CBE	PTKHTEN	ZPRTKHT	7.6.1.13
ATK REDUNDANT TANK HEATER ENABLE	RTKHTEN	04-70	7C1E	RTKHTDIS	ZBUTKHT	7.6.1.13
ATK REDUNDANT TANK HEATER DISABLE	RTKHTDIS	04-70	8CEE	RTKHTEN	ZBUTKHT	7.6.1.13
ATK TANK HEATER THERMOSTAT BYPASS	TKHTTHBY	04-70	BC2E	TKHTTHEN	ZPRTKTH	7.6.1.13
ATK TANK HEATER THERMOSTAT ENABLE	TKHTTHEN	04-70	CCCE	TKHTTHBY	ZPRTKTH	7.6.1.13
ATK PRIMARY LINE HEATER ENABLE	PLHTEN	04-70	3C3E	PLHTDIS	ZPRLNHT	7.6.1.13
ATK PRIMARY LINE HEATER DISABLE	PLHTDIS	04-70	4CDE	PLHTEN	ZPRLNHT	7.6.1.13
ATK REDUNDANT LINE HEATER ENABLE	RLHTEN	04-70	9C6E	RLHTDIS	ZBULNHT	7.6.1.13
ATK REDUNDANT LINE HEATER DISABLE	RLHTDIS	04-70	ACAE	RLHTEN	ZBULNHT	7.6.1.13
ATK LINE HEATER THERMOSTAT BYPASS	LHTTHBY	04-70	5C5E	LHTTHEN	ZPRLNTH	7.6.1.13
ATK LINE HEATER THERMOSTAT ENABLE	LHTTHEN	04-70	6C9E	LHTTHBY	ZPRLNTH	7.6.1.13



DISCRETE COMMAND (D.C.) CHARACTERISTICS ARE DEFINED IN S-700-54 PARA 2.2
*(3) 28 VDC PULSES ISOLATED FROM UNREGULATED 28VDC: I FOR ALL EVEN D.C. 2-62,
II FOR ALL ODD D.C. 1 TO 47, III FOR ALL ODD 49 TO 61.
D.C. DESIGNATIONS & REF 28V PULSE ARE DEFINED IN TABLE 6.2-1

Figure 7.6-1. Typical Relay Discrete Command Interface

7.6.1.2 PME A/B Latch Valve Driver Selection

ENABLE PME-A LATCH VALVE DRIVERS
DISABLE PME-A LATCH VALVE DRIVERS
ENABLE PME-B LATCH VALVE DRIVERS
DISABLE PME-B LATCH VALVE DRIVERS

The function of these four discrete commands is to control the +28 VDC unregulated power to PME-A and PME-B latch valve driver circuits. The functional schematic for these commands is illustrated in Figure 7.6-2. The operation of these commands is identical for both PME-A and PME-B drivers.

PME A/B LATCH VALVE DRIVER ENABLE command enables a pulse to one side of a latching relay, closing it, enabling the unregulated +28 VDC power to the associated latch valve driver circuits. The complement to the latch valve driver enable command is the PME A/B latch valve driver disable command. The disable command enables a pulse to the opposite coil of the latching relay, causing the relay to open, removing power from the driver circuits.

Telemetry verification of latch valve driver status is indicated by PM telemetry point ZLVDVRS. ZLVDVRS is a multi-level analog signal which defines driver status as follows:

Latch Valve Driver Status PME-A	PME-B	ZLVDVRS TLM VOLTS
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

7.6.1.3 Latch Valve Control

OPEN LATCH VALVE 1 AND 6
OPEN LATCH VALVE 2
OPEN LATCH VALVE 3
OPEN LATCH VALVE 4
OPEN LATCH VALVE 5
CLOSE LATCH VALVE 1 AND 6
CLOSE LATCH VALVE 2 AND 4
CLOSE LATCH VALVE 3 AND 5

The function of these eight discrete commands is to control the operation of the six latch valves. The functional schematic for these commands is illustrated in Figure 7.6-2. Operation of these commands is identical for each latch valve. In order for these commands to function properly, the latch valve drivers must first be enabled.

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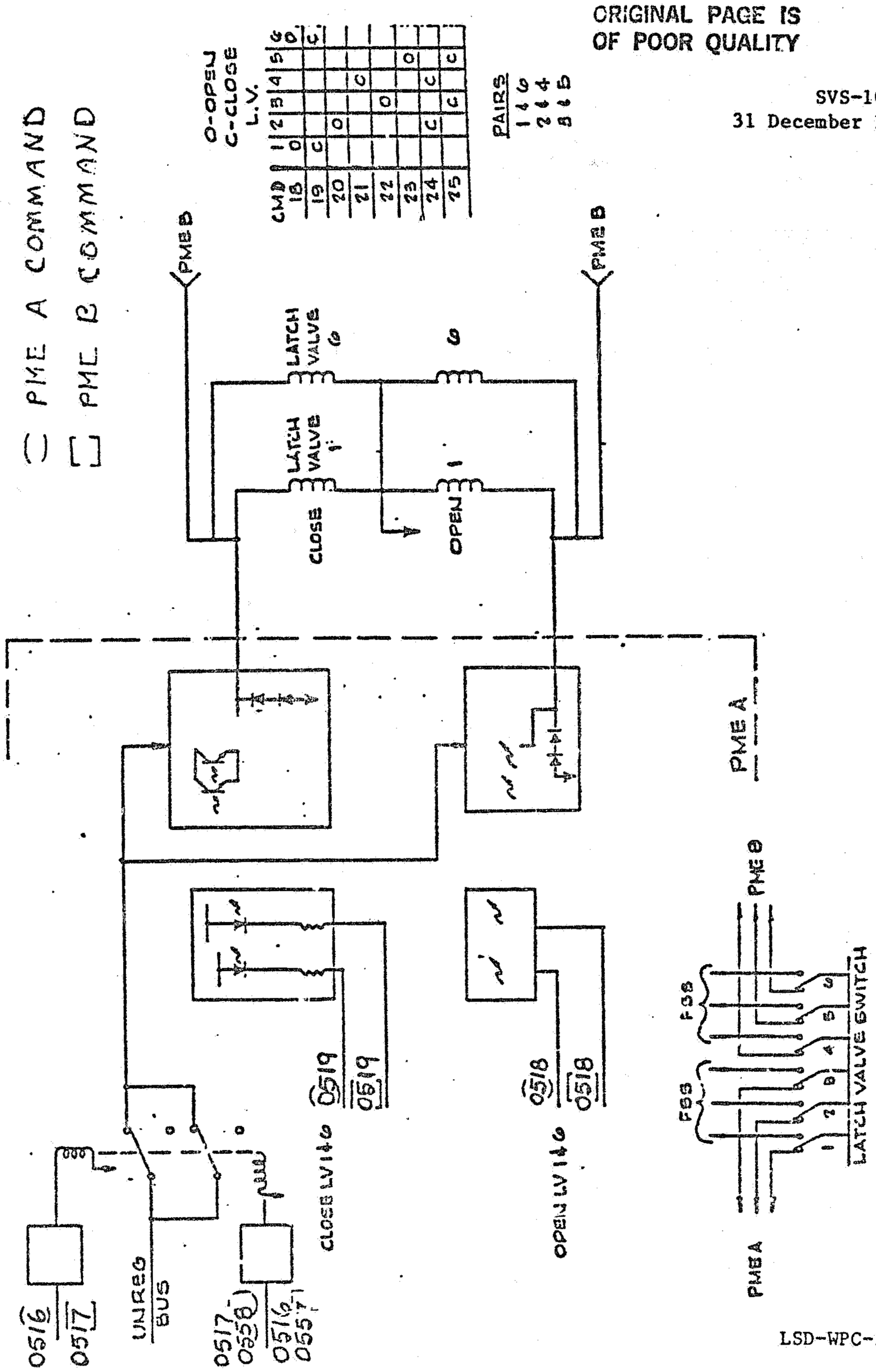

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An open latch valve command enables a pulse to an optical coupled isolator phototransistor which in turn drives one of the latch valve actuator coils, causing the valve to latch open. The complement is the latch valve close command which enables a pulse to the opposite actuator coil, latching the valve in the closed position.

Telemetry verification of latch valve open/closed status is indicated by PM telemetry points ZLV123 and ZLV456. These telemetry points are multi-level analog signals defined as follows:

Latch Valve Status ZLV123 1	2	3	TLM Volts
Open	Open	Open	0.400
Open	Open	Closed	1.879
Open	Closed	Open	2.462
Closed	Open	Open	3.025
Open	Closed	Closed	3.507
Closed	Open	Closed	3.952
Closed	Closed	Open	4.333
Closed	Closed	Closed	5.039

Latch Valve Status ZLV456 4	5	6	TLM Volts
Open	Open	Open	0.400
Open	Open	Closed	1.879
Open	Closed	Open	2.462
Closed	Open	Open	3.025
Open	Closed	Closed	3.507
Closed	Open	Closed	3.952
Closed	Closed	Open	4.333
Closed	Closed	Closed	5.039

7.6.1.4 PME A/B Selection for Attitude Control

ENABLE PME-A ATTITUDE CONTROL
DISABLE PME-A ATTITUDE CONTROL
ENABLE PME-B ATTITUDE CONTROL
DISABLE PME-B ATTITUDE CONTROL

The function of these four discrete commands is to control the unregulated +28 VDC and regulated +12.5 VDC power to PME-A and PME-B attitude control circuits. The functional schematic for these commands is illustrated in Figure 7.6-3. The operation of these commands is identical for both PME-A and PME-B.

PME A/B attitude control enable command enables a pulse to one side of a latching relay, closing it, enabling unregulated +28 VDC and regulated +12.5 VDC

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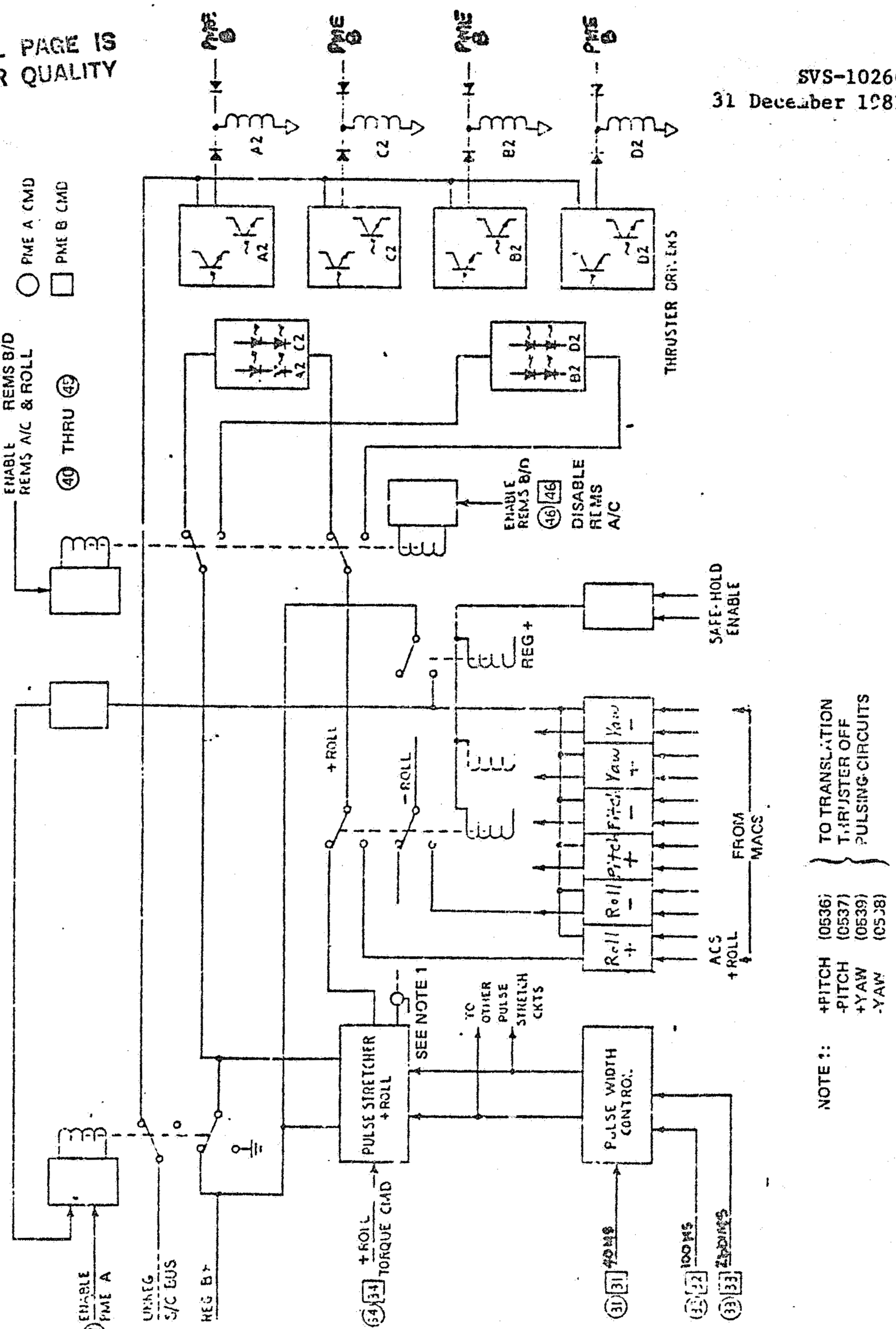

Figure 7.6-3. Attitude Thruster Control Functional Block Diagram

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power to the associated electronics used to control the operation of the attitude control thrusters. The complement to the attitude control enable command is the PME A/B disable command. The disable command enables a pulse to the opposite coil of the latching relay, causing the relay to open, removing both the regulated and unregulated power from the attitude control thruster electronics.

The telemetry verification of PME A/B attitude control status is indicated by PM telemetry point ZEABATC. ZEABATC is a multi-level analog signal which defines attitude control thruster electronics selection status as follows:

Attitude Control Thruster Electronics		ZEABATC
PME-A	PME-B	TLM Volts
Disabled	Disabled	0.40
Enabled	Enabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

7.6.1.5 Pulse Width Selection

SELECT 40 MSEC PULSE WIDTH
SELECT 100 MSEC PULSE WIDTH
SELECT 280 MSEC PULSE WIDTH

The function of these three discrete commands is to select the thruster pulse width for attitude control. The functional schematic for these commands is illustrated in Figure 7.6-3. For a given pulse with selection command to execute, at least one PME must be enabled for attitude control.

Pulse width selection is achieved by commanding either of the three discretes which configures a series of latching relays in the pulse control electronics. The complement to a given command is to select an alternate pulse width which results in a reconfiguration of the pulse control electronics.

Telemetry verification of selected pulse width is indicated by PM telemetry points ZEAPULS and ZEBPULS for PME-A and PME-B attitude control thruster electronics respectively. These points are multi-level analog signals defined as follows:

Selected Pulse Width	ZEAPULS/ZEBPULS TLM Volts
280 msec	0.40
100 msec	2.65
40 msec	3.78

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7.6.1.6 Attitude Control Torque Commands

+ROLL TORQUE COMMAND
-ROLL TORQUE COMMAND
+PITCH TORQUE COMMAND
-PITCH TORQUE COMMAND
+YAW TORQUE COMMAND
-YAW TORQUE COMMAND

The function of these six commands is to control the operation of the attitude control thrusters. The functional schematic for these commands is illustrated in Figure 7.6-3. Operation of these commands is identical for each thruster. Prior to issuing a torque command, desired PME attitude control thruster electronics, pulse width and REM selection must be commanded. In addition, the latch valves must be configured to achieve the desired propellant flow.

A given torque command enables a pulse to an optical coupled isolator phototransistor which in turn drives the thruster solenoid opening it for the selected pulse width duration. In the orbit adjust mode with all REMS enabled for translation control, the torque command also results in an off-pulse of an associated translation control thruster.

Telemetry verification of torque commands is indicated by PM telemetry points ZEAPGEN, ZEANGEN, ZEBPGEN and ZEBNGEN, for positive and negative torque commands associated with PME-A and PME-B respectively. The telemetry points are multi-level analog signals defined as follows:

Attitude Control Thruster Pulse Generated	ZEAPGEN/ZEANGEN ZEBPGEN/ZEBNGEN TLM Volts
No Pulses	0.400
Roll Pulse	1.879
Pitch Pulse	2.462
Yaw Pulse	3.025
Roll, Pitch Pulse	3.507
Roll, Yaw Pulse	3.952
Pitch, Yaw Pulse	4.333
Roll, Pitch, Yaw Pulse	5.039

The previous telemetry verifications indicate that an attitude control torque pulse was generated but failed to indicate actual thruster solenoid operation. Thruster solenoid operation is verified by PM telemetry points Z1RMAATC, Z1RMBATC, Z1RMCATC and Z1RMDATC, defined as:

REM A/B/C/D Attitude Control Thruster Status			Z1RMAATC,Z1RMBATC Z1RMCATC,Z1RMDATC
THR 2	THR 3	THR 4	TLM Volts
Off	Off	Off	0.400
Fired	Off	Off	1.879
Off	Fired	Off	2.462
Off	Off	Fired	3.025
Fired	Fired	Off	3.507
Fired	Off	Fired	3.952
Off	Fired	Fired	4.333
Fired	Fired	Fired	5.039

7.6.1.7 <u>REM Selection for Attitude Control</u>

ENABLE REMS A/C DISABLE REMS B/D FOR +ROLL
ENABLE REMS A/C DISABLE REMS B/D FOR -ROLL
ENABLE REMS A/C DISABLE REMS B/D FOR +PITCH
ENABLE REMS A/C DISABLE REMS B/D FOR -PITCH
ENABLE REMS A/C DISABLE REMS B/D FOR +YAW
ENABLE REMS A/C DISABLE REMS B/D FOR -YAW

ENABLE REMS B/D FOR ATTITUDE CONTROL DISABLE REMS A/C

The function of these seven discrete commands is to control the selection of REMS A/C or B/D for attitude control. The functional schematic for these commands is illustrated in Figure 7.6-3. Prior to issuing any commands in this series, an associated PME must first be enabled.

An enable REMS A/C command enables a pulse to one coil of a latching relay, routing the switched 12.5 VDC power and torque signals to REMS A and C. The complement to the REMS A/C enable command is the REM B/D enable for attitude control. The REM B/D enable command enables a pulse to the opposite coil of the latching relay, removing power and torque signals from REMS A/C and routing them to REMS B/D.

Telemetry verification of selected REMS enabled for attitude control is indicated by PM telemetry points ZEAPATC, ZEANATC, ZEBPATC, ZEBNATC for positive and negative, PME-A and PME-B REM selection respectively. These telemetry points are multi-level analog signals defined as follows:

REM A/C Attitude Control Thruster Status Roll	Pitch	Yaw	ZEAPATC,ZEANATC ZEBPATC,ZEBPATC TLM Volts
Disabled	Disabled	Disabled	0.400
Enabled	Disabled	Disabled	1.879
Disabled	Enabled	Disabled	2.462
Disabled	Disabled	Enabled	3.025
Enabled	Enabled	Disabled	3.507
Enabled	Disabled	Enabled	3.952
Disabled	Enabled	Enabled	4.333
Enabled	Enabled	Enabled	5.039

7.6.1.8 PME A/B Selection for Translation Control

ENABLE PME-A FOR TRANSLATION CONTROL DISABLE PME-B
ENABLE PME-B FOR TRANSLATION CONTROL DISABLE PME-A

The function of these two discrete commands is to control the regulated +12.5 VDC power to PME-A or PME-B translation control circuits. The functional schematic for these commands is illustrated in Figure 7.6-1. The operation of these commands is identical for both PME-A and PME-B.

PME-A enable for translation control command enables a pulse to one side of a latching relay in both PME-A and PME-B. In PME-A, the relay routes the regulated +12.5 VDC power to PME-A translation control electronics. In PME-B, the relay switches PME-B translation control electronic to ground. The complement to the PME-A enable command is the PME-B enable command. The PME-B enable for translation control command enables a pulse to the opposite side of the latching relay in both PME-A and PME-B, removing power from PME-A, routing power to PME-B translation control electronics.

Telemetry verification of PME A/B translation control status is indicated by PM telemetry point ZEABTRS. ZEABTRS is a multi-level analog signal which defines PME A/B selection for translation control as follows:

Selected Electronics PME-A	PME-B	ZEABTRS TLM Volts
Enabled	Disabled	2.65
Disabled	Enabled	3.78

7.6.1.9 REM Selection for Translation Control

ENABLE REMS A/C FOR TRANSLATION CONTROL
DISABLE REMS A/C FOR TRANSLATION CONTROL
ENABLE REMS B/D FOR TRANSLATION CONTROL
DISABLE REMS B/D FOR TRANSLATION CONTROL

The function of these four discrete commands is to control the selection of REMS A/C and B/D for translation control. The functional schematic for these commands is illustrated in Figure 7.6-1. Prior to issuing any commands in this series, an associated PME must first be enabled for translation control. Operation of these commands is identical for REMS A/C and B/D.

An enable REM command enables a pulse to one side of a latching relay, enabling the unregulated +28 VDC to the solenoid side of the thruster drive circuits. The complement is to disable the associated REM, removing power from the thruster drive circuits.

Telemetry verification of selected REMS enabled for translation control is indicated by PM telemetry points ZEARMTC and ZEBRMTC for PME-A and PME-B respectively. These telemetry pints are multi-level analog signals defined as follows:

Translation Control Selected REM Pair A/C	B/D	ZEARMTC/ZEBRMTC TLM Volts
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Disabled	4.99

7.6.1.10 Translation Thrust Command

TRANSLATION THRUST COMMAND

The function of this command is to control the operation of the translation control thrusters. The functional schematic for these commands is illustrated in Figure 7.6-1. Prior to issuing a translation thrust command, desired PME translation thruster electronics and REM selection must be commanded. In addition, the latch valves must be configured to achieve the desired propellant flow.

The translation thrust command enables a pulse to an optical coupled isolator phototransistor which in turn drives the thruster solenoid opening it for a refreshable 1 second duration. Issuing additional translation thrust commands before the end of the previous 1 second commanded duration results in continuous firings.

Telemetry verification of translation thrust commands is indicated by PM telemetry points ZRMACTC and ZRMBDTC for REMS A/C and REMS B/D firings respectively. These telemetry points are multi-level analog signals defined as:

REM A/C Translation Control Thurster Status A1	C1	ZRMACTC TLM Volts
Off	Off	0.40
Fired	Off	2.65
Off	Fired	3.78
Fired	Fired	4.99

REM B/D Translation Control Thruster Status B1	D1	ZRMBDTC TLM Volts
Off	Off	0.40
Fired	Off	2.65
Off	Fired	3.78
Fired	Fired	4.99

7.6.1.11 PM Heater Power Bus Control

ENABLE PRIMARY HEATER BUS
DISABLE PRIMARY HEATER BUS
ENABLE REDUNDANT HEATER BUS
DISABLE REDUNDANT HEATER BUS

The function of these four discrete commands is to enable spacecraft heater bus power to primary and redundant PM heaters. The functional schematic for these commands is illustrated in Figure 7.6-4. The operation of these commands is identical for primary and redundant heater bus control.

The enable heater bus command enables a pulse to one coil of a latching relay, closing it, enabling spacecraft heater bus power to REM and shelf heater circuits. The complement to the enable command is the disable heater bus command. The disable command enables a pulse to the opposite coil of the latching relay, causing it to open, removing power from the heater circuits.

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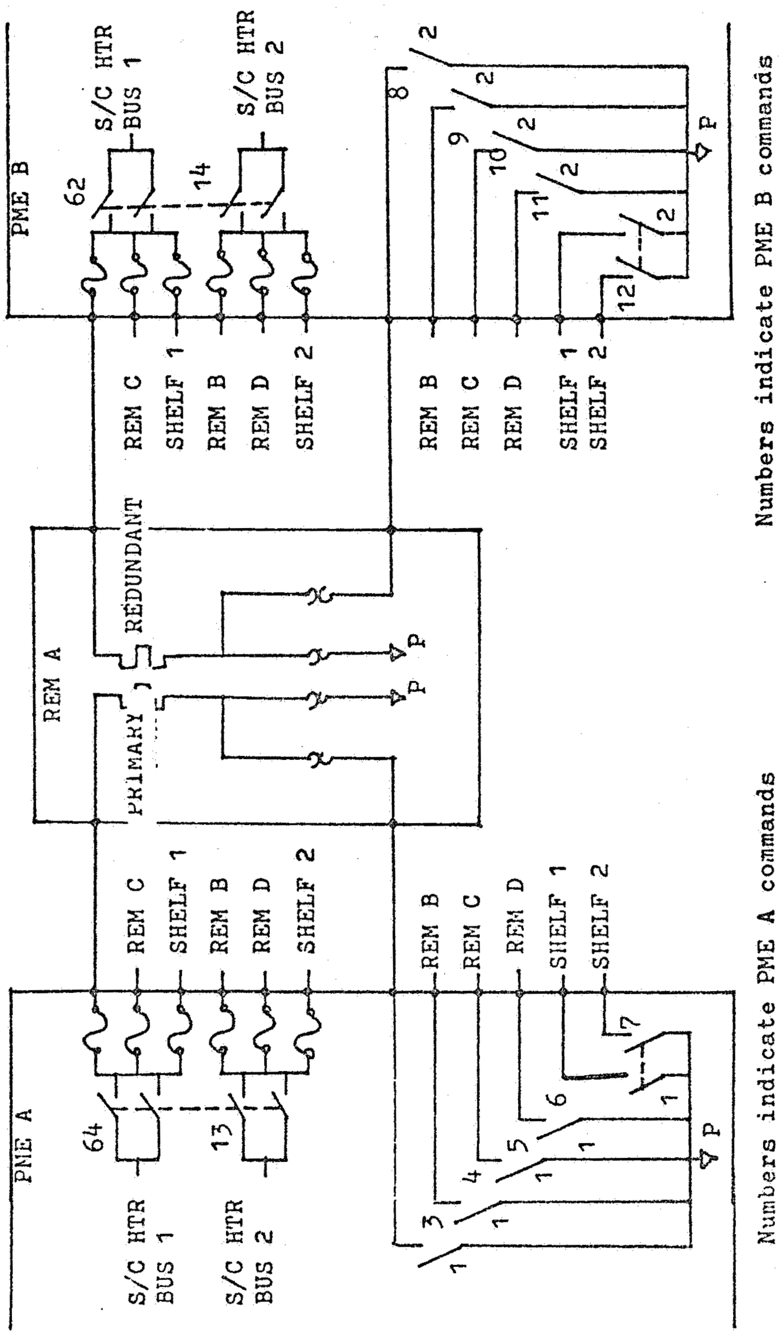

Figure 7.6-4. Heater Control Functional Block Diagram

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Telemetry verification of heater bus status is indicated by PM telemetry point ZHTRBUS. ZHTRBUS is a multi-level analog signal defined as:

Heater Power Bus Status Primary	Redundant	ZHTRBUS TLM Volts
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

7.6.1.12 Heater Thermostat Selection

PRIMARY HEATERS ON AUTO MODE MANUAL MODE OFF
REM A PRIMARY HEATERS ON MANUAL MODE
REM B PRIMARY HEATERS ON MANUAL MODE
REM C PRIMARY HEATERS ON MANUAL MODE
REM D PRIMARY HEATERS ON MANUAL MODE
SHELF PRIMARY HEATERS ON MANUAL MODE

REDUNDANT HEATERS ON AUTO MODE MANUAL MODE OFF
REM A REDUNDANT HEATERS ON MANUAL MODE
REM B REDUNDANT HEATERS ON MANUAL MODE
REM C REDUNDANT HEATERS ON MANUAL MODE
REM D REDUNDANT HEATERS ON MANUAL MODE
SHELF REDUNDANT HEATERS ON MANUAL MODE

The function of these 12 discrete commands is for the selection of heater control in the automatic or manual mode. In the automatic mode a prime thermostat is used for heater control. In the manual mode an alternate thermostat with a higher set point is switched into the heater control circuit. The operation of these commands is identical for both primary and redundant heaters.

A manual mode command enables a pulse to one coil of a latching relay, closing it, switching the alternate heater thermostat into the heater control circuit. The complement to the manual mode command is the auto mode command. The auto mode command enables a pulse to the opposite coil of the latching relay, removing the alternate thermostat from the control loop.

Telemetry verification of auto/manual mode heater operation is indicated in PM bilevel words 1 and 2 for primary and redundant heaters respectively. Acronyms for these telemetry points are as defined in Table 7.6-1. A bilevel 0 indicates operation in the automatic mode. A bilevel 1 indicates operation in the manual mode.

The functional schematic for these commands is illustrated in Figure 7.6-4.

7.6.1.13 ATK Heater Control

ATK PRIMARY TANK HEATER ENABLE
ATK PRIMARY TANK HEATER DISABLE
ATK REDUNDANT TANK HEATER ENABLE
ATK REDUNDANT TANK HEATER DISABLE
ATK TANK HEATER THERMOSTAT BYPASS
ATK TANK HEATER THERMOSTAT ENABLE

ATK PRIMARY LINE HEATER ENABLE
ATK PRIMARY LINE HEATER DISABLE
ATK REDUNDANT LINE HEATER ENABLE
ATK REDUNDANT LINE HEATER DISABLE
ATK LINE HEATER THERMOSTAT BYPASS
ATK LINE HEATER THERMOSTAT ENABLE

These commands enable the heater control functions associated with the operation of the ATK and are controlled by a single serial message command. Table 7.6-1 specifies the structure of the command required to achieve a given function. The operation of the commands is similar for tank and line heater control functions.

Prime and redundant heater enable commands enable a pulse to one coil of a latching relay, enabling spacecraft heater bus power to the associated heater circuit. The complement is the disable command which enables a pulse to the opposite coil of the latching relay, removing power from the heater circuit.

Tank and line thermostat bypass commands enable the use of alternate thermostats in the heater control circuits. Primary thermostat control can be reinstated through the use of the thermostat enable commands.

Telemetry verification of ATK heater operation is indicated by PM serial digital word Z1AHTRS. Telemetry acronyms are specified in Table 7.6-1 for the various functions. A bilevel 0 indicates heaters disabled or primary thermostats enabled. A bilevel 1 indicates heaters enabled or thermostats bypassed.

7.6.2 COMMAND SEQUENCES

This section lists the command sequences which relate to the operation of the propulsion module.

PM Initialization for Attitude Control A-Side

ENABLE PME-A FOR ATTITUDE CONTROL
ENABLE REM A/C FOR +ROLL
ENABLE REM A/C FOR -ROLL
ENABLE REM A/C FOR +PITCH
ENABLE REM A/C FOR -PITCH
ENABLE REM A/C FOR +YAW
ENABLE REM A/C FOR -YAW
SELECT PULSE WIDTH (40, 100 OR 280 MS)
ENABLE PME-A LATCH VALVE DRIVERS
CONFIGURE LATCH VALVES
DISABLE PME-A LATCH VALUE DRIVERS

PM Initialization for Attitude Control B-Side

ENABLE PME-B FOR ATTITUDE CONTROL
ENABLE REMS B/D DISABLE ALL A/C
SELECT PULSE WIDTH (40, 100 OR 280 MS)
ENABLE PME-B LATCH VALVE DRIVERS
CONFIGURE LATCH VALVES
DISABLE PME-B LATCH VALVE DRIVERS

PM Initialization for Translation Control A-Side

ENABLE PME-A FOR TRANSLATION CONTROL
ENABLE REMS A/C FOR TRANSLATION CONTROL
ENABLE REMS B/D FOR TRANSLATION CONTROL
ENABLE PME-A LATCH VALVE DRIVERS
CONFIGURE LATCH VALVES
DISABLE PME-A LATCH VALVE DRIVERS

PM Initialization for Translation Control B-Side

ENABLE PME-B FOR TRANSLATION CONTROL
ENABLE REMS A/C FOR TRANSLATION CONTROL
ENABLE REMS B/D FOR TRANSLATION CONTROL
ENABLE PME-B LATCH VALVE DRIVERS
CONFIGURE LATCH VALVES
DISABLE PME-B LATCH VALVE DRIVERS

PM SAFING

ENABLE PME-A LATCH VALVE DRIVERS
CLOSE LATCH VALVE 1 AND 6
CLOSE LATCH VALVE 2 AND 4
CLOSE LATCH VALVE 3 AND 5
DISABLE PME-A LATCH VALVE DRIVERS
DISABLE PME-A FOR ATTITUDE CONTROL
DISABLE PME-B FOR ATTITUDE CONTROL
DISABLE REMS A/C FOR TRANSLATION CONTROL
DISABLE REMS B/D FOR TRANSLATION CONTROL

7.6.3 COMMAND RESTRAINTS

This section lists the command restraints associated with the operation of the propulsion module. The following restraints apply:

- It is a recommended operating procedure that PME-A be selected when using ACE A and PME-B be selected when using ACE B.

- PME-A or PME-B must be enabled for attitude control if off-pulsing is required during an orbit adjust maneuver.

7.7 PM TELEMETRY

Operation of the propulsion module is monitored using 48 telemetry channels of which 26 are active analog, 19 are conditioned (passive) analog, two are bilevel digital, and one is serial digital.

The telemetry points are listed in Table 7.7-1 and described in Paragraphs 7.7.1.1 thru 7.7.2.3. Telemetry limits appear in Table 7.7-2; derivation circuits appear in Section 7.7.3. For information regarding calibration curves for the telemetered functions, see Appendix A.7.

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Table 7.7-1. PM Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
PM-01	BILEVEL WORD 01:						7.7.2.1
	RIU 05 MATE STANDBY 1/OFF	ZMATENF	B0	97(17)	97(17)	05-32	
	RIU 05 B ON/A ON	ZRIUSBA	B1	97(17)	97(17)	05-33	
	REM A PRI HTR THMSTAT SEL RED/PRI	ZRMAPRHT	B3	97(17)	97(17)	05-35	
	REM B PRI HTR THMSTAT SEL RED/PRI	ZRMBPRHT	B4	97(17)	97(17)	05-36	
	REM C PRI HTR THMSTAT SEL RED/PRI	ZRMCPRHT	B5	97(17)	97(17)	05-37	
	REM D PRI HTR THMSTAT SEL RED/PRI	ZRMDPRHT	B6	97(17)	97(17)	05-38	
	SHELF PRI HTR THMSTAT SEL RED/PRI	ZSHFPRHT	B7	97(17)	97(17)	05-39	
PM-02	BILEVEL WORD 02:						7.7.2.2
	REM A RED HTR THMSTAT SEL RED/PRI	ZRMABUHT	B0	98(17)	98(17)	05-40	
	REM B RED HTR THMSTAT SEL RED/PRI	ZRMBBUHT	B1	98(17)	98(17)	05-41	
	REM C RED HTR THMSTAT SEL RED/PRI	ZRMCBUHT	B2	98(17)	98(17)	05-42	
	REM D RED HTR THMSTAT SEL RED/PRI	ZRMDBUHT	B3	98(17)	98(17)	05-43	
	SHELF RED HTR THMSTAT SEL RED/PRI	ZSHFBUHT	B4	98(17)	98(17)	05-44	
PM-03	REM A TEMP1(PME-A),TEMP3(PME-B)	ZTRMA1A3	P	97(37)	97(37)	05-16	7.7.1.1
PM-04	REM A TEMP2(PME-A),TEMP4(PME-B)	ZTRMA2A4	P	97(38)	97(38)	05-17	7.7.1.1
PM-05	REM B TEMP1(PME-A),TEMP3(PME-B)	ZTRMB1B3	P	98(123)	98(123)	05-18	7.7.1.1
PM-06	REM B TEMP2(PME-A),TEMP4(PME-B)	ZTRMB2B4	P	98(124)	98(124)	05-19	7.7.1.1
PM-07	REM C TEMP1(PME-A),TEMP3(PME-B)	ZTRMC1C3	P	98(87)	98(87)	05-20	7.7.1.1
PM-08	REM C TEMP2(PME-A),TEMP4(PME-B)	ZTRMC2C4	P	98(88)	98(88)	05-21	7.7.1.1
PM-09	REM D TEMP1(PME-A),TEMP3(PME-B)	ZTRMD1D3	P	97(89)	97(89)	05-22	7.7.1.1
PM-10	REM D TEMP2(PME-A),TEMP4(PME-B)	ZTRMD2D4	P	97(90)	97(90)	05-23	7.7.1.1
PM-11	TANK 1 TEMP	ZTTANK1	P	97(85)	97(85)	05-24	7.7.1.2
PM-12	TANK 2 TEMP	ZTTANK2	P	97(94)	97(94)	05-25	7.7.1.2

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Table 7.7-1. PM Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
PM-13	TANK 3 TEMP	ZTTANK3	P	98(23)	98(23)	05-26	7.7.1.2
PM-14	L/V1TEMP(PME-A),L/V4TEMP(PME-B)	ZTLV1LV4	P	98(24)	98(24)	05-27	7.7.1.3
PM-15	L/V2TEMP(PME-A),L/V5TEMP(PME-B)	ZTLV2LV5	P	98(91)	98(91)	05-28	7.7.1.3
PM-16	L/V3TEMP(PME-A),L/V6TEMP(PME-B)	ZTLV3LV6	P	98(92)	98(92)	05-29	7.7.1.3
PM-17	BEAM TEMP CENTER(PME-A),PME(PME-B)	ZTBMCTR	P	98(93)	98(93)	05-30	7.7.1.4
PM-18	BEAM TEMP REM A(PME-A),REM B(PME-B)	ZTBMRMAB	P	98(94)	98(94)	05-31	7.7.1.4
PM-19	FUEL TANK PRESSURE	ZFULPSI	A	98(47)	98(47)	05-14	7.7.1.5
PM-20	PRI/REDUND HTR BUS ENA/DISA	ZHTRBUS	A	97(117)	97(117)	05-34	7.7.1.6
PM-21	PME A/B LATCH VALVE DRIVER ENA/DISA	ZLVDVRS	A	96(126)	96(126)	05-45	7.7.1.7
PM-22	LATCH VALVES 1,2,3 OPEN/CLOSED	ZLV123	A	97(126)	97(126)	05-46	7.7.1.8
PM-23	LATCH VALVES 4,5,6 OPEN/CLOSED	ZLV456	A	98(126)	98(126)	05-47	7.7.1.8
PM-24	PME AAB ATT CONTROL EN/DISA	ZEABTC	A	96(105)	96(105)	05-48	7.7.1.9
PM-25	PME A 40/100/280 MS PULSE SELECT	ZEAPULS	A	98(112)	98(112)	05-49	7.7.1.10
PM-26	PME B 40/100/280 MS PULSE SELECT	ZEBPULS	A	98(113)	98(113)	05-50	7.7.1.10
PM-27	ACS DIRECT CONTROL INPUTS ENA/DISA	ZACSDIR	A	96(109)	96(109)	05-51	7.7.1.11
PM-28	PME A POS ATT CONT REM A/C ENA/DISA	ZEAPATC	A	97(109)	97(109)	05-56	7.7.1.12
PM-29	PME A NEG ATT CONT REM A/C ENA/DISA	ZEANATC	A	98(109)	98(109)	05-57	7.7.1.12
PM-30	PME B POS ATT CONT REM A/C ENA/DISA	ZEBPATC	A	97(110)	97(110)	05-58	7.7.1.12
PM-31	PME B NEG ATT CONT REM A/C ENA/DISA	ZEBNATC	A	98(110)	98(110)	05-59	7.7.1.12

Table 7.7-1. PM Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
PM-32	PME A POS ATT CONT TORQ PULSE GEN	ZEAPGEN	A	96(112)	96(112)	05-52	7.7.1.13
PM-33	PME A NEG ATT CONT TORQ PULSE GEN	ZEANGEN	A	97(112)	97(112)	05-53	7.7.1.13
PM-34	PME B POS ATT CONT TORQ PULSE GEN	ZEBPGEN	A	96(113)	96(113)	05-54	7.7.1.13
PM-35	PME B NEG ATT CONT TORQ PULSE GEN	ZEBNGEN	A	97(113)	97(113)	05-55	7.7.1.13
PM-36	PME A/B TRANSLATION CONTROL ENA/DISA	ZEABTRS	A	98(115)	98(115)	05-60	7.7.1.14
PM-37	PME A TR CONT REM A/C,B/D ENA/DIS	ZEARMTC	A	96(114)	96(114)	05-61	7.7.1.15
PM-38	PME B TR CONT REM A/C,B/D ENA/DIS	ZEBRMTC	A	96(115)	96(115)	05-62	7.7.1.15
PM-39	REM A/C TRANSL CONT THRUSTERS ON/OFF	ZRMACTC	A	97(114)	97(114) 06	05-12	7.7.1.16
PM-40	REM B/D TRANSL CONT THRUSTERS ON/OFF	ZRMBDTC	A	97(115)	97(115) 70	05-13	7.7.1.16
PM-41	REM A ATT CONTROL THRUSTERS ON/OFF	Z1RMAATC Z2RMAATC	A	04 68	04 68	05-00	7.7.1.17
PM-42	REM C ATT CONTROL THRUSTERS ON/OFF	Z1RMCATC Z2RMCATC	A	36 100	36 100	05-01	7.7.1.17
PM-43	REM B ATT CONTROL THRUSTERS ON/OFF	Z1RMBATC Z2RMBATC	A	05 69	05 69	05-02	7.7.1.17
PM-44	REM D ATT CONTROL THRUSTERS ON/OFF	Z1RMDATC Z2RMDATC	A	37 104	37 104	05-03	7.7.1.17
PM-45	ATK HEATER 1-4 STATUS:	Z1AHTRS					7.7.2.3
	UNUSED BIT		S0	32(64)	32(64)	04-03	
	UNUSED BIT		S1	32(64)	32(64)	04-03	
	ATK PRI TANK HTR ENA/DISA	ZPRTKHT	S2	32(64)	32(64)	04-03	
	ATK PRI LINE HTR ENA/DISA	ZPRLNHT	S3	32(64)	32(64)	04-03	
	ATK LINE HTR THMSTAT BYP/ENA	ZPRLNTH	S4	32(64)	32(64)	04-03	

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Table 7.7-1. PM Telemetry List

User ID	TLM Function Description	Acronym	Sig Type	Matrix Loc Mission	Matrix Loc Engr	RIU-CH	Reference Paragraph
	ATK RED TANK HTR ENA/DISA	ZBUTKHT	S5	32(64)	32(64)	04-03	
	ATK RED LINE HTR ENA/DISA	ZBULNHT	S6	32(64)	32(64)	04-03	
	ATK TANK HTR THMSTAT BYP/ENA	ZBULNTH	S7	32(64)	32(64)	04-03	
PM-48	ATK TANK TEMPERATURE	ZT1ATNK	P	96(64)	96(64)	04-26	7.7.1.18
PM-49	ATK FUEL TEMPERATURE	ZT1AFUL	P	97(64)	97(64)	04-27	7.7.1.18
PM-50	ATK LINE TEMPERATURE	ZT1ALIN	P	98(70)	98(70)	04-28	7.7.1.18

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Table 7.7-2. PM Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	Eng Units
PM-03	ZTRMA1A3	REM/SHELF HTR PWR ENA	35	85*	°C
PM-04	ZTRMA2A4	REM/SHELF HTR PWR ENA	35	85*	°C
PM-05	ZTRMB1B3	REM/SHELF HTR PWR ENA	35	85*	°C
PM-06	ZTRMB2B4	REM/SHELF HTR PWR ENA	35	85*	°C
PM-07	ZTRMC1C3	REM/SHELF HTR PWR ENA	35	85*	°C
PM-08	ZTRMC2C4	REM/SHELF HTR PWR ENA	35	85*	°C
PM-09	ZTRMD1D3	REM/SHELF HTR PWR ENA	35	85*	°C
PM-10	ZTRMD2D4	REM/SHELF HTR PWR ENA	35	85*	°C
PM-11	ZTTANK1	REM/SHELF HTR PWR ENA	10	60	°C
PM-12	ZTTANK2	REM/SHELF HTR PWR ENA	10	60	°C
PM-13	ZTTANK3	REM/SHELF HTR PWR ENA	10	60	°C

*Excludes firing temperature. Firing and soakback temperature upper limit = 120°C.

Table 7.7-2. PM Telemetry Limits

User ID	Acronym	Mode	Limits Lower	Limits Upper	Eng Units
PM-14	ZTLV1LV4	REM/SHELF HTR PWR ENA	10	60	°C
PM-15	ZTLV2LV5	REM/SHELF HTR PWR ENA	10	60	°C
PM-16	ZTLV3LV6	REM/SHELF HTR PWR ENA	10	60	°C
PM-17	ZTBMCTR	REM/SHELF HTR PWR ENA	10	60	°C
PM-18	ZTBMRMAB	REM/SHELF HTR PWR ENA	10	60	°C
PM-19	ZFULPSI	REM/SHELF HTR PWR ENA	50	350	PSI
PM-48	ZT1ATNK	ATK TANK HTR ENA	10	60	°C
PM-49	ZT1AFUL	ATK TANK HTR ENA	10	60	°C
PM-50	ZT1ALIN	ATK LINE HTR ENA	10	60	°C

7.7.1 ANALOG TELEMETRY MONITORS

The propulsion module utilizes 45 analog telemetry monitors, including 26 active and 19 passive analog telemetry points. These points are listed by user ID in Table 7.7-1 and 7.7-2 for telemetry matrix location and operating limits respectively. The following paragraphs describe these telemetry monitors.

7.7.1.1 Rocket Engine Module Temperature Monitors

REM A TEMP 1 (PME-A), TEMP 3 (PME-B)	(PM-03)
REM A TEMP 2 (PME-A), TEMP 4 (PME-B)	(PM-04)
REM B TEMP 1 (PME-A), TEMP 3 (PME-B)	(PM-05)
REM B TEMP 2 (PME-A), TEMP 4 (PME-B)	(PM-06)
REM C TEMP 1 (PME-A), TEMP 3 (PME-B)	(PM-07)
REM C TEMP 2 (PME-A), TEMP 4 (PME-B)	(PM-08)
REM D TEMP 1 (PME-A), TEMP 3 (PME-B)	(PM-09)
REM D TEMP 2 (PME-A), TEMP 4 (PME-B)	(PM-10)

These telemetry points monitor the temperature of the four REM's as measured by passive temperature probes indicating individual thruster baseplate temperatures. Identical circuits are used to monitor all REM temperatures, with a typical circuit illustrated in Figure 7.7-1.

7.7.1.2 Tank Temperature Monitors

TANK 1 TEMP	(PM-11)
TANK 2 TEMP	(PM-12)
TANK 3 TEMP	(PM-13)

These telemetry points monitor the temperature of the three main PM fuel tanks as measured by passive temperature probes. Identical circuits are used to monitor all tank temperatures, with a typical circuit illustrated in Figure 7.7-1.

7.7.1.3 Latch Valve Temperature Monitors

L/V 1 TEMP (PME-A), L/V 4 TEMP (PME-B)	(PM-14)
L/V 2 TEMP (PME-A), L/V 5 TEMP (PME-B)	(PM-15)
L/V 3 TEMP (PME-A), L/V 6 TEMP (PME-B)	(PM-16)

These telemetry points monitor the temperature of the six latch valves as measured by passive temperature probes on each valve. Identical circuits are used to monitor all valve temperatures, with a typical circuit illustrated in Figure 7.7-1.

7.7.1.4 Beam Temperature Monitors

BEAM TEMP CENTER (PME-A), PME (PME-B)	(PM-17)
BEAM TEMP REM A (PME-A), REM B (PME-B)	(PM-18)

These telemetry points monitor the temperature of the I-beam structure used to support the three main propellant tanks. One probe monitors the center truss where all three beams meet. The other sensors are located on each of three arms. Each sensor is a passive device, with a typical telemetry derivation circuit illustrated in Figure 7.7-1.

7.7.1.5 Fuel Tank Pressure Monitor

Fuel Tank Pressure (PM-19)

This telemetry point monitors fuel tank manifold pressure via a strain gage sensing element as shown in Figure 7.7-2. The pressure transducer senses absolute pressure throughout the range from zero to 500 psia.

7.7.1.6 Heater Power Bus Status Monitor

PRI/REDUND HTR BUS ENA/DISA (PM-20)

This telemetry point monitors the status of REM and shelf heater power, indicating whether the prime or redundant heater bus is enabled. This function is defined in terms of telemetry volts as follows:

Heater Power Bus Status		
Primary	Redundant	TLM Volts
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

Heater power bus status is derived as shown in Figure 7.7-3. Note that primary heater power bus is controlled thru PME A, redundant thru PME B.

7.7.1.7 Latch Valve Driver Status Monitor

PME A/B LATCH VALVE DRIVER ENA/DISA (PM-21)

This telemetry point monitors the status of the latch valve drivers, indicating whether PME A or PME B drivers are enabled. Latch valve driver status is defined in terms of telemetry volts as follows:

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Latch Valve Driver Status

PME A	PME B	TLM Volts
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

Latch valve driver status is derived as shown in Figure 7.7-4.

7.7.1.8 Latch Valve Status Monitor

LATCH VALVE 1,2,3 OPEN/CLOSED (PM-22)
LATCH VALVE 4,5,6 OPEN/CLOSED (PM-23)

These telemetry points monitor the status of the latch valves, indicating whether they are open or closed. Latch valves 1 and 6 control the flow of propellant to the translation thrusters, while latch valves 2 thru 5 control the flow to REM A, B, C and D attitude thrusters respectively. Latch valve 1,2,3 status is defined in terms of telemetry volts as:

Latch Valve Status

1	2	3	TLM Volts
Open	Open	Open	0.400
Open	Open	Closed	1.879
Open	Closed	Open	2.462
Closed	Open	Open	3.025
Open	Closed	Closed	3.507
Closed	Open	Closed	3.952
Closed	Closed	Open	4.333
Closed	Closed	Closed	5.039

Similarly, latch valve 4,5,6 status is defined as:

Latch 4	Valve 5	Status 6	TLM Volts
Open	Open	Open	0.400
Open	Open	Closed	1.879
Open	Closed	Open	2.462
Closed	Open	Open	3.025
Open	Closed	Closed	3.507
Closed	Open	Closed	3.952
Closed	Closed	Open	4.333
Closed	Closed	Closed	5.039

Latch valve status is derived as shown in Figure 7.7-5.

7.7.1.9 Attitude Control Electronics Status Monitor

PME A/B ATT CONTROL ENA/DISA (PM-24)

This telemetry point indicates which set of propulsion module electronics has been selected to drive the attitude control thrusters. Its status is defined in terms of telemetry volts as follows:

Selected Electronics PME A	PME B	TLM Volts
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

Attitude control electronics status is derived as shown in Figure 7.7-6.

7.7.1.10 Selected Thruster Pulse Width Telemetry

PME A 40/100/280 MS PULSE SELECT (PM-25)
PME B 40/100/280 MS PULSE SELECT (PM-26)

These telemetry points indicate thruster pulse width duration as selected for use by the attitude control thrusters and are defined as:

Selected Pulse Width	TLM Volts
280 msec	0.40
100 msec	2.65
40 msec	3.78

Selected thruster pulse width telemetry is derived as shown in Figure 7.7-7.

7.7.1.11 ACS Direct Control Input Status Monitor

ACS DIRECT CONTROL INPUTS ENA/DISA (PM-27)

This telemetry point monitors the status of the direct ACS input enable relay, used to enable direct thruster inputs from MACS during safe-hold. Its status is defined in terms of telemetry volts as:

ACS Direct Control Input Status

PME A	PME B	TLM Volts
Enable	Enable	0.40
Disable	Enable	2.65
Enable	Disable	3.78
Disable	Disable	4.99

The telemetry derivation circuit for this function is illustrated in Figure 7.7-8.

7.7.1.12 REM A/C Attitude Control Thruster Status Monitor

PME A POS ATT CONT REM A/C ENA/DISA (PM-28)
PME A NEG ATT CONT REM A/C ENA/DISA (PM-29)
PME B POS ATT CONT REM A/C ENA/DISA (PM-30)
PME B NEG ATT CONT REM A/C ENA/DISA (PM-31)

These telemetry points monitor the status of PME A/B REM A/C attitude control thrusters, indicating whether the ± roll, pitch and yaw thrusters are enabled. These functions are defined interms of telemetry volts as follows:

REM A/C Attitude Control Thruster Status			
Roll	Pitch	Yaw	TLM Volts
Disabled	Disabled	Disabled	0.400
Enabled	Disabled	Disabled	1.879
Disabled	Enabled	Disabled	2.462
Disabled	Disabled	Enabled	3.025
Enabled	Enabled	Disabled	3.507
Enabled	Disabled	Enabled	3.952
Disabled	Enabled	Enabled	4.333
Enabled	Enabled	Enabled	5.039

A circuit typical of the derivation of these telemetry points is illustrated in Figure 7.7-9.

7.7.1.13 Generated Attitude Control Pulse Monitor

PME A POS ATT CONT TORQ PULSE GEN (PM-32)
PME A NEG ATT CONT TORQ PULSE GEN (PM-33)
PME B POS ATT CONT TORQ PULSE GEN (PM-34)
PME B NEG ATT CONT TORQ PULSE GEN (PM-35)

These telemetry points monitor what, if any, attitude control thruster pulses have been generated by either PME A or PME B. An indication of ± roll, pitch and yaw pulses being generated is included in these functions, defined in terms of telemetry volts as:

PME A/PME B Attitude Control Thruster Pulse Generated	TLM Volts
No Pulses	0.400
Roll Pulse	1.879
Pitch Pulse	2.462
Yaw Pulse	3.025
Roll, Pitch Pulse	3.507
Roll, Yaw Pulse	3.952
Pitch, Yaw Pulse	4.333
Roll, Pitch, Yaw Pulse	5.039

These telemetry functions are derived as shown in Figure 7.7-10.

7.7.1.14 Translation Control Electronics Status Monitor

PME A/B TRANSLATION CONTROL ENA/DISA (PM-36)

This telemetry point indicates which set of propulsion module electronics has been selected to drive the translation control thrusters. Its status is defined in terms of telemetry volts as follows:

Selected Electronics PME A	PME B	TLM Volts
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

Translation control electronics status is derived as shown in Figure 7.7-11.

7.7.1.15 Translation Control REM Select Monitors

PME A TR CONT REM A/C,B/D ENA/DIS (PM-37)
PME B TR CONT REM A/C,B/D ENA/DIS (PM-38)

These telemetry points indicate which pair of REM's have been selected for translation control. The function of these monitors are identical for PME A and PME B, defined in terms of telemetry volts as:

Translation Control Selected Rem Pair A/C	B/D	TLM Volts
Disabled	Disabled	0.40
Enabled	Disabled	2.65
Disabled	Enabled	3.78
Enabled	Enabled	4.99

The telemetry derivation circuit for these functions is shown in Figure 7.7-12.

7.7.1.16 Translation Control Thruster Firing Monitors

REM A/C TRANSL CONT THRUSTERS ON/OFF	(PM-39)
REM B/D TRANSL CONT THRUSTERS ON/OFF	(PM-40)

These telemetry points monitor actual translation control thruster firings, indicating which individual translation control thrusters are fired. The status of REM A/C translation control thrusters is defined in terms of telemetry volts as:

REM A/C Translation Control Thruster Status		
A1	C1	TLM Volts
Off	Off	0.40
Fired	Off	2.65
Off	Fired	3.78
Fired	Fired	4.99

Similarly, REM B/D translation control thruster status is defined as:

REM B/D Translation Control Thruster Status		
B1	D1	TLM Volts
Off	Off	0.40
Fired	Off	2.65
Off	Fired	3.78
Fired	Fired	4.99

The telemtry derivation circuit for these functions is illustrated in Figure 7.7-13.

7.7.1.17 Attitude Control Thruster Firing Monitors

REM A ATT CONTROL THRUSTERS ON/OFF	(PM-41)
REM B ATT CONTROL THRUSTERS ON/OFF	(PM-42)
REM C ATT CONTROL THRUSTERS ON/OFF	(PM-43)
REM D ATT CONTROL THRUSTERS ON/OFF	(PM-44)

These telemetry points monitor actual attitude control thruster firings, indicating which individual attitude control thrusters are fired. Indication of attitude control thruster firings is identical for each REM, defined in terms of telemetry volts as:

Attitude Control Thruster Status

THR 2	THR 3	THR 4	TLM Volts
Off	Off	Off	0.400
Fired	Off	Off	1.879
Off	Fired	Off	2.462
Off	Off	Fired	3.025
Fired	Fired	Off	3.507
Fired	Off	Fired	3.952
Off	Fired	Fired	4.333
Fired	Fired	Fired	5.039

The telemetry derivation circuit for these functions is illustrated in Figure 7.7-14.

7.7.1.18 Auxiliary Tank Kit Temperature Monitors

ATK Tank Temperature (PM-48)
ATK Fuel Temperature (PM-49)
ATK Line Temperature (PM-50)

These telemetry points monitor the temperature of the auxiliary tank kit as measured by passive temperature probes indicating tank, fuel and line temperatures. Identical circuits are used to monitor all three temperatures, with a typical circuit illustrated in Figure 7.7-1.

Note that the ATK telemetry interface is thru the signal conditioning and control unit rather than the PM.

7.7.2 DIGITAL TELEMETRY MONITORS

The propulsion module utilizes three digital telemetry monitors. Of these, two are bilevel status words, while the third is a serial digital word. Each word is defined in the following paragraphs.

7.7.2.1 Bilevel Word 01 (PM-01)

This telemetry function consists of eight bilevel status bits combined to form telemetry word PM-01. The bits define or partially define the status of the propulsion module remote interface units, and primary REM and shelf heaters. Bilevel word 01 is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<-------------PM-01------------->							
Bit ID	B0	B1	B2	B3	B4	B5	B6	B7

Bit	Function
B0	RIU 05 MATE STANDBY 1/OFF
B1	RIU 05 B ON/A ON
B2	UNUSED BIT = 1
B3	REM A PRI HTR THMSTAT SEL RED/PRI
B4	REM B PRI HTR THMSTAT SEL RED/PRI
B5	REM C PRI HTR THMSTAT SEL RED/PRI
B6	REM D PRI HTR THMSTAT SEL RED/PRI
B7	SHELF PRI HTR THMSTAT SEL RED/PRI

Bits 0 and 1 indicate the status of RIU A and B, either of which can be in one of three modes; Off, Standby 1, or On. Note, both RIU's cannot be on simultaneously. Bit 0 (ZMATENF) indicates the state of the mate to the current RIU in use. Bit 1 (ZRIUSBA) indicates which RIU is currently in use. Together these two bits define RIU status.

ZRTUSBA	ZMATENF	RIU Status	
B1	B0	A	B
0	0	On	Off
0	1	On	Standby 1
1	1	Standby 1	On
1	0	Off	On

Bits 3 thru 7 indicate which thermostats are being used for primary REM and shelf heater control, and are derived as shown in Figure 7.7-15. Bilevel status is defined as:

Bilevel Status	Primary Heater Thermostat Selected
0	Prime
1	Redundant

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7.7.2.2 Bilevel Word 02 (PM-02)

This telemetry function consists of eight bilevel status bits combined to form telemetry word PM-02. The bits define the state of the redundant REM and shelf heaters. Bilevel word 02 is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<-------------			PM-02				------------->
Bit ID	B0	B1	B2	B3	B4	B5	B6	B7

Bit	Function
B0	REM A RED HTR THMSTAT SEL RED/PRI
B1	REM B RED HTR THMSTAT SEL RED/PRI
B2	REM C RED HTR THMSTAT SEL RED/PRI
B3	REM D RED HTR THMSTAT SEL RED/PRI
B4	SHELF RED HTR THMSTAT SEL RED/PRI
B5	UNUSED BIT = 1
B6	UNUSED BIT = 1
B7	UNUSED BIT = 1

Bits 0 thru 4 indicate which thermostats are being used for redundant REM and shelf heater control, and are derived as shown in Figure 7.7-15. Bilevel status is defined as:

Bilevel Status	Redundant Heater Thermostat Selected
0	Prime
1	Redundant

7.7.2.3 Serial Digital Word Z1AHTRS (PM-45)

This telemetry function consists of eight bilevel status bits combined to form telemetry word PM-45. The bits define the state of the prime and redundant Auxiliary Tank Kit (ATK) thermal control functions: Z1AHTRS is defined as:

Bit Weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
User ID	<-------------			PM-45				------------->
Bit ID	B0	B1	B2	B3	B4	B5	B6	B7

Bit	Function	
S0	UNUSED BIT = 1	
S1	UNUSED BIT = 1	
S2	ATK PRIMARY TANK HEATER	ENABLE/DISABLE
S3	ATK PRIMARY LINE HEATER	ENABLE/DISABLE
S4	ATK LINE HEATER THERMOSTAT	BYPASS/ENABLE

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S5	ATK REDUNDANT TANK HEATER	ENABLE/DISABLE
S6	ATK REDUNDANT LINE HEATER	ENABLE/DISABLE
S7	ATK TANK HEATER THERMOSTAT	BYPASS/ENABLE

The tank and line heater telemetry functions monitor the status of the ATK prime and redundant heater control relays, defined as:

Bilevel Status	Tank/Line Heater Mode
0	Disable
1	Enable

The tank and line heater thermostat telemetry functions monitor whether the heaters are controlled closed loop with a thermostat or open loop with the thermostat bypassed. Bilevel status is defined as:

Bilevel Status	Tank/Line Thermostat Mode
0	Enabled
1	Bypassed

Note that the ATK telemetry interface is through the signal conditioning and control unit rather than the PM.

7.7.3 TELEMETRY DERIVATION CIRCUITS

This section provides functional schematics of the telemetry circuits referenced in the preceeding paragraphs. The schematics have been simplified and are provided as an aid to understanding the telemetry interface.

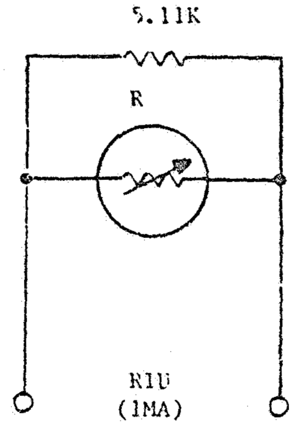

Figure 7.7-1. Passive Temperature Telemetry Monitor

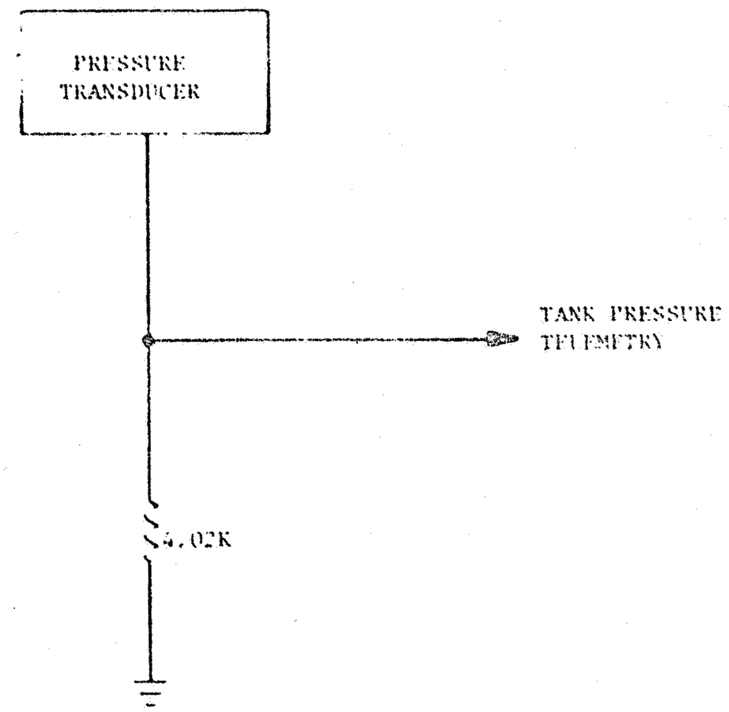

Figure 7.7-2. Fuel Tank Pressure Monitor

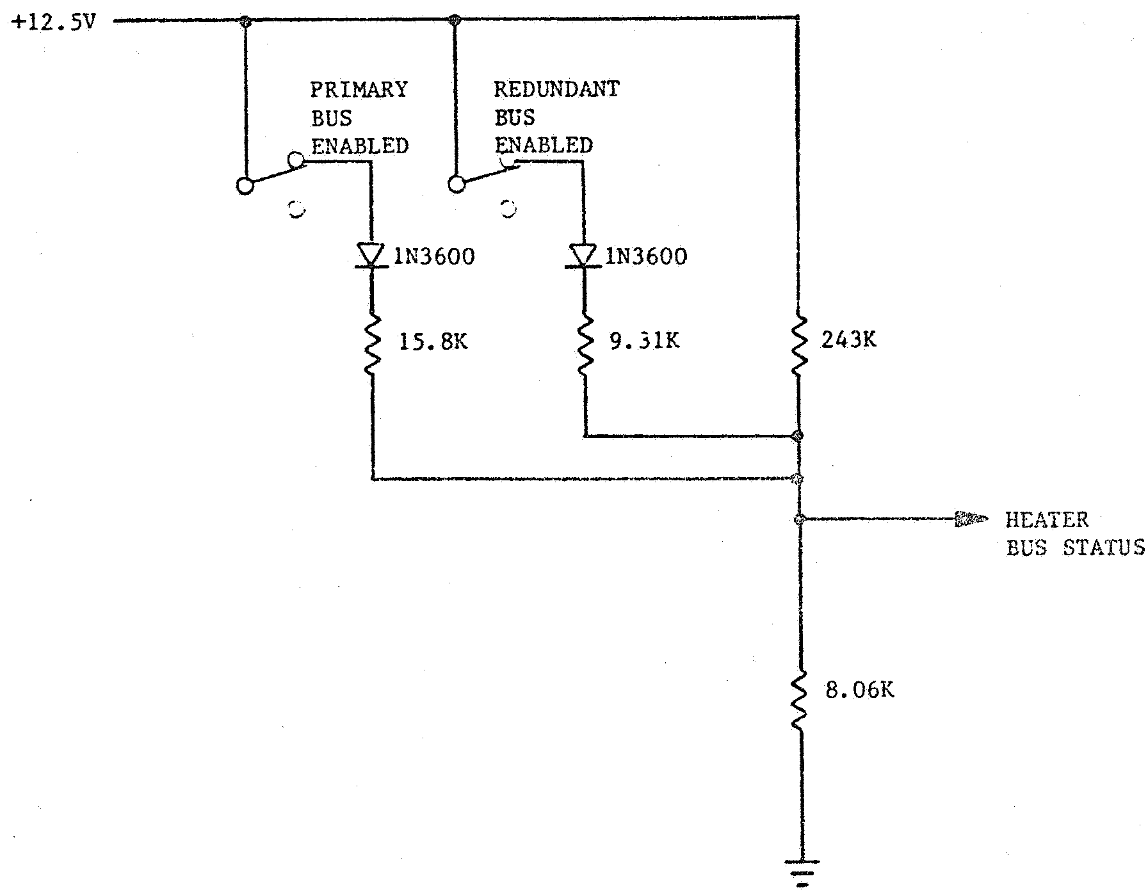

Figure 7.7-3. Heater Power Bus Status Monitor

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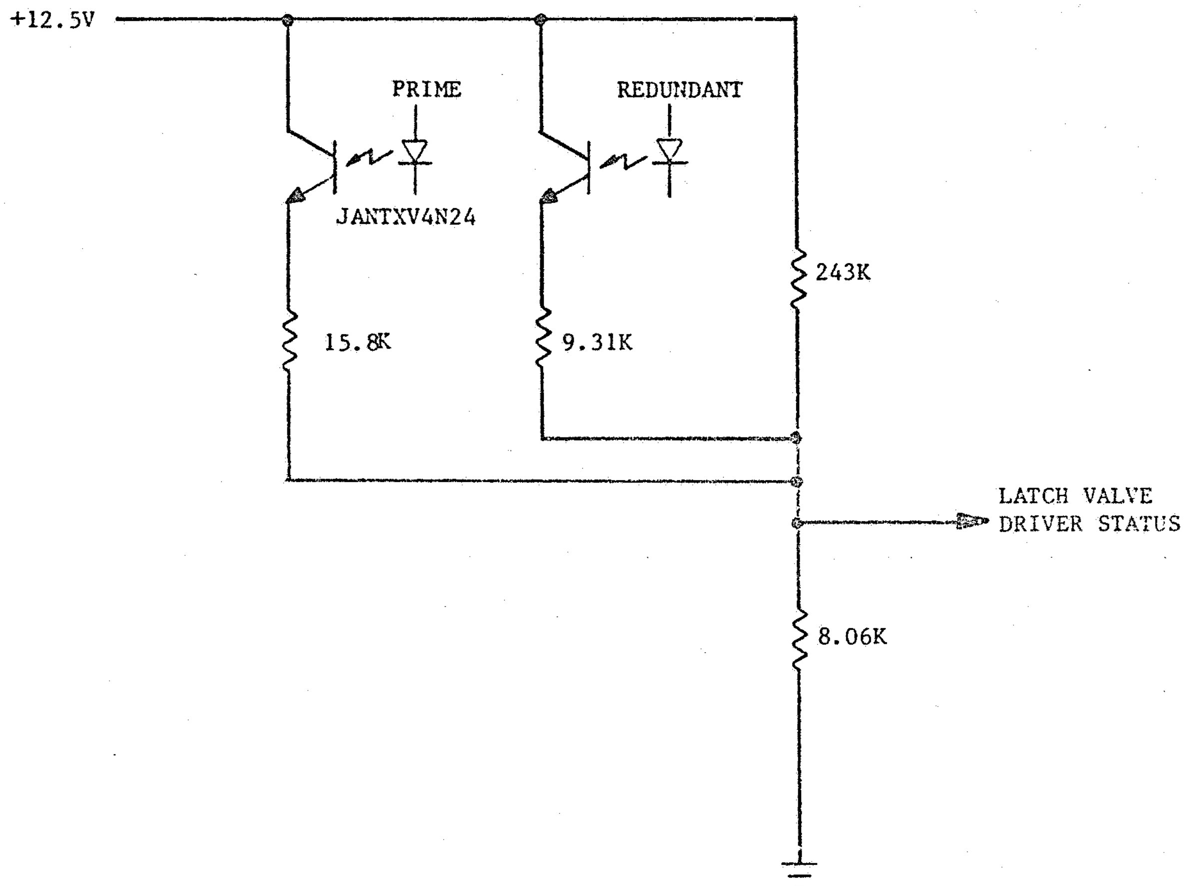

Figure 7.7-4. Latch Valve Driver Status Monitor

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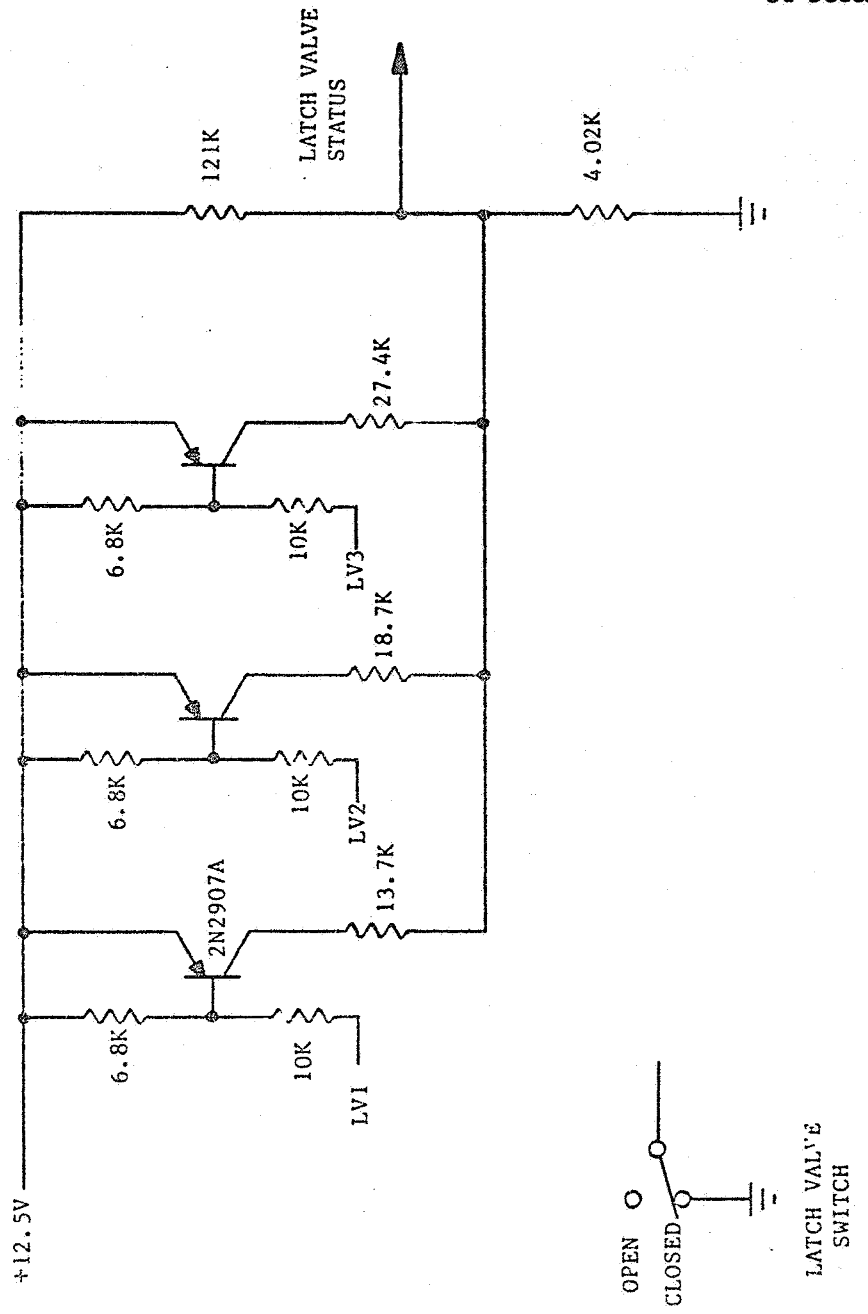

Figure 7.7-5. Latch Valve Status Monitor

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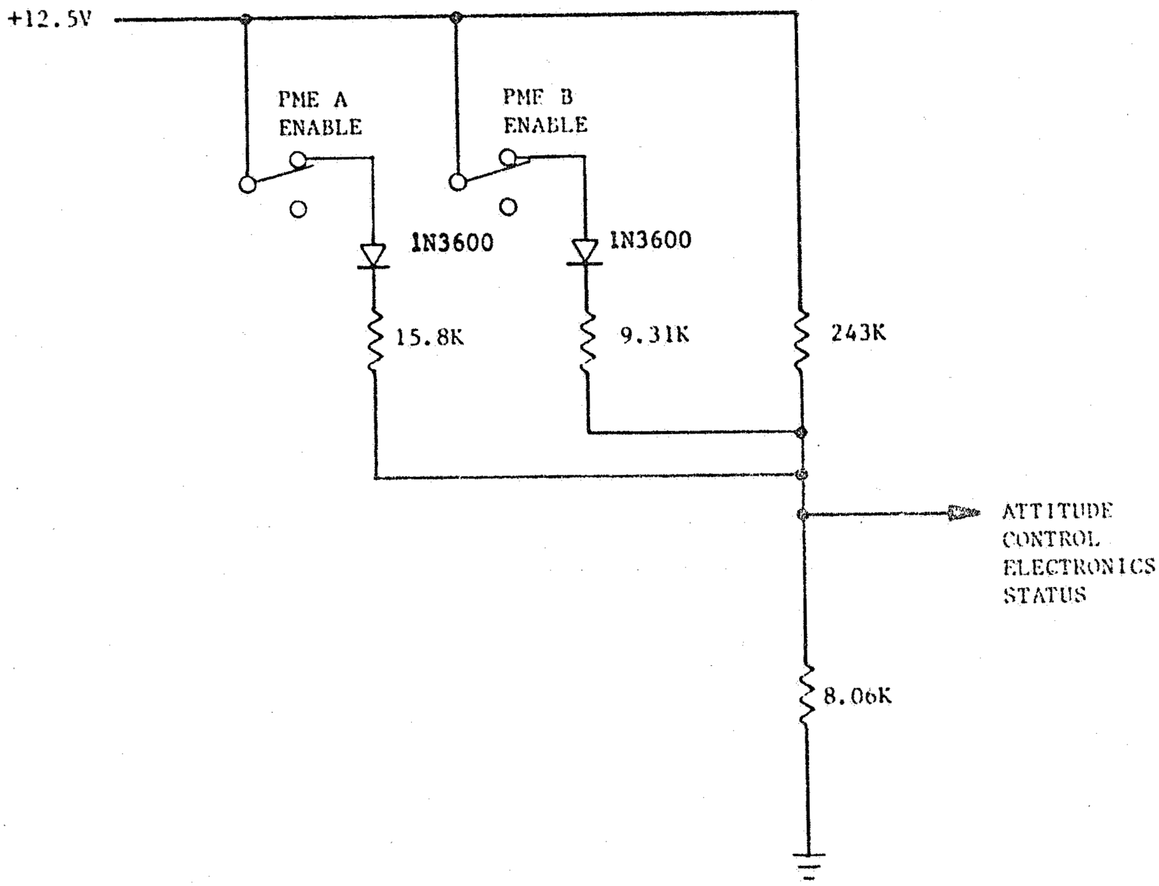

Figure 7.7-6. Attitude Control Electronics Status Monitor

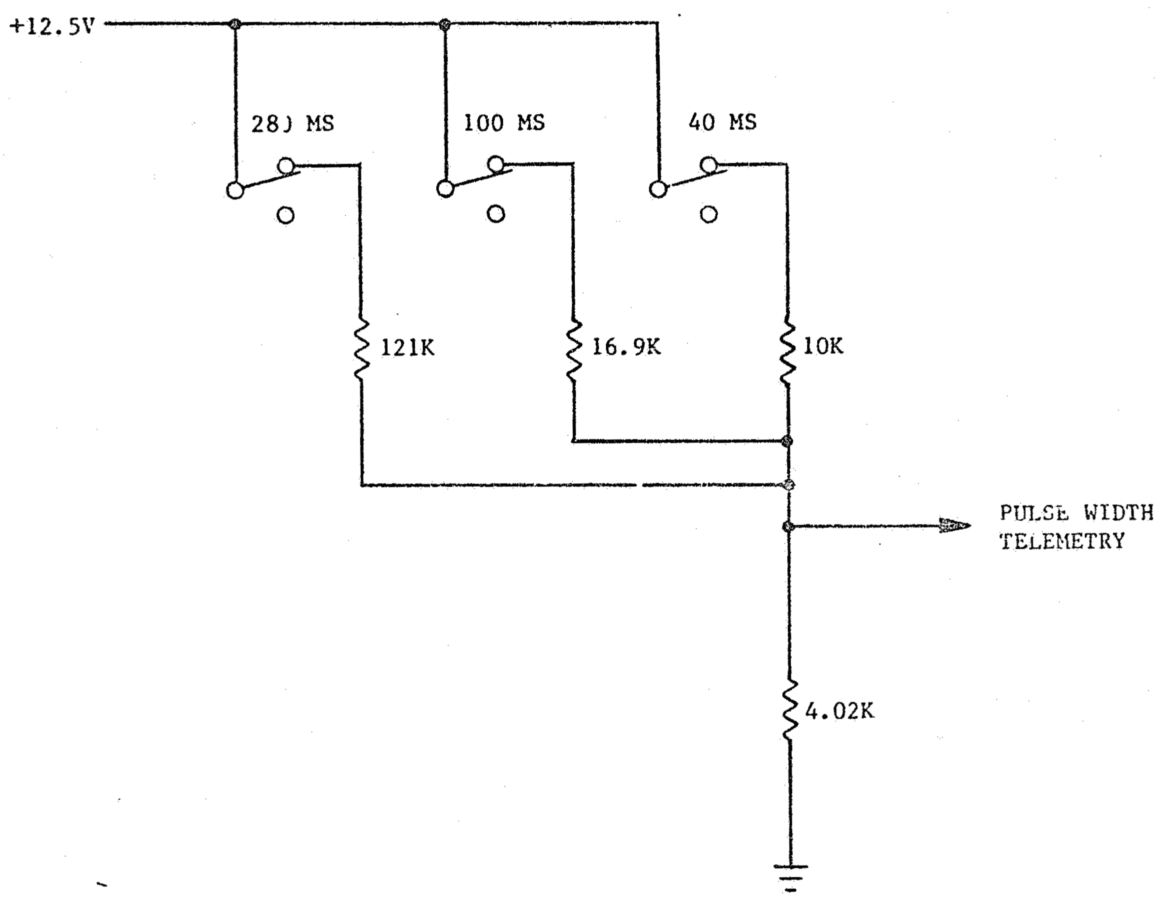

Figure 7.7-7. Selected Thruster Pulse Width Telemetry

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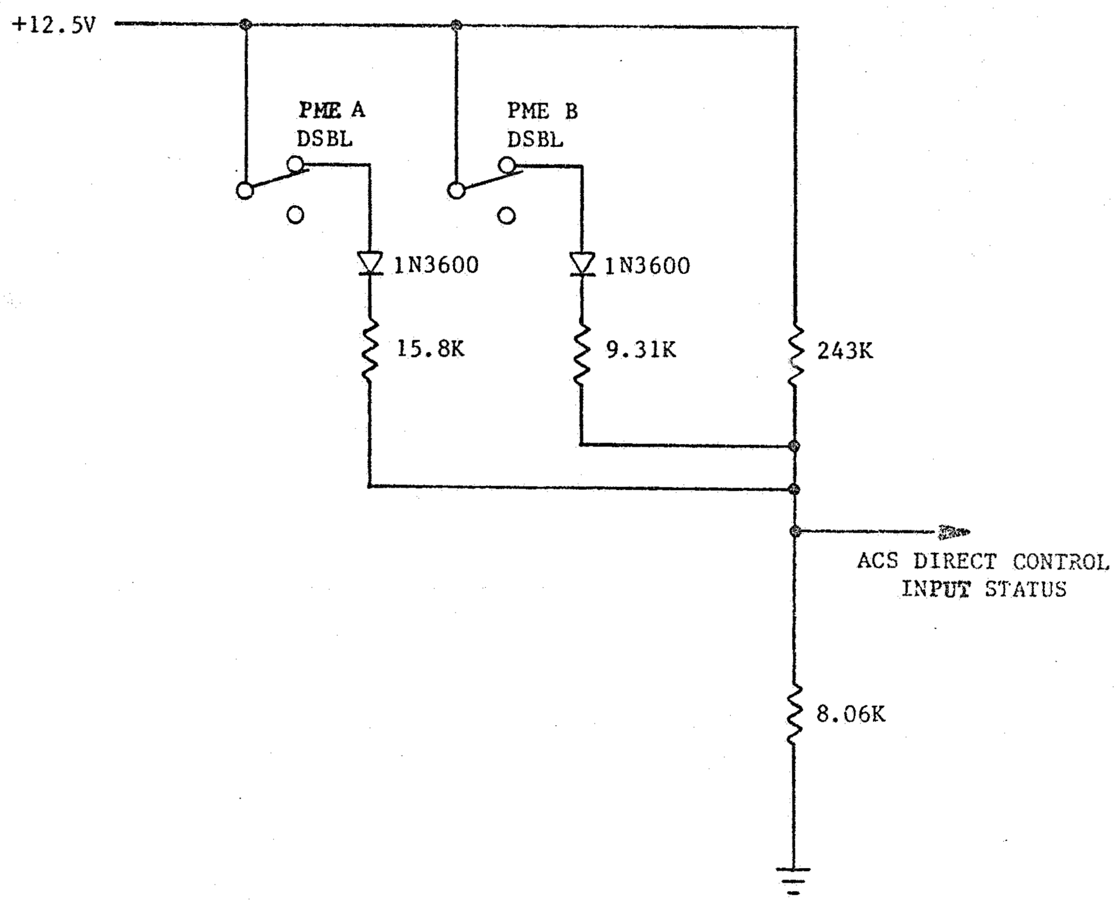

Figure 7.7-8. ACS Direct Control Input Status Monitor

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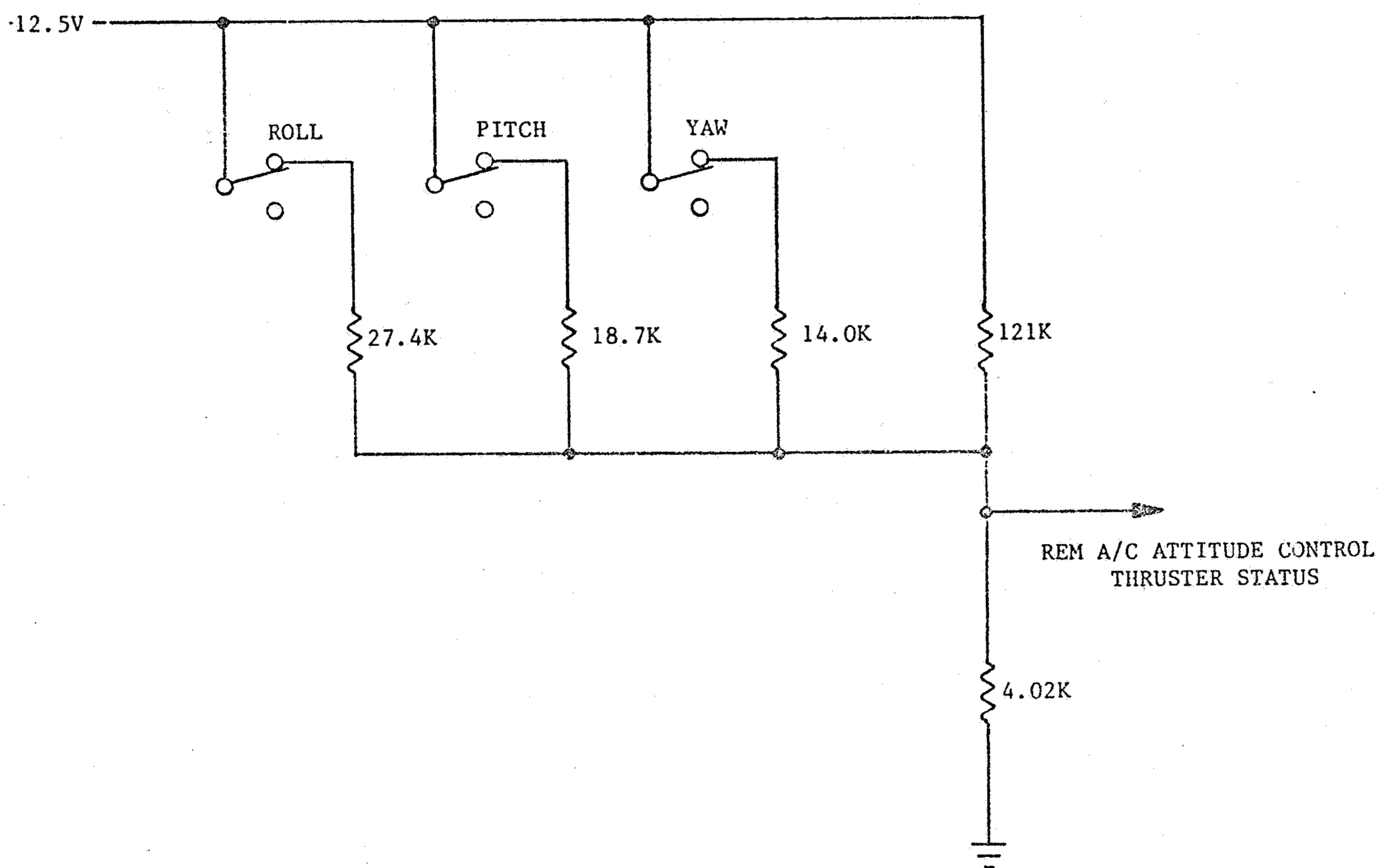

Figure 7.7-9. REM A/C Attitude Control Thruster Status Monitor

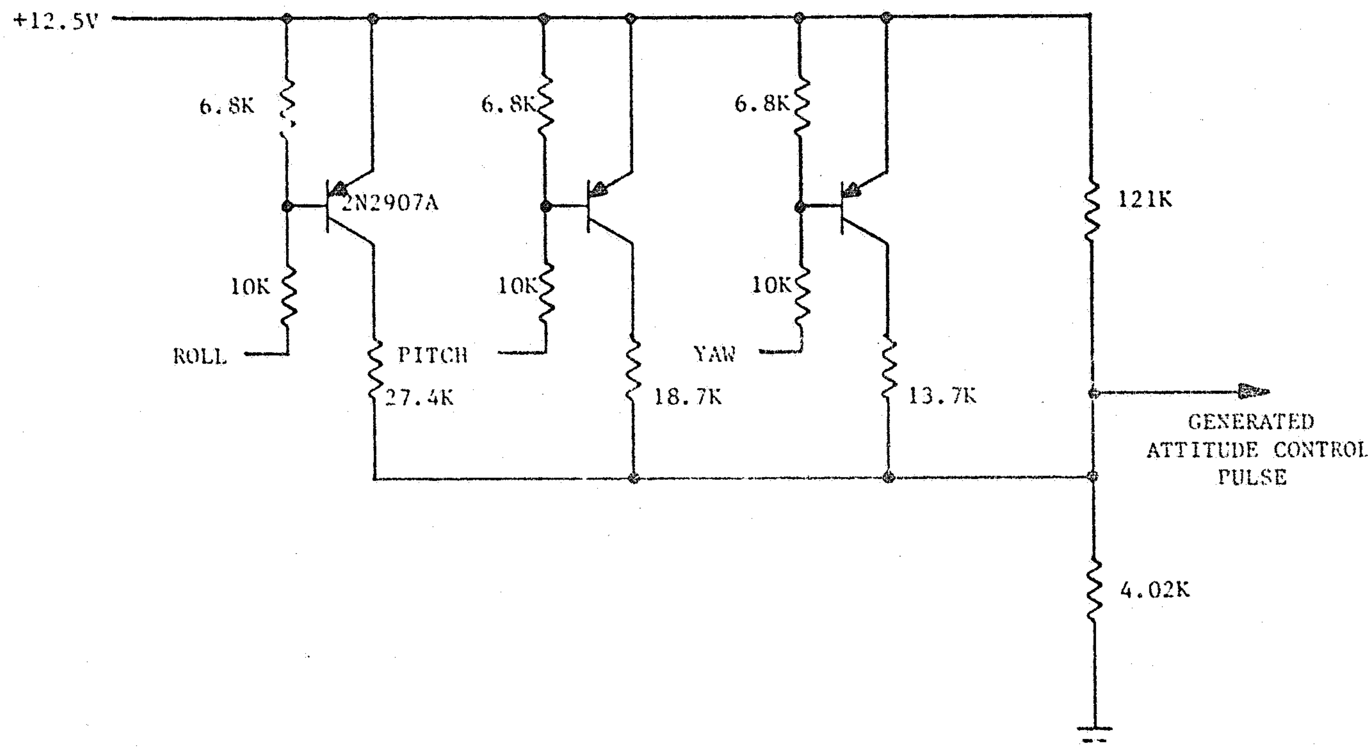

Figure 7.7-10. Generated Attitude Control Pulse Monitor

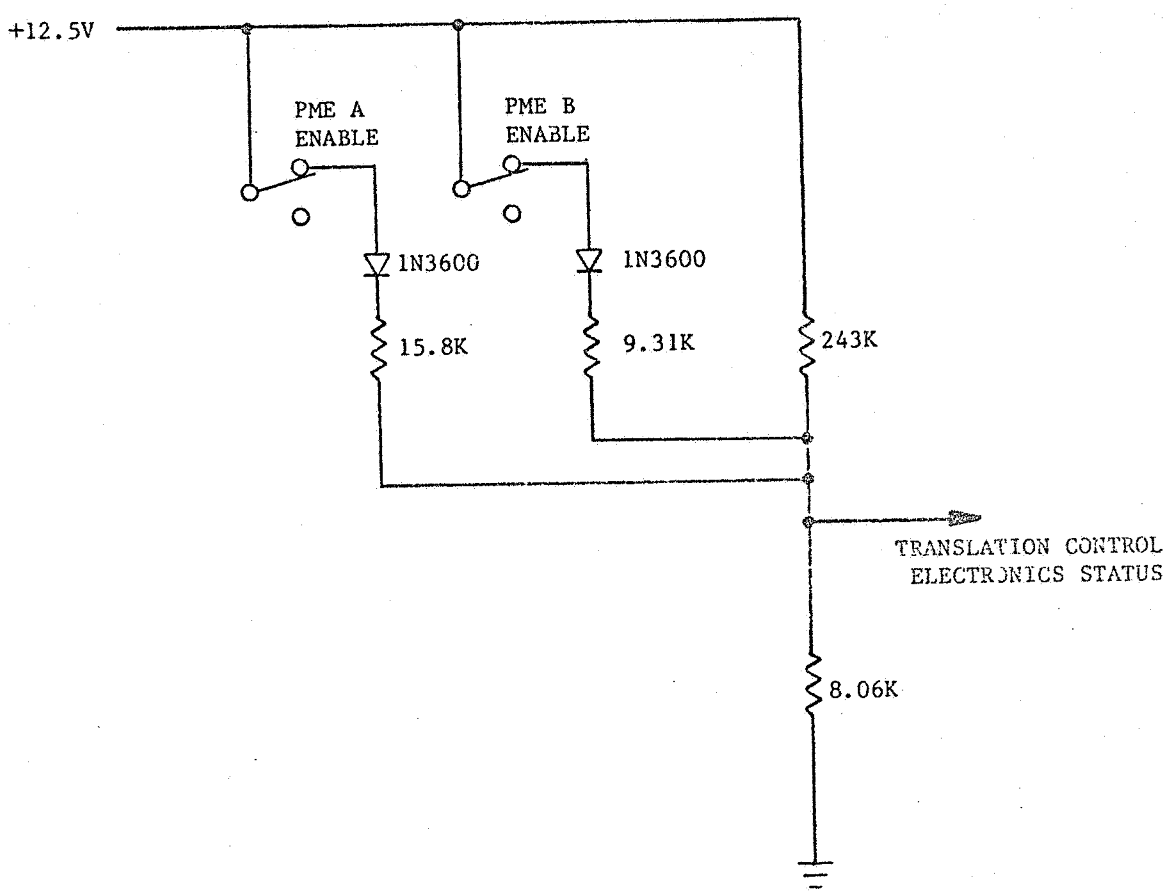

Figure 7.7-11. Translation Control Electronics Status Monitor

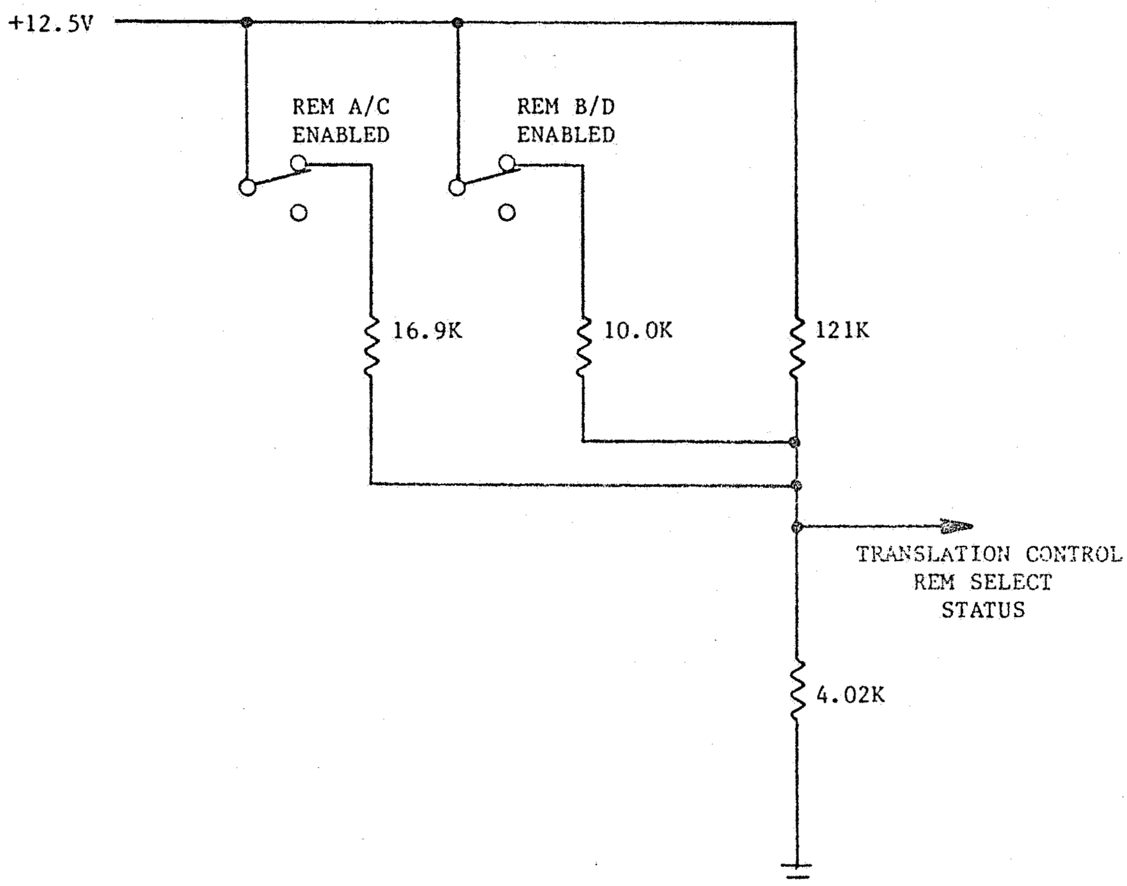

Figure 7.7-12. Translation Control REM Select Monitors

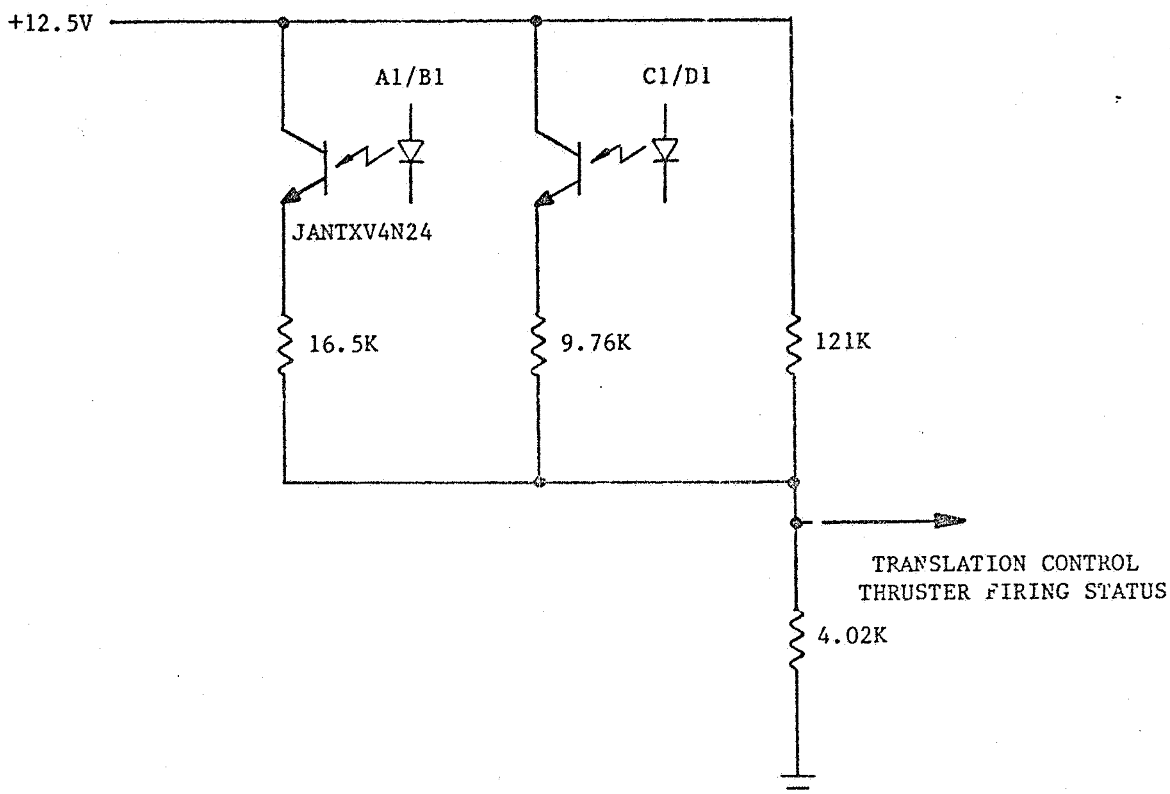

Figure 7.7-13. Translation Control Thruster Firing Monitors

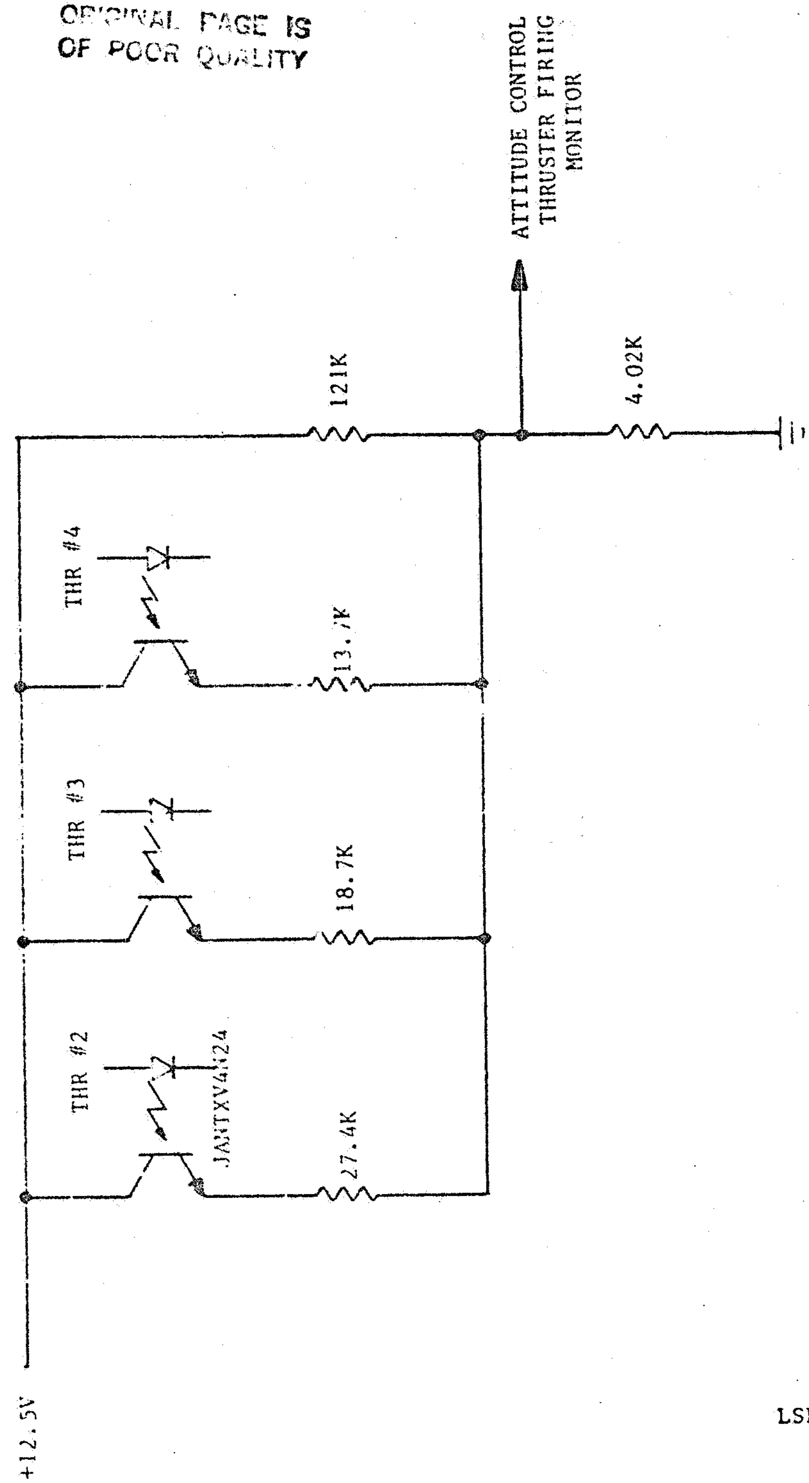

Figure 7.7-14. Attitude Control Thruster Firing Monitors

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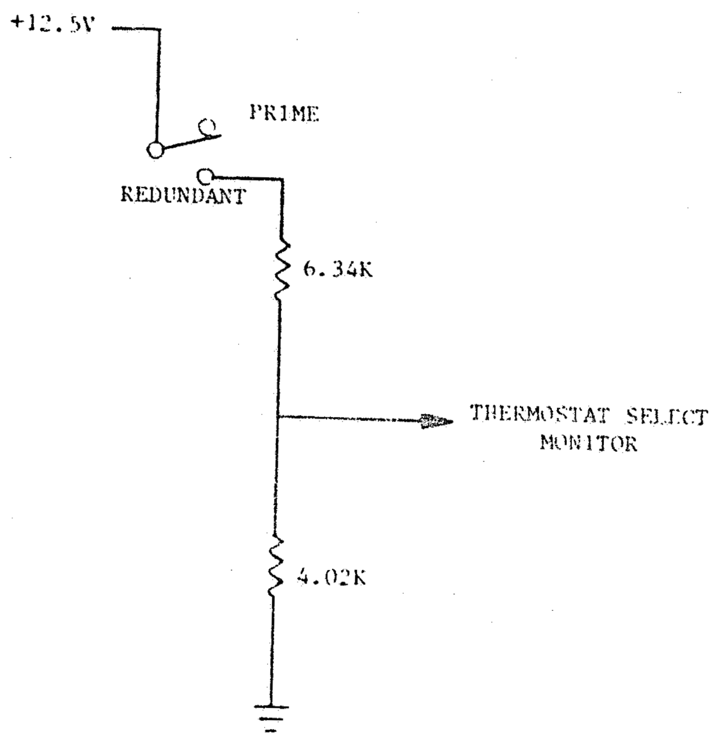

Figure 7.7-15. Heater Thermostat Selection Monitor

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8.0 SIGNAL CONDITIONING AND CONTROL UNIT

SECTION 8.0

SIGNAL CONDITIONING AND CONTROL UNIT (SC&CU)

8.1 FUNCTIONAL DESCRIPTION

The SC&CU is mounted on a longeron of the spacecraft structure between the Modular Power Subsystem (MPS) and the Communications and Data Handling (C&DH) modules as shown in Figure 8.1-1. Power for the SC&CU is provided from the MPS by two unfused, redundant power buses. All bus protection circuitry for the SC&CU circuitry and its loads is provided within the unit.

Commands and telemetry interfaces with the SC&CU via a redundant Multiplex Data Bus (MDB) that interfaces the C&DH module with all subsystems and the payload. Commands and telemetry are decoded and multiplexed by a redundant pair of Remote Interface Unit (RIU). The SC&CU conditions the commands issued by the RIU's and the telemetry inputs to the RIU's as required for the controlled functions. Figure 8.1-2 is a functional block diagram of SC&CU external interfaces, while Figure 8.1-3 is a functional block diagram of SC&CU internal interfaces. Figure 8.1-4 details the functional interfaces between the SC&CU and the PDU. Figure 8.1-5 details the Instrument Module Heater Control.

8.2 PERFORMANCE CAPABILITIES

8.2.1 POWER CONSUMPTION

The power consumption in the SC&CU control and monitoring circuits is less than 15 watts on an orbital average basis, including the RIU's but exclusive of heaters. Heater power does not exceed 25 watts on an orbital average basis. Average RIU power is less than 4.6 watts total for the two RIU's.

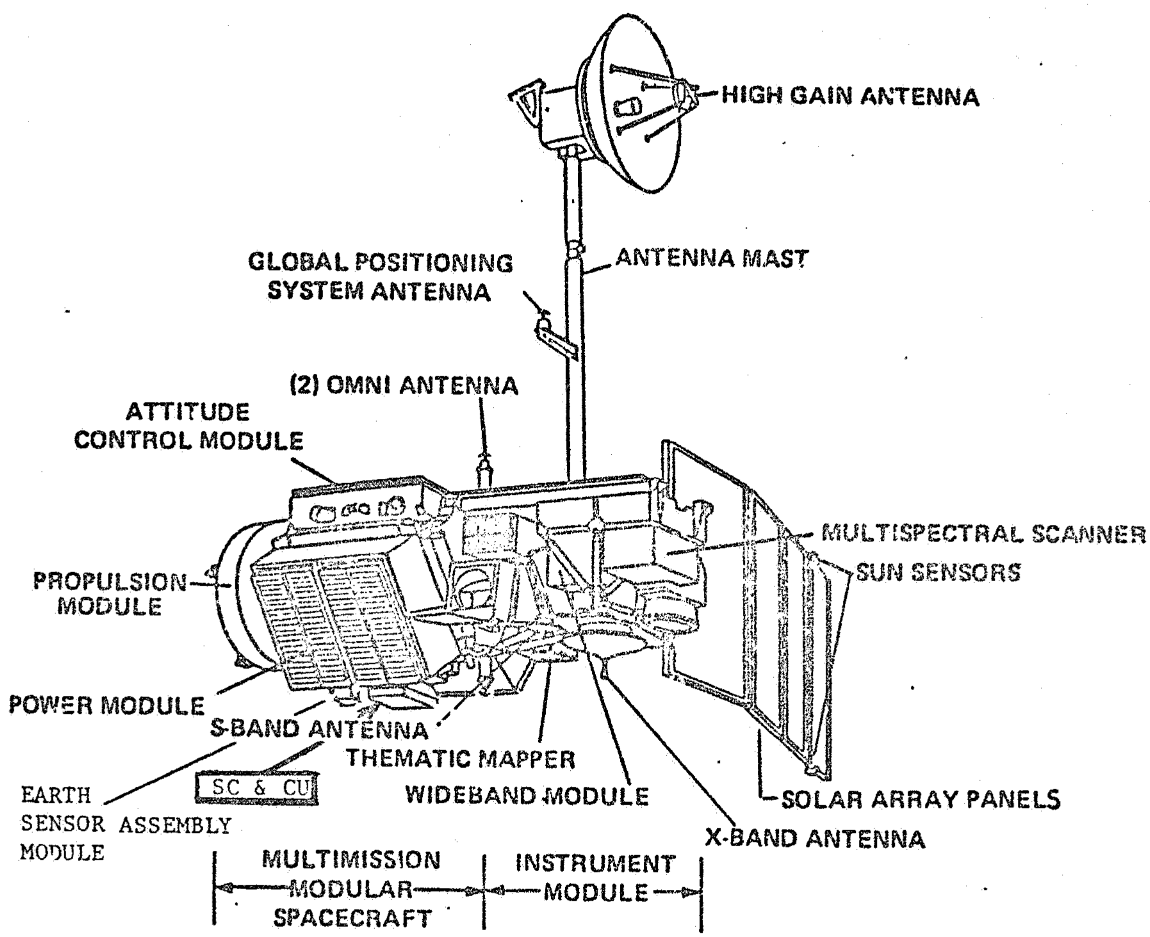

Figure 8.1-1. SC&CU Location on Flight Segment

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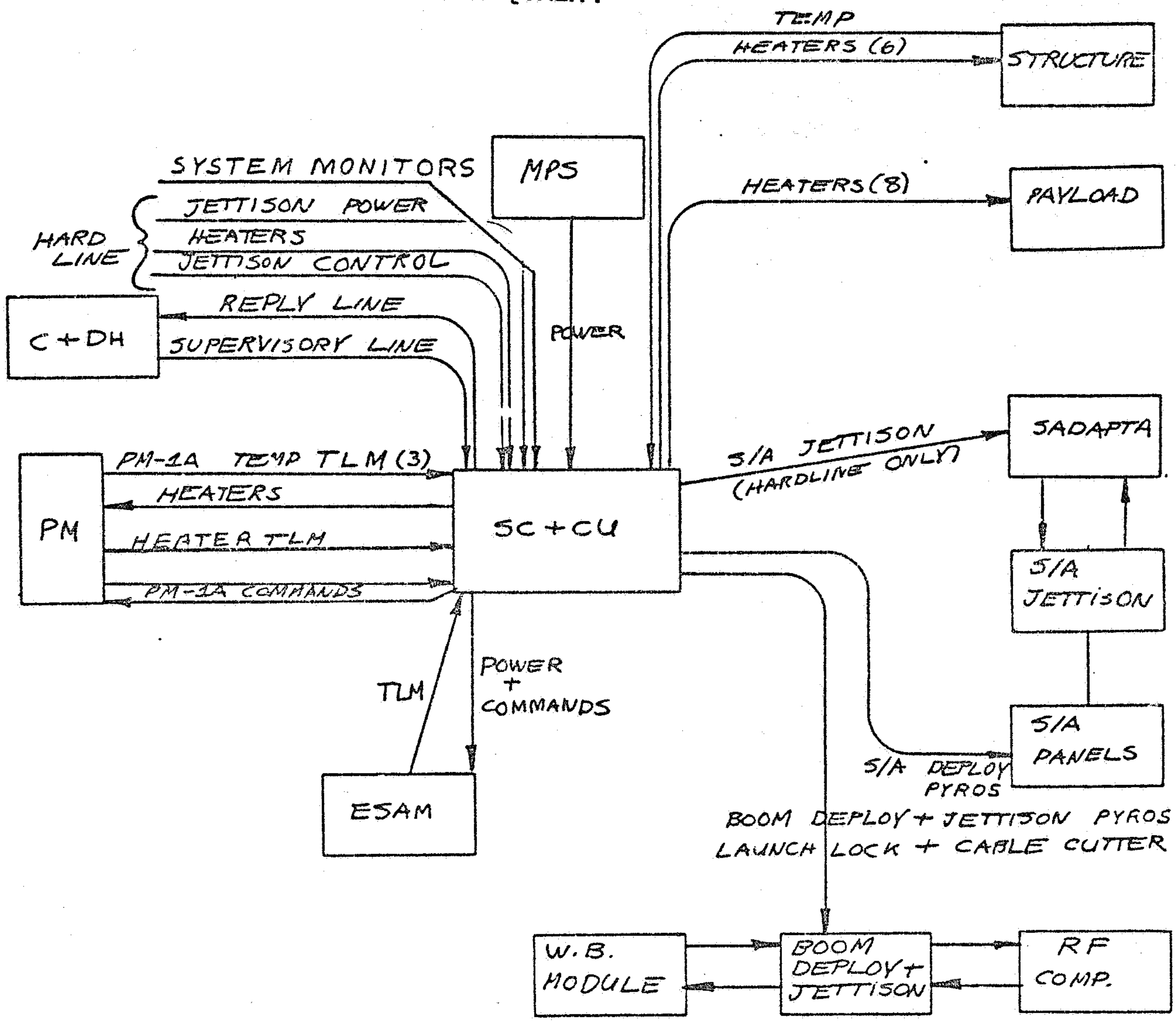

Figure 8.1-2. SC&CU External Interfaces

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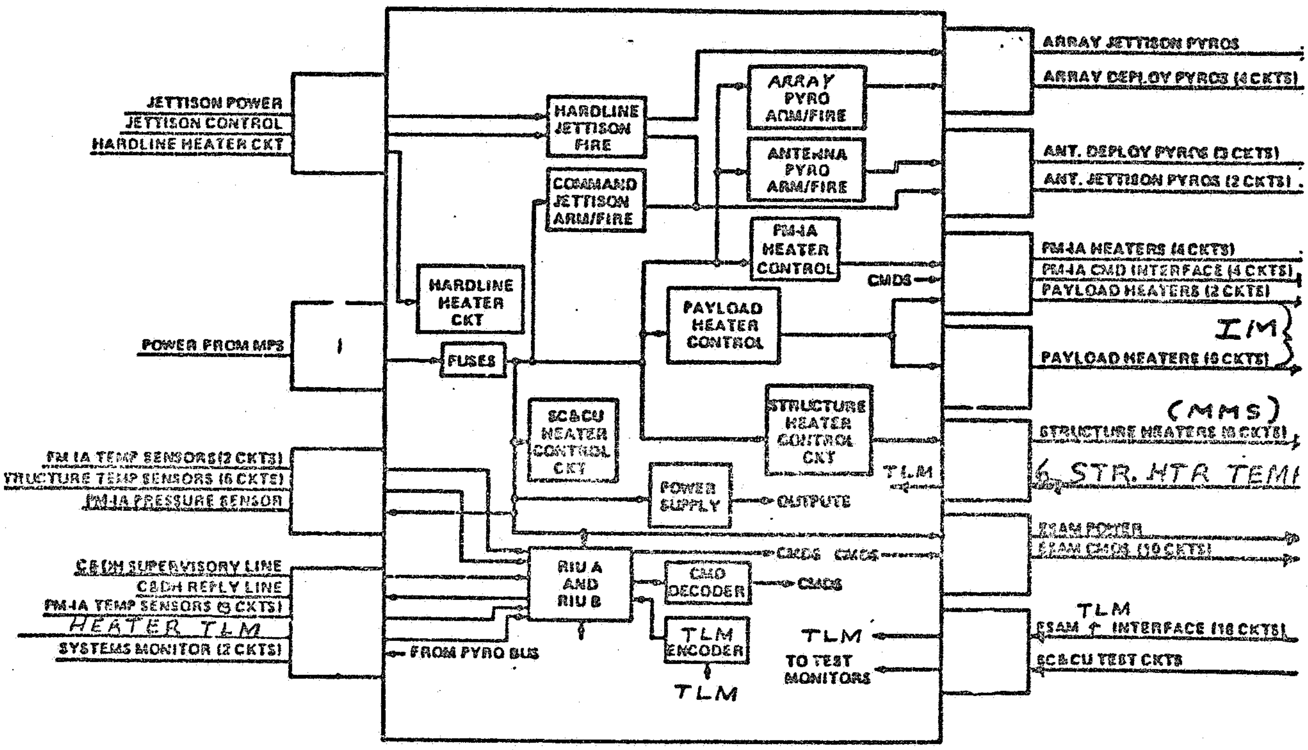

Figure 8.1-3. SC&CU Internal Interfaces

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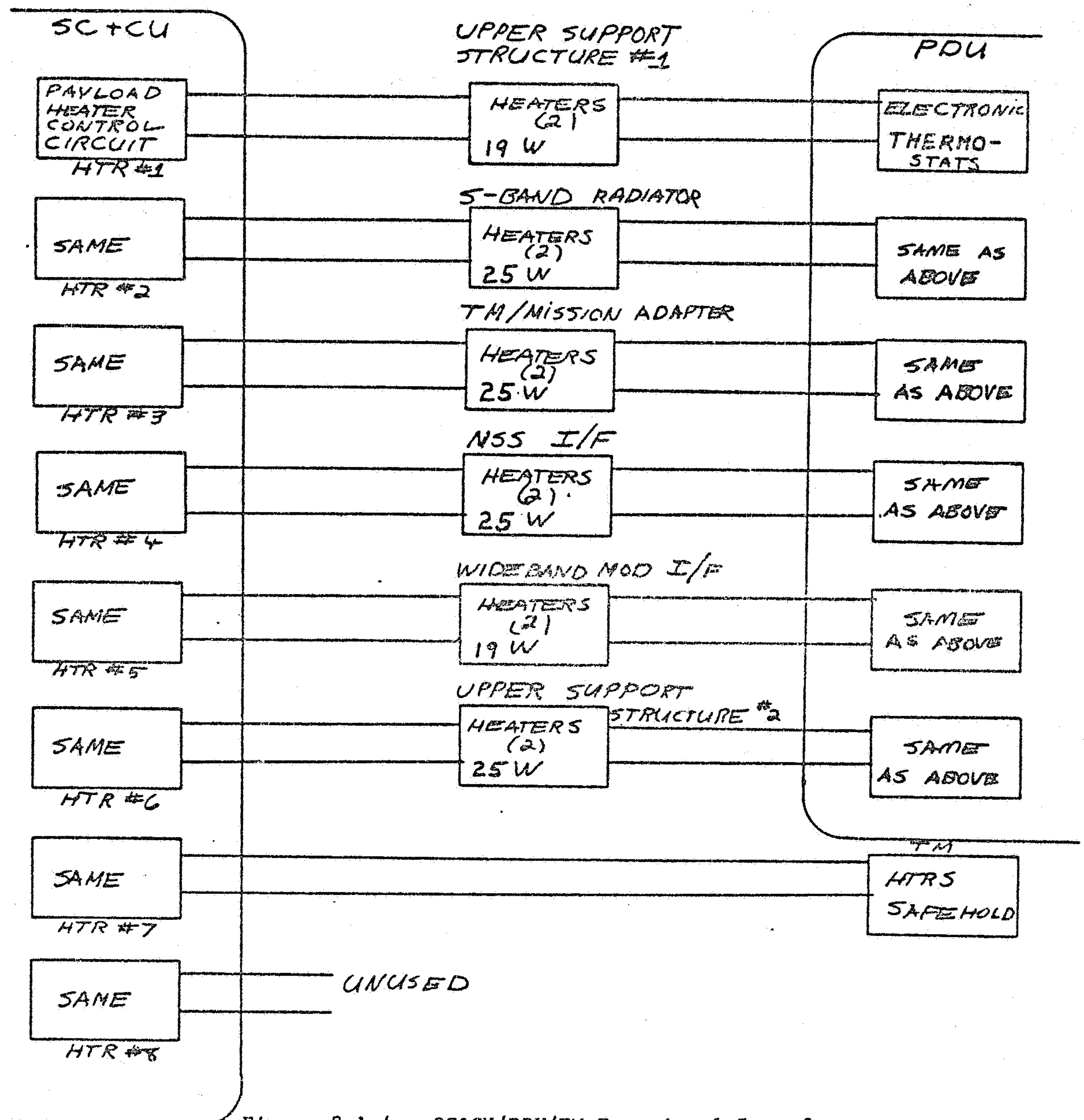

Figure 8.1-4. SC&CU/PDU/TM Functional Interfaces

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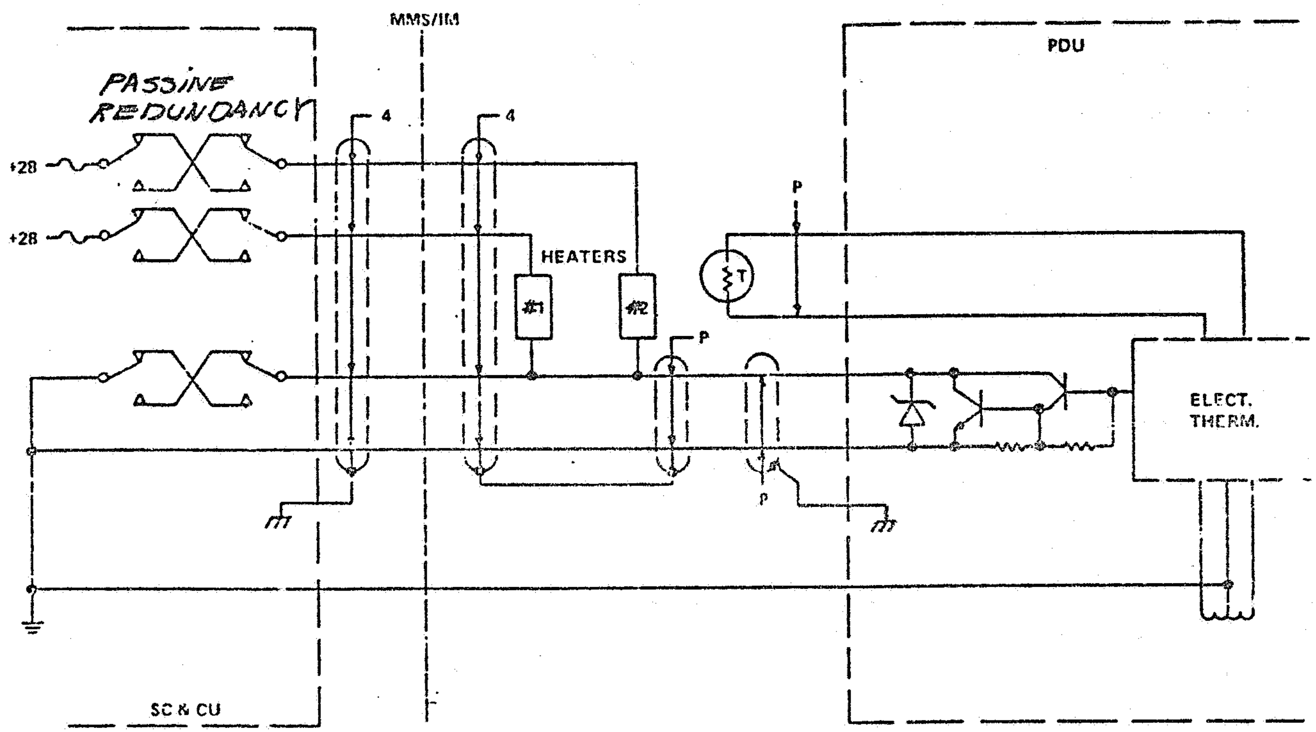

Figure 8.1-5. Instrument Module Heater Control

8.2.2 COMMAND AND TELEMETRY

Redundant command and telemetry circuitry is provided for all SC&CU functions except as specifically defined. This shall be implemented by the use of redundant RIU's.

8.2.3 HEATERS

8.2.3.1 Flight Heaters

1. Spacecraft Structure and SC&CU Heaters - The spacecraft structure heaters have a maximum capacity of 1.0 ampere.

2. Payload Heaters - The SC&CU shall provide bus protection and power control circuitry for eight payload heater circuit configurations. Each circuit is capable of controlling a maximum current of 1.20 amperes at maximum bus voltage.

3. PM-IA Heaters - The SC&CU provides bus protection and power control circuitry for two redundant PM-IA heaters, both of which contain thermostat bypass capability.

8.2.3.2 Hardline Heaters

A hardline heater circuit is provided in the SC&CU. The heater(s) and thermostat(s) are sized to maintain survival temperatures for all SC&CU circuitry when spacecraft power is turned off for resupply operations. The heater circuit is designed for operation on a 28 ± 4 V DC power source and is electrically isolated from all other spacecraft circuitry.

8.2.4 TEMPERATURE SENSORS

The SC&CU has the capability for redundantly monitoring temperatures at six locations on the MMS structure.

In addition, the internal temperatures of each of the two RIU's are monitored by connecting each RIU's temperature sensor to both RIU's. External shunt resistors are not required because the RIU's contain internal shunt resistors.

The SC&CU accommodates six redundant temperature sensors (three primary and three backup) at three locations for PM-IA tank and line temperature monitoring. These sensors do not require conditioning circuitry.

The SC&CU also accommodates two internal standard range temperature sensors. A precision 5.1-kilohm resistor is provided in the SC&CU for paralleling each thermistor.

8.2.5 PYROTECHNIC CIRCUITRY

The SC&CU provides redundant pyrotechnic arming, safing and firing circuitry for all spacecraft pyrotechnic devices. The circuitry is designed to fire Type NSI-1 NASA Standard Initiators.

The circuitry provides commandable safe/arm switching and a manual safe/arm/test interface with provisions for checking firing circuit characteristics with the arming plug installed. Each firing circuit provides individual fusistors for firing two pyrotechnic devices simultaneously. The firing pulse is at least 50 ms of switched 28-volt power. For some applications, only one initiator can be used for each firing circuit; however, each circuit has provisions for two initiators.

8.2.5.1 Solar Array Deploy Pyrotechnic Circuitry

Four primary and four redundant pyrotechnic firing circuits are provided from dedicated primary and redundant pyrotechnic arming buses for deployment of the solar array. The solar array pyrotechnic circuitry is capable of meeting the following requirements:

1. Able to group-arm and group-safe all the solar array deployment functions.

2. Able to arm and then fire four bridgewires (primary and redundant sides of two pyrotechnic devices) simultaneously from the "A" side, with capability of arming and firing the same four bridgewires from the "B" side. It is able to arm and then fire the remaining four bridgewires (primary and redundant sides of two pyrotechnic devices) simultaneously from the "A" side, with capability of arming and firing the same four bridgewires from the "B" side.

8.2.5.2 Boom Antenna Pyrotechnic Circuitry

Four primary and four redundant pyrotechnic firing circuits are provided via dedicated primary and redundant pyrotechnic arming buses. The payload pyrotechnic circuitry is capable of meeting the following requirements:

1. Able to group-arm and group-safe all the antenna deployment functions.

2. Able to arm and then fire three bridgewires (primary side of three pyrotechnic devices) from the "A" side with the capability of arming and firing three bridgewries (redundant side of thre pyrotechnic devices) from the "B" side. Each bridgewire is to be armed and fired separately.

3. Has a spare primary and spare redundant arming and firing circuit.

8.2.6 JETTISON CIRCUITRY

The following circuitry is provided for jettisoning appendages during retrieval operations:

8.1.6.1 Hardline Jettison

Circuitry is provided for jettisoning appendages during retrieval operations by hardline control from the Shuttle Flight Support System (FSS). Power, arming and firing circuitry provided as part of the FSS shall control safe/fire relays in the SC&CU via a hardline umbilical circuit. The switched power provided for firing the pyros is 28 ± 4 volts. Each firing circuit in the SC&CU is controlled via level-type relays that safe the pyros when de-energized. Each circuit is capable of firing two Type NSI-1 NASA Standard Initiators via separate fusistors. The hardline jettison circuitry is capable of meeting the following requirements:

1. Able to fire a primary side bridgewire from the "A" side with capability of firing the redundant side bridgewire from the "B" side to Jettison the solar array.

2. Able to fire two bridgewires (primary side of two pyrotechnic devices) fro the "A" side with capability of firing two bridgewires (redundant side of two pyrotechnic devices) from the "B" side to jettison the antenna boom. Each bridgewire is to be fired separately.

3. Has a spare primary and redundant firing circuit.

8.2.6.2 Command Jettison

Four primary and four redundant firing circuits are provided via dedicated primary and redundant pyrotechnic firing buses for commandable jettison of appendages. The command jettison circuitry are capable of meeting the following requirements:

1. Able to group-arm and group-safe all command jettison functions.

2. Able to arm and fire two bridgewires (primary side of two pyrotechnic devices) from the "A" side with capability of arming and firing two bridgewires (redundant side of two pyrotechnic devices) from the "B" side to jettison the antenna boom. Each bridgewire is armed and fired separately. The two arming and firing circuits are configured to fire the same bridgewire as the hardline jettison circuits to jettison the antenna boom.

3. Has two spare primary and two spare redundant firing circuits.

8.2.7 EARTH SENSOR ASSEMBLY MODULE (ESAM)

8.2.7.1 Commands

The SC&CU provides ten redundant discrete commands (ten from each RIU) for ESAM control. The commands are grouped so that five are associated with the 28-V Pulse Bus I and five with the 28-V Pulse Bus II. In addition, both 28-V pulse buses are provided.

8.2.7.2 Telemetry

The SC&CU provides sixteen redundant active analog telemetry channels for ESAM monitoring. RIU channel assignments are selected so that the ESAM telemetry return is not common with any other SC&CU telemetry functions.

8.2.7.3 Power

The SC&CU provides fused, unregulated power to the ESAM. The fuse size is 2.0 amperes.

8.3 MODES OF OPERATION

Deploy: Solar array and antenna boom

Operate: MMS heaters, IM heaters, SC&CU heaters.

Jettison: Antenna Boom - transmit jettison command from Ground Station or space shuttle.
Solar Array - transmit jettison command from space shuttle.

8.4 CONSTRAINTS

Time between execution of SC&CU serial commands is 128 milliseconds (10 commands per second).

8.5 REDUNDANCY

The SC&CU subsystem is completely redundant. Dual components and circuits are provided for all functions, (refer to Figure 8.1-6).

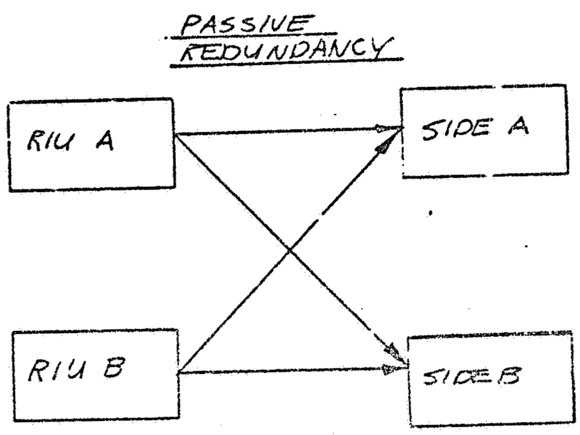

Figure 8.1-6. SCGCU Redundancy

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8.6 SC&CU COMMANDS

The redundant RIU's contained in the SC&CU module (RIU 4A and 4B) provide commands for SC&CU functions and for the Earth Sensor Assembly Module (ESAM). Any command may be executed by either RIU.

Discrete commands are listed in Table 8.6-1, which contains the command address (RIU and channel) and the unique acronym assigned to each command function. ESAM commands in the table are listed for information only; those commands are described in Section 3.6 (MACS commands).

All serial magnitude commands are sent to address 470 (RIU 4, serial command enable line 0). Table 8.6-2 contains the unique acronyms assigned to specific serial command bit patterns and functions. In the DATA column, the 16-bit magnitude data is presented in hexadecimal form.

Table 8.6-3 provides command verification via SC&CU telemetry. In addition, the table indicates prerequisite commands (or states) and complementary commands.

Command descriptions are provided in Section 8.6.1, command sequences in Section 8.6.2, and command restraints in Section 8.6.3.

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Table 8.6-1. Discrete Commands

RIU	CHAN	Acronym	Command Name
			SC&CU COMMANDS:
4	00	SRIUEN	RIU 4 SELF ENABLE (STANDBY 1)
4	63	RIUSB2	RIU 4 SELF STANDBY 2 (MATE RIU DISABLE)
4	26	MRIUDI	RIU 4 MATE DISABLE (BACKUP)
4	49	SCUAON	SC&CU A ON/B OFF
4	53	SCUBON	SC&CU B ON/A OFF
4	01	APYREN	ENABLE A SIDE PYROS
4	11	APYRDI	DISABLE A SIDE PYROS
4	36	BPYREN	ENABLE B SIDE PYROS
4	46	BPYRDI	DISABLE B SIDE PYROS
4	04	ENAHTA	SC&CU HEATER A ENABLE
4	14	DISHTA	SC&CU HEATER A DISABLE
4	21	BYPTHA	SC&CU HEATER A THERMOSTAT BYPASS
4	31	ENATHA	SC&CU HEATER A THERMOSTAT ENABLE
4	33	ENAHTB	SC&CU HEATER B ENABLE
4	43	DISHTB	SC&CU HEATER B DISABLE
4	48	BYPTHB	SC&CU HEATER B THERMOSTAT BYPASS
4	58	ENATHB	SC&CU HEATER B THERMOSTAT ENABLE
			ESAM COMMANDS:
4	18	ES1ON	ESA 1 POWER ON
4	13	ES1OFF	ESA 1 POWER OFF
4	40	ES1HTEN	ESA 1 HEATER ENABLE
4	25	ES1HTDIS	ESA 1 HEATER DISABLE/LOGIC DISABLE
4	07	ES2ON	ESA 2 POWER ON
4	34	ES2OFF	ESA 2 POWER OFF
4	19	ES2HTEN	ESA 2 HEATER ENABLE
4	54	ES2HTDIS	ESA 2 HEATER DISABLE/LOGIC DISABLE
4	39	ES2LOGEN	ESA 2 LOGIC ENABLE
4	60	ES1LOGEN	ESA 1 LOGIC ENABLE

NOTE: ESAM commands are listed for information only. Section 3.6 contains ESAM command descriptions.

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Table 8.6-2. Serial Command Acronyms

Data	Acronym	Command Name
		PAYLOAD HEATER COMMANDS:
1173	S1HAEN	UPPER SUPPORT STRUCTURE HEATER 1 A ENABLE
21B3	S1HADI	UPPER SUPPORT STRUCTURE HEATER 1 A DISABLE
3133	S1HBEN	UPPER SUPPORT STRUCTURE HEATER 1 B ENABLE
41D3	S1HBDI	UPPER SUPPORT STRUCTURE HEATER 1 B DISABLE
5153	S1THBY	UPPER SUPPORT STRUCTURE HEATER 1 THERMOSTAT BYPASS
6193	S1THEN	UPPER SUPPORT STRUCTURE HEATER 1 THERMOSTAT ENABLE
7113	SBHAEN	DASB RADIATOR PRIMARY HEATER ENABLE
81E3	SBHADI	DASB RADIATOR PRIMARY HEATER DISABLE
9163	SBHBEN	DASB RADIATOR REDUNDANT HEATER ENABLE
A1A3	SBHBDI	DASB RADIATOR REDUNDANT HEATER DISABLE
B123	SBTHBY	DASB RADIATOR HEATER THERMOSTAT BYPASS
C1C3	SBTHEN	DASB RADIATOR HEATER THERMOSTAT ENABLE
1274	MAHAEN	TM/MISSION ADAPTER PRIMARY HEATER ENABLE
22B4	MAHADI	TM/MISSION ADAPTER PRIMARY HEATER DISABLE
3234	MAHBEN	TM/MISSION ADAPTER REDUNDANT HEATER ENABLE
42D4	MAHBDI	TM/MISSION ADAPTER REDUNDANT HEATER DISABLE
5254	MATHBY	TM/MISSION ADAPTER HEATER THERMOSTAT BYPASS
6294	MATHEN	TM/MISSION ADAPTER HEATER THERMOSTAT ENABLE
7214	MSHAEN	MSS INTERFACE PRIMARY HEATER ENABLE
82E4	MSHADI	MSS INTERFACE PRIMARY HEATER DISABLE
9264	MSHBEN	MSS INTERFACE REDUNDANT HEATER ENABLE
A2A4	MSHBDI	MSS INTERFACE REDUNDANT HEATER DISABLE
B224	MSTHBY	MSS INTERFACE HEATER THERMOSTAT BYPASS
C2C4	MSTHEN	MSS INTERFACE HEATER THERMOSTAT ENABLE
1375	WBHAEN	WB MODULE INTERFACE PRIMARY HEATER ENABLE
23B5	WBHADI	WB MODULE INTERFACE PRIMARY HEATER DISABLE
3335	WBHBEN	WB MODULE INTERFACE REDUNDANT HEATER ENABLE
43D5	WBHBDI	WB MODULE INTERFACE REDUNDANT HEATER DISABLE
5355	WBTHBY	WB MODULE INTERFACE HEATER THERMOSTAT BYPASS
6395	WBTHEN	WB MODULE INTERFACE HEATER THERMOSTAT ENABLE
7315	S2HAEN	UPPER SUPPORT STRUCTURE HEATER 2A ENABLE
83E5	S2HADI	UPPER SUPPORT STRUCTURE HEATER 2A DISABLE
9365	S2HBEN	UPPER SUPPORT STRUCTURE HEATER 2B ENABLE
A3A5	S2HBDI	UPPER SUPPORT STRUCTURE HEATER 2B DISABLE
B325	S2THBY	UPPER SUPPORT STRUCTURE HEATER 2 THERMOSTAT BYPASS
C3C5	S2THEN	UPPER SUPPORT STRUCTURE HEATER 2 THERMOSTAT ENABLE
1476	TMHAEN	TM SAFEHOLD HEATER 1 ENABLE
24B6	TMHADI	TM SAFEHOLD HEATER 1 DISABLE
3436	TMHBEN	TM SAFEHOLD HEATER 2 ENABLE

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Table 8.6-2. Serial Command Acronyms

Data	Acronym	Command Name
44D6	TMHBDI	TM SAFEHOLD HEATER 2 DISABLE
5456	TMTHBY	TM SAFEHOLD HEATER THERMOSTAT BYPASS
6496	TMTHEN	TM SAFEHOLD HEATER THERMOSTAT ENABLE
7416	PH8AEN	PAYLOAD HEATER 8 PRIMARY ENABLE
84E6	PH8ADI	PAYLOAD HEATER 8 PRIMARY DISABLE
9466	PH8BEN	PAYLOAD HEATER 8 REDUNDANT ENABLE
A4A6	PH8BDI	PAYLOAD HEATER 8 REDUNDANT DISABLE
B426	PTH8BY	PAYLOAD THERMOSTAT 8 BYPASS
C4C6	PTH8EN	PAYLOAD THERMOSTAT 8 ENABLE
		MMS STRUCTURE HEATER COMMANDS:
1577	SCH1EN	SPACECRAFT HEATER 1 ENABLE
25B7	SCH1DI	SPACECRAFT HEATER 1 DISABLE
3537	SCTH1BY	SPACECRAFT THERMOSTAT 1 BYPASS
45D7	SCTH1EN	SPACECRAFT THERMOSTAT 1 ENABLE
5557	SCH2EN	SPACECRAFT HEATER 2 ENABLE
6597	SCH2DI	SPACECRAFT HEATER 2 DISABLE
7517	SCTH2BY	SPACECRAFT THERMOSTAT 2 BYPASS
85E7	SCTH2EN	SPACECRAFT THERMOSTAT 2 ENABLE
9567	SCH3EN	SPACECRAFT HEATER 3 ENABLE
A5A7	SCH3DI	SPACECRAFT HEATER 3 DISABLE
B527	SCTH3BY	SPACECRAFT THERMOSTAT 3 BYPASS
C5C7	SCTH3EN	SPACECRAFT THERMOSTAT 3 ENABLE
1678	SCH4EN	SPACECRAFT HEATER 4 ENABLE
26B8	SCH4DI	SPACECRAFT HEATER 4 DISABLE
3638	SCTH4BY	SPACECRAFT THERMOSTAT 4 BYPASS
46D8	SCTH4EN	SPACECRAFT THERMOSTAT 4 ENABLE
5658	SCH5EN	SPACECRAFT HEATER 5 ENABLE
6698	SCH5DI	SPACECRAFT HEATER 5 DISABLE
7618	SCTH5BY	SPACECRAFT THERMOSTAT 5 BYPASS
86E8	SCTH5EN	SPACECRAFT THERMOSTAT 5 ENABLE
9668	SCH6EN	SPACECRAFT HEATER 6 ENABLE
A6A8	SCH6DI	SPACECRAFT HEATER 6 DISABLE
B628	SCTH6BY	SPACECRAFT THERMOSTAT 6 BYPASS
C6C8	SCTH6EN	SPACECRAFT THERMOSTAT 6 ENABLE
		SOLAR ARRAY DEPLOY PYRO COMMANDS:
187A	ADMARM	ARRAY DEPLOY MASTER ARM
986A	ADRARM	ARRAY DEPLOY MASTER ARM (BACKUP COMMAND)
689A	ADMSAF	ARRAY DEPLOY MASTER SAFE

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Table 8.6-2. Serial Command Acronyms

Data	Acronym	Command Name
E88A	ADRSAF	ARRAY DEPLOY MASTER SAFE (BACKUP COMMAND)
C8CA	AD1ARM	ARM ARRAY DEPLOY PYRO SET 1 (PYROS 1A,2B & 2A,1B)
28BA	AD1FIRE	FIRE ARRAY DEPLOY PYRO SET 1 (PYROS 1A,2B & 2A,1B)
A8AA	AD2ARM	ARM ARRAY DEPLOY PYRO SET 2 (PYROS 3A,4B & 4A,3B)
48DA	AD2FIRE	FIRE ARRAY DEPLOY PYRO SET 2 (PYROS 3A,4B & 4A,3B)
		ANTENNA BOOM DEPLOY PYRO COMMANDS:
1779	BDMARM	ANTENNA DEPLOY MASTER ARM
9769	BDRARM	ANTENNA DEPLOY MASTER ARM (BACKUP COMMAND)
6799	BDMSAF	ANTENNA DEPLOY MASTER SAFE
E789	BDRSAF	ANTENNA DEPLOY MASTER SAFE (BACKUP COMMAND)
D749	BUNLARM	ARM BOOM RELEASE (UNLATCH) PYRO
27B9	BUNFIRE	FIRE BOOM RELEASE (UNLATCH) PYRO
C7C9	GIM1ARM	ARM GDA LAUNCH LOCK PYRO 1
3739	GIM1FIRE	FIRE GDA LAUNCH LOCK PYRO 1
B729	GIM2ARM	ARM GDA LAUNCH LOCK PYRO 2
47D9	GIM2FIRE	FIRE GDA LAUNCH LOCK PYRO 2
A7A9	BSPARM	ARM SPARE PYRO
5759	BSPFIRE	FIRE SPARE PYRO
		ANTENNA JETTISON PYRO COMMANDS:
197B	BJMARM	ANTENNA JETTISON MASTER ARM
996B	BJRARM	ANTENNA JETTISON MASTER ARM (BACKUP COMMAND)
699B	BJMSAF	ANTENNA JETTISON MASTER SAFE
E98B	BJRSAF	ANTENNA JETTISON MASTER SAFE (BACKUP COMMAND)
D94B	CCUTARM	ARM CABLE CUTTER (GUILLOTINE) PYRO
29BB	CCUTFIRE	FIRE CABLE CUTTER (GUILLOTINE) PYRO
C9CB	JETARM	ARM BOOM JETTISON (MARMON CLAMP RELEASE) PYRO
393B	JETFIRE	FIRE BOOM JETTISON (MARMON CLAMP RELEASE) PYRO
B92B	JSP1ARM	ARM SPARE PYRO 1
49DB	JSP1FIRE	FIRE SPARE PYRO 1
A9AB	JSP2ARM	ARM SPARE PYRO 2
595B	JSP2FIRE	FIRE SPARE PYRO 2
		PM-1A HEATER COMMANDS:
1C7E	PTKHTEN	PM-1A PRIMARY TANK HEATER ENABLE
2CBE	PTKHTDIS	PM-1A PRIMARY TANK HEATER DISABLE
7C1E	RTKHTEN	PM-1A REDUNDANT TANK HEATER ENABLE
8CEE	RTKHTDIS	PM-1A REDUNDANT TANK HEATER DISABLE
3C3E	PLHTEN	PM-1A PRIMARY LINE HEATER ENABLE

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Table 8.6-2. Serial Command Acronyms

Data	Acronym	Command Name
4CDE	PLHTDIS	PM-1A PRIMARY LINE HEATER DISABLE
5C5E	LHTTHBY	PM-1A LINE HEATER THERMOSTAT BYPASS
6C9E	LHTTHEN	PM-1A LINE HEATER THERMOSTAT ENABLE
9C6E	RLNHTEN	PM-1A REDUNDANT LINE HEATER ENABLE
ACAE	RLNHTDIS	PM-1A REDUNDANT LINE HEATER DISABLE
BC2E	TKHTTHBY	PM-1A TANK HEATER THERMOSTAT BYPASS
CCCE	TKHTTHEN	PM-1A TANK HEATER THERMOSTAT ENABLE

NOTE: PM-1A commands using acronyms are transmitted in the form /PM,ACRONYM using the ground test data base. All other commands in this table are transmitted in the form /SCCU,ACRONYM.

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Table 8.6-3. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
SRIUEN	8.6.1.1			URIUSBA=0	RIU A
				URIUSBA=1	RIU B
RIUSB2	8.6.1.1	SRIUEN		UMATENF=0	
MRIUDI	8.6.1.1			UMATENF=0	
SCUAON	8.6.1.2		SCUBON	UBOFFAON=1	A ON
				UAOFFBON=0	B OFF
SCUBON	8.6.1.2		SCUAON	UAOFFBON=1	B ON
				UBOFFAON=0	A OFF
APYREN	8.6.1.5		APYRDI	UASPYRED=1	
APYRDI	8.6.1.5		APYREN	UASPYRED=0	
BPYREN	8.6.1.5		BPYRDI	UBSPYRED=1	
BPYRDI	8.6.1.5		BPYREN	UBSPYRED=0	
ENAHTA	8.6.1.3		DISHTA	UHTRAED=1	
DISHTA	8.6.1.3		ENAHTA	UHTRAED=0	
ENAHTB	8.6.1.3		DISHTB	UHTRBED=1	
DISHTB	8.6.1.3		ENAHTB	UHTRBED=0	
BYPTHB	8.6.1.3		ENATHB	UTHTBBE=1	
ENATHB	8.6.1.3		BYPTHB	UTHTBBE=0	
BYPTHA	8.6.1.3		ENATHA	UTHTABE=1	
ENATHA	8.6.1.3		BYPTHA	UTHTABE=0	
S1HAEN	8.6.1.4.2		S1HADI	USS1AHTR=1	
S1HADI	8.6.1.4.2		S1HAEN	USS1AHTR=0	
S1HBEN	8.6.1.4.2		S1HBDI	USS1BHTR=1	
S1HBDI	8.6.1.4.2		S1HBEN	USS1BHTR=0	
S1THBY	8.6.1.4.2		S1THEN	USS1THT=1	
S1THEN	8.6.1.4.2		S1THBY	USS1THT=0	
SBHAEN	8.6.1.4.2		SBHADI	USBHTRA=1	
SBHADI	8.6.1.4.2		SBHAEN	USBHTRA=0	
SBHBEN	8.6.1.4.2		SBHBDI	USBHTRB=1	
SBHBDI	8.6.1.4.2		SBHBEN	USBHTRB=0	
SBTHBY	8.6.1.4.2		SBTHEN	USBTHT=1	
SBTHEN	8.6.1.4.2		SBTHBY	USBTHT=0	
MAHAEN	8.6.1.4.2		MAHADI	UTMMAHA=1	
MAHADI	8.6.1.4.2		MAHAEN	UTMMAHA=0	
MAHBEN	8.6.1.4.2		MAHBDI	UTMMAHB=1	
MAHBDI	8.6.1.4.2		MAHBEN	UTMMAHB=0	
MATHBY	8.6.1.4.2		MATHEN	UTMMATH=1	
MATHEN	8.6.1.4.2		MATHBY	UTMMATH=0	
MSHAEN	8.6.1.4.2		MSHADI	UMSAHTA=1	

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Table 8.6-3. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
MSHADI	8.6.1.4.2		MSHAEN	UMSAHTA=0	
MSHBEN	8.6.1.4.2		MSHBDI	UMSAHTB=1	
MSHBDI	8.6.1.4.2		MSHBEN	UMSAHTB=0	
MSTHBY	8.6.1.4.2		MSTHEN	UMSATHT=1	
MSTHEN	8.6.1.4.2		MSTHBY	UMSATHT=0	
WBHAEN	8.6.1.4.2		WBHADI	UWBHTRA=1	
WBHADI	8.6.1.4.2		WBHAEN	UWBHTRA=0	
WBHBEN	8.6.1.4.2		WBHBDI	UWBHTRB=1	
WBHBDI	8.6.1.4.2		WBHBEN	UWBHTRB=0	
WBTHBY	8.6.1.4.2		WBTHEN	UWBTHT=1	
WBTHEN	8.6.1.4.2		WBTHBY	UWBTHT=0	
S2HAEN	8.6.1.4.2		S2HADI	USS2AHTR=1	
S2HADI	8.6.1.4.2		S2HAEN	USS2AHTR=0	
S2HBEN	8.6.1.4.2		S2HBDI	USS2BHTR=1	
S2HBDI	8.6.1.4.2		S2HBEN	USS2BHTR=0	
S2THBY	8.6.1.4.2		S2THEN	USS2THT=1	
S2THEN	8.6.1.4.2		S2THBY	USS2THT=0	
TMHAEN	8.6.1.4.2		TMHADI	UTMHTR1=1	
TMHADI	8.6.1.4.2		TMHAEN	UTMHTR1=0	
TMHBEN	8.6.1.4.2		TMHBDI	UTMHTR2=1	
TMHBDI	8.6.1.4.2		TMHBEN	UTMHTR2=0	
TMTHBY	8.6.1.4.2		TMTHEN	UTMTHT=1	
TMTHEN	8.6.1.4.2		TMTHBY	UTMTHT=0	
PH8AEN	8.6.1.4.2		PH8ADI	UPL8AHTR=1	NOT USED
PH8ADI	8.6.1.4.2		PH8AEN	UPL8AHTR=0	NOT USED
PH8BEN	8.6.1.4.2		PH8BDI	UPL8BHTR=1	NOT USED
PH8BDI	8.6.1.4.2		PH8BEN	UPL8BHTR=0	NOT USED
PTH8BY	8.6.1.4.2		PTH8EN	UPL8THT=1	NOT USED
PTH8EN	8.6.1.4.2		PTH8BY	UPL8THT=0	NOT USED
SCH1EN	8.6.1.4.1		SCH1DI	USCHTR1=1	
SCH1DI	8.6.1.4.1		SCH1EN	USCHTR1=0	
SCTH1BY	8.6.1.4.1		SCTH1EN	USC1THT=1	
SCTH1EN	8.6.1.4.1		SCTH1BY	USC1THT=0	
SCH2EN	8.6.1.4.1		SCH2DI	USCHTR2=1	
SCH2DI	8.6.1.4.1		SCH2EN	USCHTR2=0	
SCTH2BY	8.6.1.4.1		SCTH2EN	USC2THT=1	
SCTH2EN	8.6.1.4.1		SCTH2BY	USC2THT=0	
SCH3EN	8.6.1.4.1		SCH3DI	USCHTR3=1	
SCH3DI	8.6.1.4.1		SCH3EN	USCHTR3=0	

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Table 8.6-3. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
SCTH3BY	8.6.1.4.1		SCTH3EN	USC3THT=1	
SCTH3EN	8.6.1.4.1		SCTH3BY	USC3THT=0	
SCH4EN	8.6.1.4.1		SCH4DI	USCHTR4=1	
SCH4DI	8.6.1.4.1		SCH4EN	USCHTR4=0	
SCTH4BY	8.6.1.4.1		SCTH4EN	USC4THT=1	
SCTH4EN	8.6.1.4.1		SCTH4BY	USC4THT=0	
SCH5EN	8.6.1.4.1		SCH5DI	USCHTR5=1	
SCH5DI	8.6.1.4.1		SCH5EN	USCHTR5=0	
SCTH5BY	8.6.1.4.1		SCTH5EN	USC5THT=1	
SCTH5EN	8.6.1.4.1		SCTH5BY	USC5THT=0	
SCH6EN	8.6.1.4.1		SCH6DI	USCHTR6=1	
SCH6DI	8.6.1.4.1		SCH6EN	USCHTR6=0	
SCTH6BY	8.6.1.4.1		SCTH6EN	USC6THT=1	
SCTH6EN	8.6.1.4.1		SCTH6BY	USC6THT=0	
PTKHTEN	8.6.1.4.3		PTKHTDIS	ZPRTKHT=1	
PTKHTDIS	8.6.1.4.3		PTKHTEN	ZPRTKHT=0	
RTKHTEN	8.6.1.4.3		RTKHTDIS	ZBUTKHT=1	
RTKHTDIS	8.6.1.4.3		RTKHTEN	ZBUTKHT=0	
TKHTTHBY	8.6.1.4.3		TKHTTHEN	ZBULNTH=1	
TKHTTHEN	8.6.1.4.3		TKHTTHBY	ZBULNTH=0	
PLHTEN	8.6.1.4.3		PLHTDIS	ZPRLNHT=1	
PLHTDIS	8.6.1.4.3		PLHTEN	ZPRLNHT=0	
RLNHTEN	8.6.1.4.3		RLNHTDIS	ZBULNHT=1	
RLNHTDIS	8.6.1.4.3		RLNHTEN	ZBULNHT=0	
LHTTHBY	8.6.1.4.3		LHTTHEN	ZPRLNTH=1	
LHTTHEN	8.6.1.4.3		LHTTHBY	ZRLLNTH=0	
ADMARM	8.6.1.5.2	8.6.1.5.1	ADMSAF	UADPMAS=1	ON SIDE
			ADRSAF	UADUMAS=1	OFF SIDE
ADRARM	8.6.1.5.2	8.6.1.5.1	ADMSAF	UADPMAS=1	ON SIDE
			ADRSAF	UADUMAS=1	OFF SIDE
ADMSAF	8.6.1.5.2	8.6.1.5.1	ADMARM	UADPMAS=0	ON SIDE
			ADRARM	UADUMAS=0	OFF SIDE
ADRSAF	8.6.1.5.2	8.6.1.5.1	ADMARM	UADPMAS=0	ON SIDE
			ADRARM	UADUMAS=0	OFF SIDE
AD1ARM	8.6.1.5.2	8.6.1.5.1	ADMSAF	UADST1A=1	1A&2B
			ADRSAF	UADST1B=1	2A&1B
AD1FIRE	8.6.1.5.2	AD1ARM		NO DIR VER	
AD2ARM	8.6.1.5.2	8.6.1.5.1	ADMSAF	UADST2A=1	3A&4B
			ADRSAF	UADST2B=1	4A&3B

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Table 8.6-3. Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
AD2FIRE	8.6.1.5.2	AD2ARM		NO DIR VER	
BDMARM	8.6.1.5.3	8.6.1.5.1	BDMSAF	UBDPMAS=1	ON SIDE
			BDRSAF	UBDUMAS=1	OFF SIDE
BDRARM	8.6.1.5.3	8.6.1.5.1	BDMSAF	UBDPMAS=1	ON SIDE
			BDRSAF	UBDUMAS=1	OFF SIDE
BDMSAF	8.6.1.5.3	8.6.1.5.1	BDMARM	UBDPMAS=0	ON SIDE
			BDRARM	UBDUMAS=0	OFF SIDE
BDRSAF	8.6.1.5.3	8.6.1.5.1	BDMARM	UBDPMAS=0	ON SIDE
			BDRARM	UBDUMAS=0	OFF SIDE
GIM1ARM	8.6.1.5.3	8.6.1.5.1	BDMSAF	UBDGIM1=1	
			BDRSAF		
GIM1FIRE	8.6.1.5.3	GIM1ARM		NO DIR VER	
GIM2ARM	8.6.1.5.3	8.6.1.5.1	BDMSAF	UBDGIM2=1	
			BDRSAF		
GIM2FIRE	8.6.1.5.3	GIM2ARM		NO DIR VER	
BSPARM	8.6.1.5.3	8.6.1.5.1	BDMSAF	UBDSPAR=1	NOT USED
			BDRSAF		
BSPFIRE	8.6.1.5.3	BSPARM		NO DIR VER	NOT USED
BJMARM	8.6.1.5.4	8.6.1.5.1	BJMSAF	UBJPMAS=1	ON SIDE
			BJRSAF	UBJUMAS=1	OFF SIDE
BJRARM	8.6.1.5.4	8.6.1.5.1	BJMSAF	UBJPMAS=1	ON SIDE
			BJRSAF	UBJUMAS=1	OFF SIDE
BJMSAF	8.6.1.5.4	8.6.1.5.1	BJMARM	UBJPMAS=0	ON SIDE
			BJRARM	UBJUMAS=0	OFF SIDE
BJRSAF	8.6.1.5.4	8.6.1.5.1	BJMARM	UBJPMAS=0	ON SIDE
			BJRARM	UBJUMAS=0	OFF SIDE
CCUTARM	8.6.1.5.4	8.6.1.5.1	BJMSAF	UBJCCUT=1	
			BJRSAF		
CCUTFIRE	8.6.1.5.4	CCUTARM		NO DIR VER	
JETARM	8.6.1.5.4	8.6.1.5.1	BJMSAF	UBJPYRO=1	
			BJRSAF		
JETFIRE	8.6.1.5.4	JETARM		NO DIR VER	
JSP1ARM	8.6.1.5.4	8.6.1.5.1	BJMSAF	UBJSPAR1=1	NOT USED
			BJRSAF		
JSP1FIRE	8.6.1.5.4	JSP1ARM		NO DIR VER	NOT USED
JSP2ARM	8.6.1.5.4	8.6.1.5.1	BJMSAF	UBJSPAR2=1	NOT USED
			BJRSAF		
JSP2FIRE	8.6.1.5.4	JSP2ARM		NO DIR VER	NOT USED

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8.6.1 COMMAND DESCRIPTIONS

This section provides descriptions of the command functions using the acronyms defined in Tables 8.6-1 and 8.6-2. Descriptions of ESAM commands are presented in Section 3.6 and are not a part of this section.

In the ground test data base and software, all commands described in this section are of the form /SCCU,ACRONYM except PM-1A heater control commands. The PM-1A heater commands are of the form /PM,ACRONYM.

All commands described herein are addressed to RIU 4 (A or B) and all may be executed/distributed by either the A or B RIU. There are no commands dedicated to RIU A only or RIU B only.

8.6.1.1 RIU 4 Control

The SC&CU RIU's (RIU 4A and 4B) are connected in a redundant configuration such that either can provide communication between the CU and the SC&CU, PM-1A, and ESAM subsystems via the Multiplex Data Bus (MDB). An RIU has three modes: Off, Standby 1, and Standby 2 (full on). In all modes, the power converters in both RIUs are on and both of the MDB redundant supervisory line pairs are continuously monitored by the RIUs.

In normal operation, one RIU will be in the Standby 2 state and its mate will be in the Off state. When power is restored after interruption, both will assume their prior states. In order to activate the alternate RIU, it is necessary to address two commands, SRIUEN and RIUSB2, to the off RIU. SRIUEN causes an Off RIU to assume the Standby 1 state. In this mode it can only accept discrete commands. RIUSB2 is then sent to the same RIU, which causes it to assume the Standby 2 (full on) state and simultaneously place its mate in the Off state. A backup mate Off command, MRIUDI, is provided in the event RIUSB2 fails to place the mate RIU in the Off state. MRIUDI should be addressed only to a RIU in the Standby 2 state, and never to one in the Standby 1 state. The latter condition will result in one RIU Off and the other in Standby 1 causing loss of RIU 4 telemetry data in the realtime telemetry data stream. The CU requires a full on RIU to acquire telemetry data via the MDB.

8.6.1.2 SC&CU Power Control

One of the redundant sides of the SC&CU is always powered whenever the spacecraft is powered. The on side is determined by one of the two mutually exclusive commands SCUAON and SCUBON (reference Figure 8.6-1).

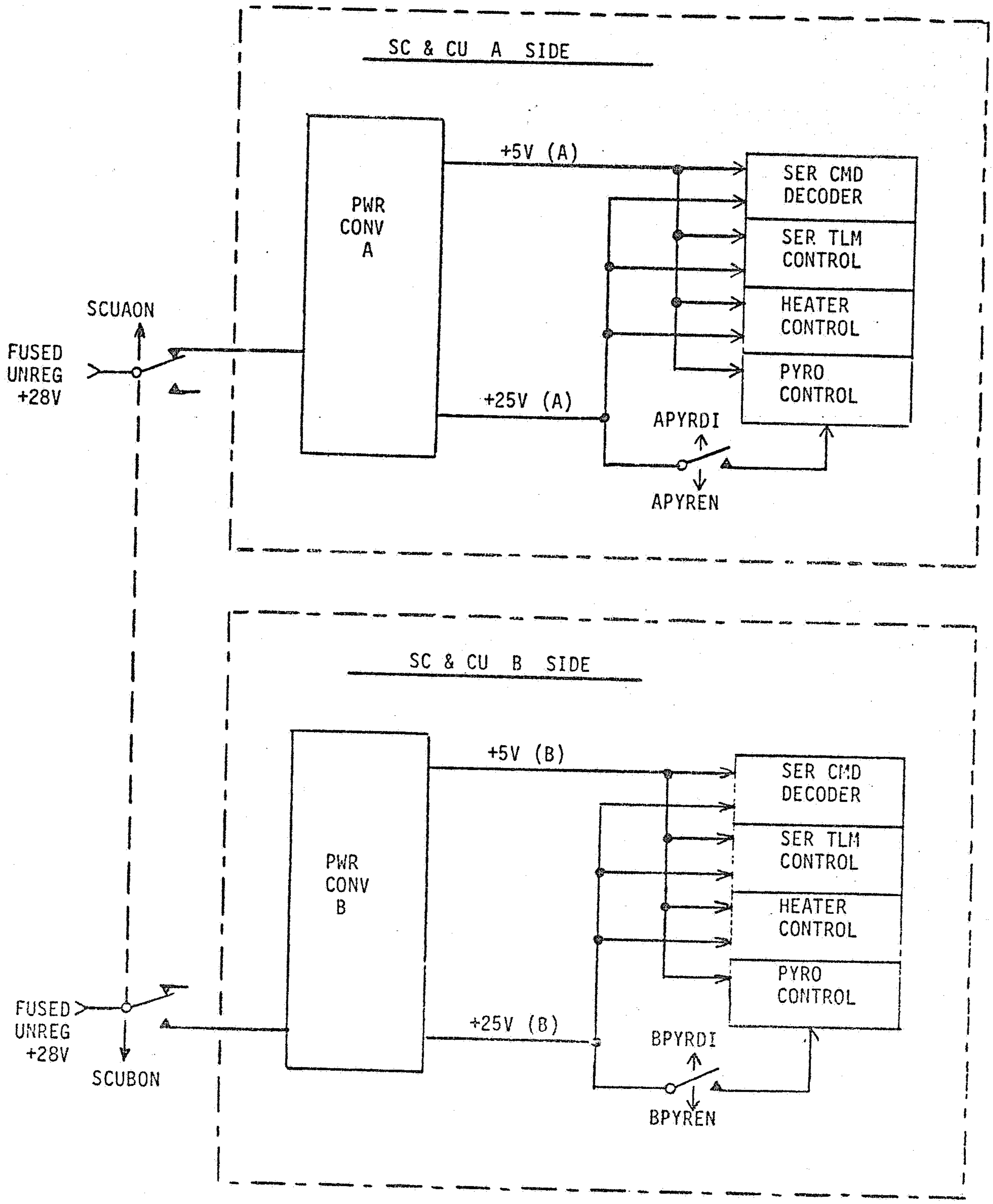

Figure 8.6-1. SC&CU Power Control and Pyro Enable Commands

SCUAON turns on the A side power converter and simultaneously turns off the B side power converter. The A converter provides 5 V(A) logic power to all of the A side circuits and 25 V(A) power to all A side circuits with the exception that 25 V(A) power to the pyro control circuits is controlled by pyro enable/disable commands (APYREN/APYRDI) as a safety interlock (see Paragraph 8.6.1.5).

SCUBON turns on the B side power converter and simultaneously turns off the A side power converter. The 5 V(B) and 25 V(B) power outputs are provided to the B side circuits as described in the preceding paragraph for the A side.

There is no SC&CU Off command. Either the A or B side in commanded on, not both. Telemetry verifications for these commands are obtained from the monitors UBOFFAON and UAOFFBON.

8.6.1.3 Module Heater Control

The SC&CU module contains four heaters, configured redundantly, with two heaters on each of two identical circuits. Each circuit contains two resistive 12.5 watt heaters controlled by a mechanical thermostat. Discrete commands provide power enable/disable and thermostat bypass/enable control for the heaters as shown in Figure 8.6-2. These commands, listed below, are independent of which side of the SC&CU is on. Telemetry verifications are obtained from the monitors UHTRAED, UHTRBED, UTHTABE and UTHTBBE.

Heater A	Heater B	Function Commanded
ENAHTA	ENAHTB	Enable heater power
DISHTA	DISHTB	Disable heater power
BYPTHA	BYPTHB	Bypass heater thermostat
ENATHA	ENATHB	Enable heater thermostat

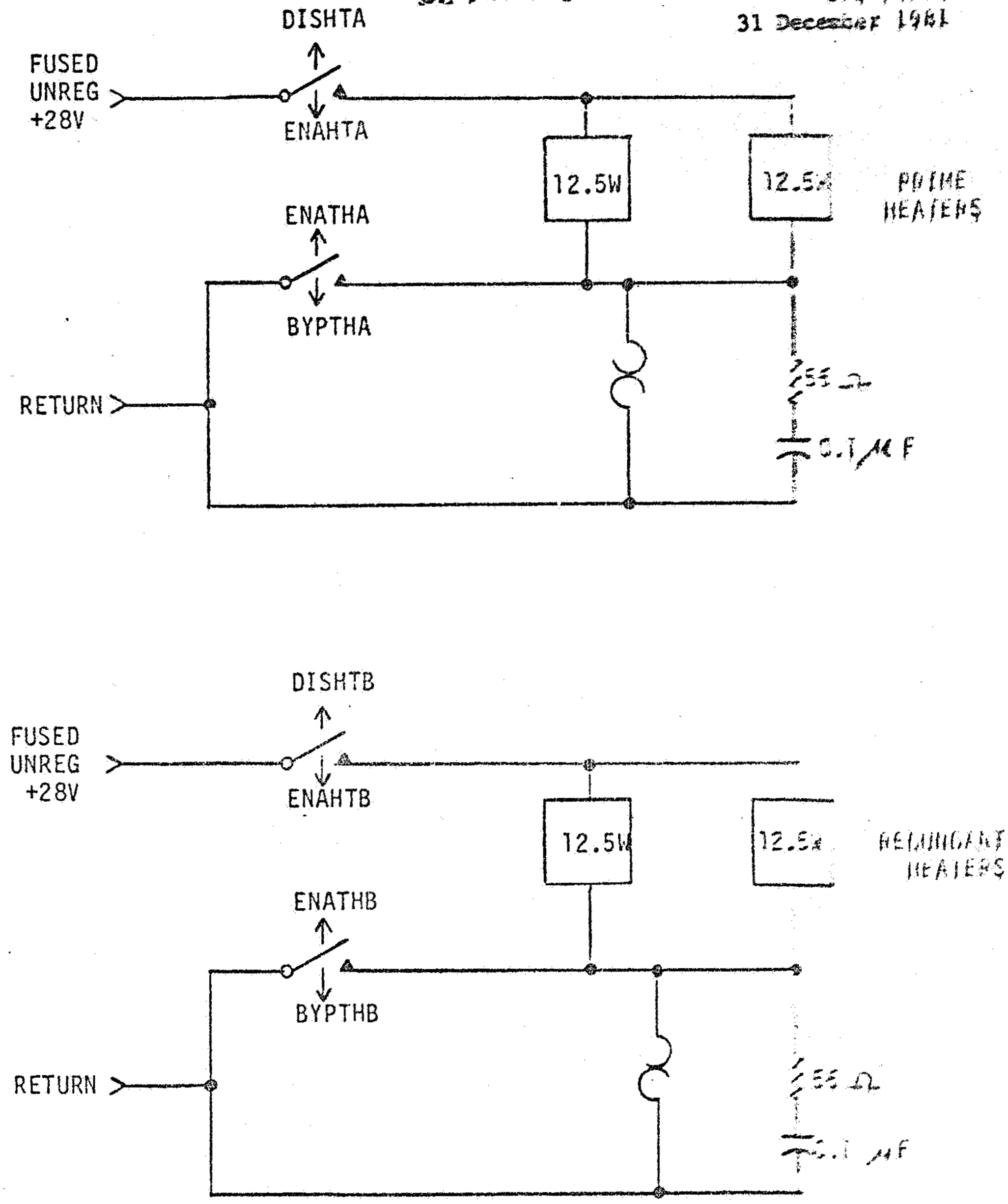

Figure 8.6-2. SC & CU Module Heater Control

8.6.1.4 External Heater Control

The SC&CU provides power and command control for the following heater circuits located external to the SC&CU module.

1. 6 non-redundant MMS structure heater circuits

2. 8 payload heater circuits, each with primary and redundant heaters.

3. 2 PM-1A heater circuits, each with primary and redundant heaters.

Heater locations are provided in Section 19.0 of this manual. Heater control commands are serial digital commands which are distributed by either RIU to both sides of the SC&CU. Relays and logic on the SC&CU A and B sides are configured so that whichever side is on will execute the commands. Figure 8.6-3 provides a functional diagram of this type configuration for one complementary command pair. All heater command pairs operate in the same manner as indicated in Figure 8.6-4(a). The simplified diagram of Figure 8.6-4(b) illustrates command functions, whether obtained from RIU A or B or from SC&CU A or B.

8.6.1.4.1 MMS Structure Heater Control

There are 6 MMS structure heater circuits designated spacecraft heaters 1 through 6. Each circuit consists of one heater and a mechanical thermostat, and is represented by Figure 8.6-4 with the redundant heater and K2 contacts deleted. The commands associated with these heaters are listed below. Telemetry verifications for the commands are presented in Table 8.6-3.

S/C Heater	Heater Enable	Heater Disable	Thmstat Enable	Thmstat Bypass
1	SCH1EN	SCH1DI	SCTH1EN	SCTH1BY
2	SCH2EN	SCH2DI	SCTH2EN	SCTH2BY
3	SCH3EN	SCH3DI	SCTH3EN	SCTH3BY
4	SCH4EN	SCH4DI	SCTH4EN	SCTH4BY
5	SCH5EN	SCH5DI	SCTH5EN	SCTH5BY
6	SCH6EN	SCH6DI	SCTH6EN	SCTH6BY

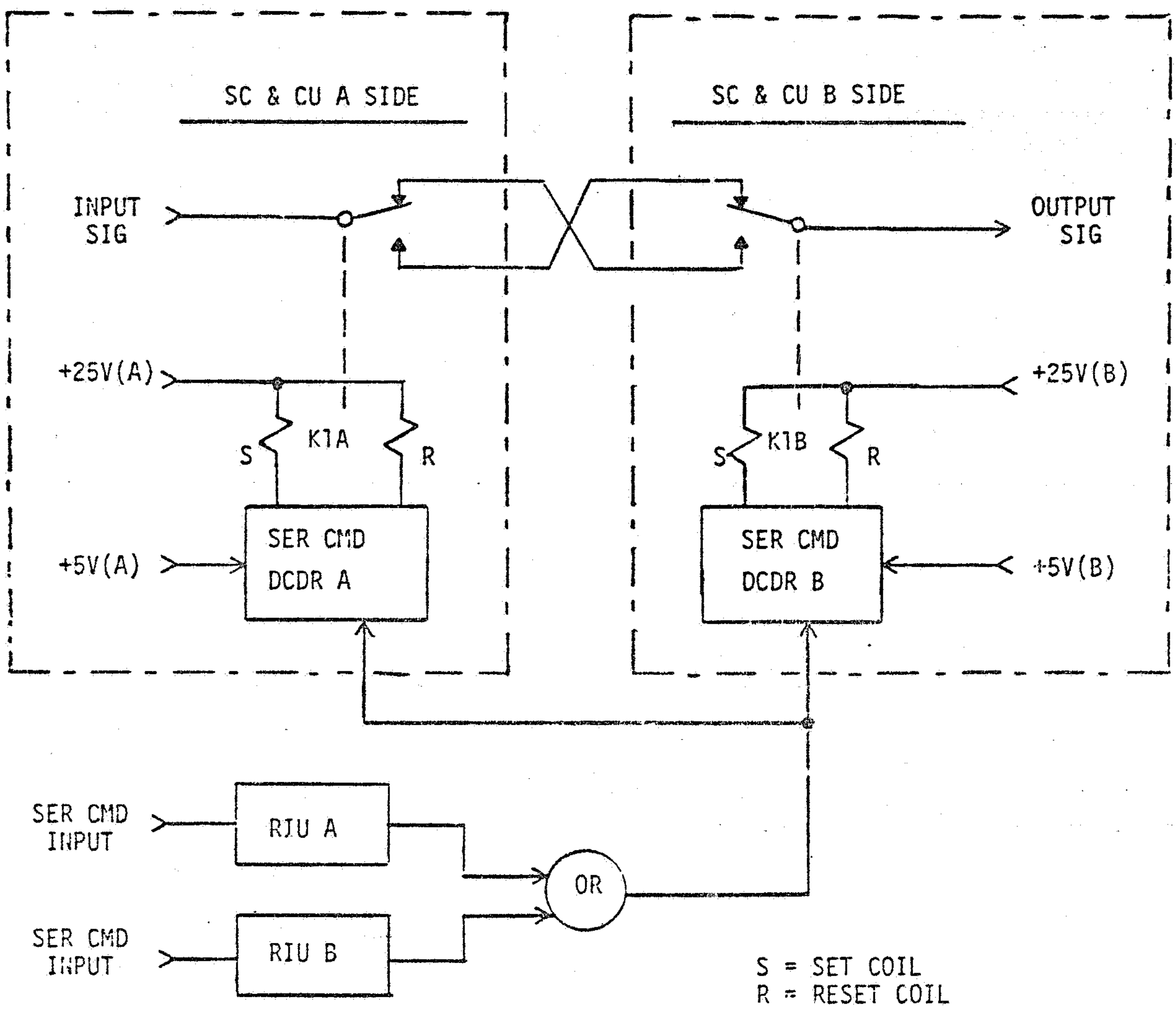

Figure 8.6-3. Simplified Heater Serial Command Functional Diagram

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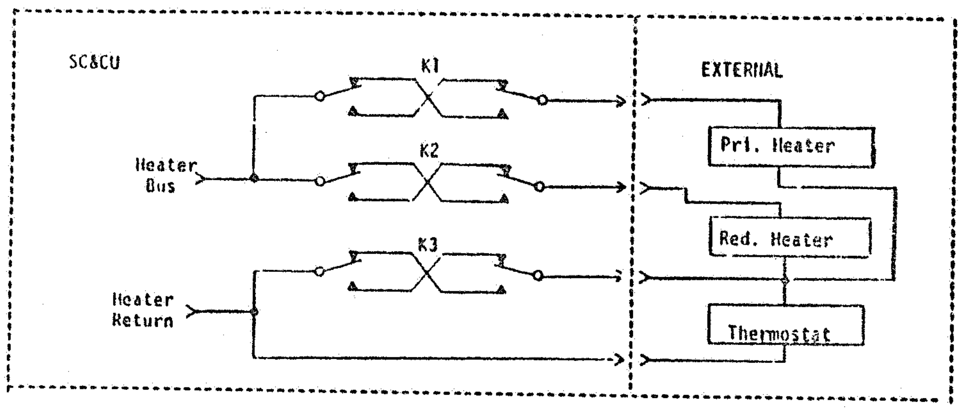
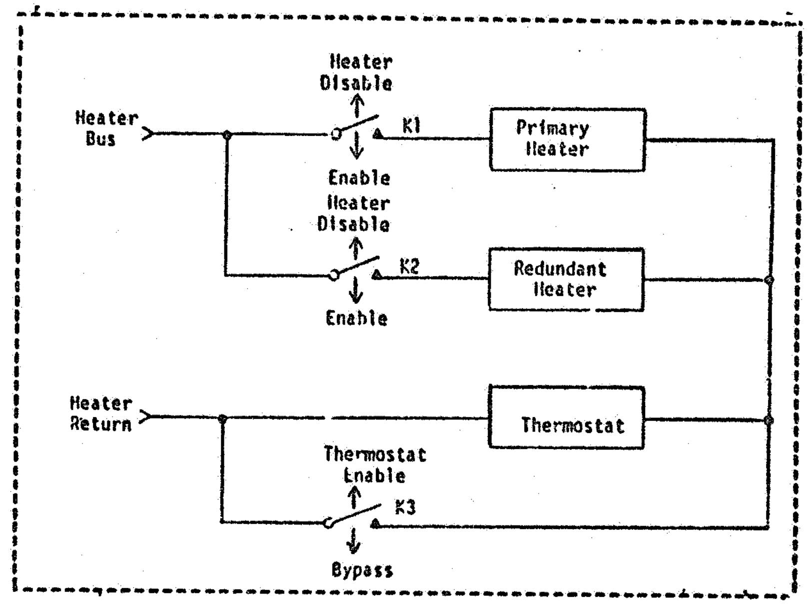


(A) TYPICAL CIRCUIT



(B) SIMPLIFIED CIRCUIT

Figure 8.6-4 External Heater Control Circuit

8.6.1.4.2 Payload Heater Control

The SC&CU provides power and commands for 8 heater circuits designated payload heaters 1 through 8. Seven of the control circuits are used for heaters on the instrument module. The eighth is a spare which is not used, although the commands and telemetry verifications exist within the SC&CU.

Each payload heater circuit consists of a primary and redundant heater sharing a common thermostat as shown in Figure 8.6-4. The heaters have been sized so that one of the redundant heaters will provide the necessary heating with the other heater as a backup. Thus, when heat is required in a specific area, the heater configuration should be primary heater enabled, redundant heater disabled, and heater thermostat enabled.

Payload heater control circuits 1 through 7 are connected to heaters in the instrument module in the order listed in Table 8.6-2 under Payload Heater Commands. The commands required for heater control are listed below. Payload heater control circuit 8 is not connected to any heaters.

Payload Heater	Pri. Heater Enable/Disable	Red. Heater Enable/Disable	Thermostat Bypass/Enable
1	S1HAEN/S1HADI	S1HBEN/S1HBDI	S1THBY/S1THEN
2	SBHAEN/SBHADI	SBHBEN/SBHBDI	SBTHBY/SBTHEN
3	MAHAEN/MAHADI	MAHBEN/MAHBDI	MATHBY/MATHEN
4	MSHAEN/MSHADI	MSHBEN/MSHBDI	MSTHBY/MSTHEN
5	WBHAEN/WBHADI	WBHBEN/WBHBDI	WBTHBY/WBTHEN
6	S2HAEN/S2HADI	S2HBEN/S2HBDI	S2THBY/S2THEN
7	TMHAEN/TMHADI	TMHBEN/TMHBDI	TMTHBY/TMTHEN
8	PH8AEN/PH8ADI	PH8BEN/PH8BDI	PTH8BY/PTH8EN

8.6.1.4.3 PM-1A Heater Control

The SC&CU provides power and commands for two heater circuits on the PM-1A auxiliary tank kit of the MMS propulsion module. Each circuit consists of a primary and redundant heater sharing a common mechanical thermostat as shown in Figure 8.6-4. One heater circuit provides heat to the PM-1A fuel tank, as required. The other heater circuit provides heat to the PM-1A fuel lines. The commands required for heater control are listed below.

PM-1A Heater	Pri. Heater Enable/Disable	Red. Heater Enable/Disable	Thermostat Bypass/Enable
Tank	PTKHTEN/PTKHTDIS	RTKHTEN/RTKHTDIS	TKHTTHBY/TKHTTHEN
Line	PLHTEN/PLHTDIS	RLNHTEN/RLNHTDIS	LHTTHBY/LHTTHEN

8.6.1.5 Pyrotechnic Circuit Control

The SC&CU provides command control and power for all spacecraft pyro devices. Each device contains two bridgewires, primary (A) and redundant (B). Firing of either the A or B bridgewire causes the device to fire.

Pyro command control by RIU commands is accomplished by functional groups in the SC&CU. The groups are: solar array deploy pyros, antenna deploy pyros, and antenna jettison pyros. Each group is provided with master arm and master safe functions. The master safe function places all pyros in the group in a safe condition. The master arm function is an enable function to provide individual arming and firing capability for each pyro in the group.

8.6.1.5.1 Prerequisite Commands

Pyro devices may be armed and fired from either the SC&CU A side or B side, whichever is on. The antenna deploy and jettison devices are configured such that primary bridgewires are armed/fired by the A side and redundant bridgewires by the B side. The solar array deploy devices are configured such that all bridgewires are armed/fired by either side of the SC&CU.

Figure 8.6-5 illustrates functionally the relay configuration required to arm and fire one pyro device N in a functional group. The following description applies to pyro control from the SC&CU A side. Control from the B side is identical.

The initial requirement for firing pyros from the A side is SCUAON to provide +5 V(A) and +25 V(A) secondary voltages. The +5 V provides logic power for the A side serial command decoder and pyro control circuits. The +25 V provides relay coil power for the pyro arm and fire relays of Figure 8.6-5. The +25 V coil power is only available when the A side pyros enable/disable relay is latched in the enable position. Therefore, APYREN is the second requirement.

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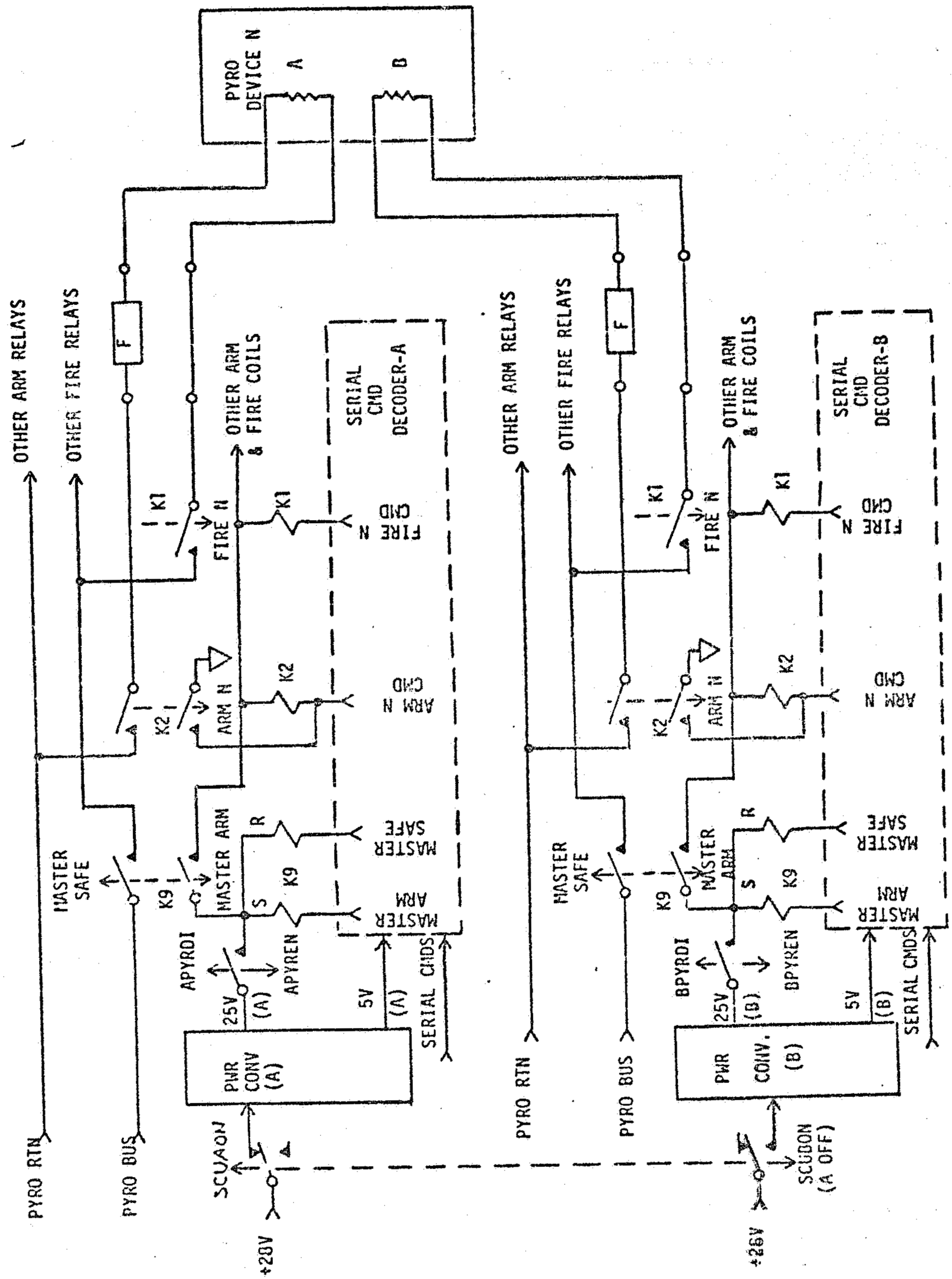

Figure 8.6-5. Functional Schematic for Firing Pyro N

The master arm/safe latching relay (K9 in the figure) requires both SCUAON and APYREN to operate. A master arm command sets K9 and provides +25 V coil power to one side of the arm and fire relay coils for pyro N, and also connects the high (+28 V) side of the pyro bus to the normally open contacts of the pyro N fire relay. The ARM N command provides a momentary ground to one side of the coil of non-latching relay K2. When K2 operates, one set of its contacts is used to hold it closed and another set connects the pyro bus return to one side of the pyro N bridgewire. As evident from Figure 8.6-5, three pre-conditions are required in order to execute the ARM N command. These are: SC&CU A must be on, A side pyros must be enabled, and a master arm command must have been executed. Removal of any one of the three conditions will cause K2 to drop out (by removing +25 V coil power) which will place K2 in the safe condition. This can be accomplished by either a master safe command or APYRDI or SCUBON.

The FIRE N command requires all the pre-conditions for the ARM N command plus execution of the ARM N command in order to fire pyro N. The FIRE N command operates non-latching relay K1 causing the high (+28 V) side of the pyro bus to be connected through a fusistor to one side of the pyro N bridgewire for the duration of the fire pulse. Since the other side of the bridgewire had been connected to the pyro bus return by the ARM N command, the bridgewire will fire causing pyro N to fire.

Figure 8.6-6 is a logic diagram using AND gates to indicate prerequisites for firing of individual pyro devices within a group. If the output of any gate is a 0, the device will not be fired.

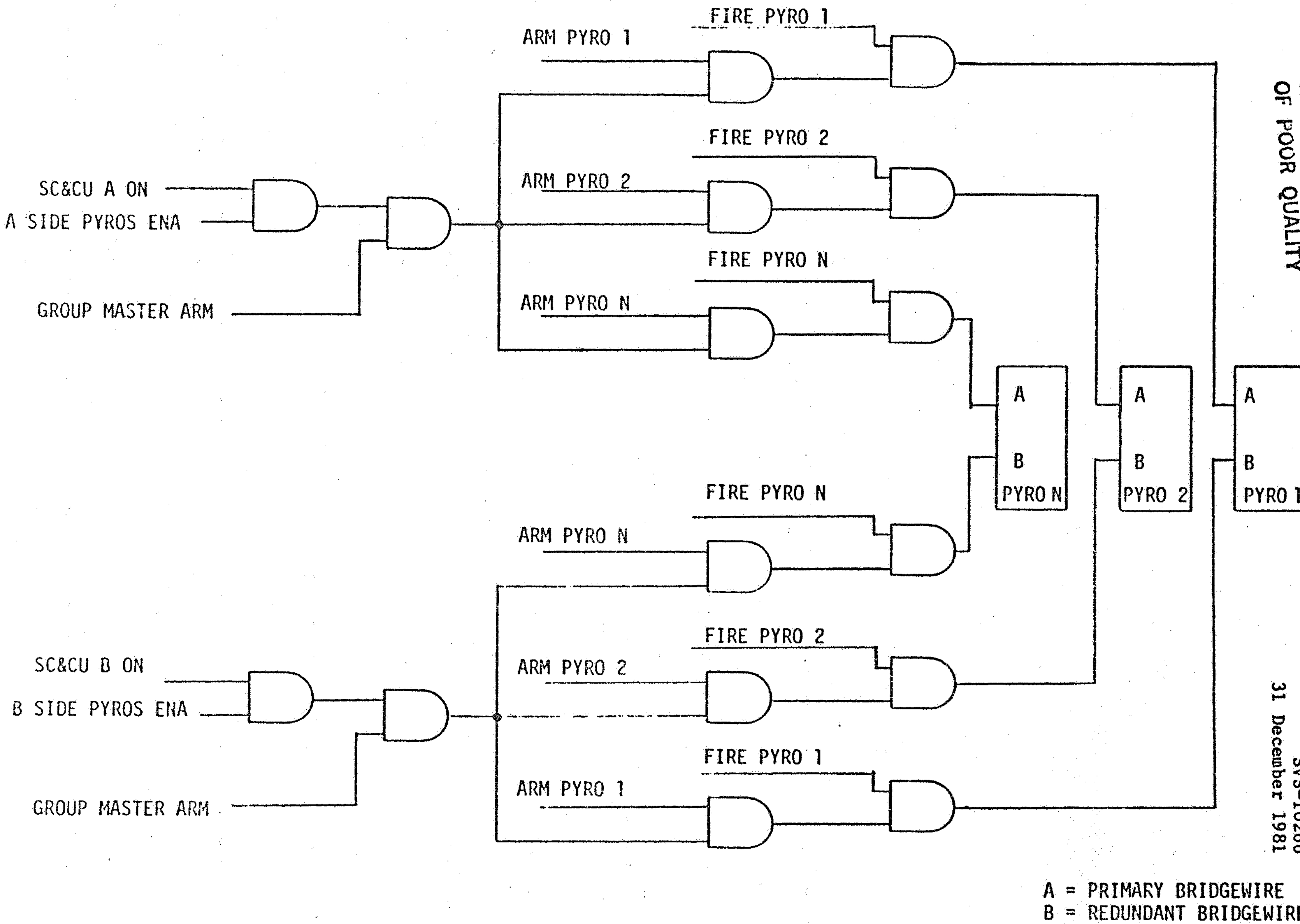

Figure 8.6-6 Pyro Control Logic Diagram for One [illegible]

8.6.1.5.2 Solar Array Deploy Pyro Commands

The stowed solar array is secured by four retention/release pyro devices during launch. Locations of the devices, designated array deploy pyros 1 through 4, are shown in Figure 8.6-7. The SC&CU is configured to fire the pyros, before the array is deployed, in two sets. The primary and redundant bridgewires of pyros 1 and 2 are fired as set 1, and the primary and redundant bridgewires of pyros 3 and 4 are fired as set 2. Either or both sets may be fired from either the SC&CU A side or B side; the same bridgewires are fired from both sides. For the following command descriptions, SCUAON and APYREN are prerequisites for arming and firing from the A side, and SCUBON and BPYREN are prerequisites for arming and firing from the B side.

The array deploy pyro group master arm function is provided by either of the commands ADMARM and ADRARM, where ADRARM is a backup command for use in the event ADMARM fails to execute. Both commands perform the same function, setting relay K9 in Figure 8.6-5.

The master safe function is provided by either of the commands ADMSAF and ADRSAF (backup safe command) where either command resets K9, placing all arm relays in the group in the safe condition.

AD1ARM provides the arm function for the primary and redundant bridgewires of array deploy pyros 1 and 2 as described for the ARM N command in Paragraph 8.6.1.5.1, and AD1FIRE causes the four bridgewires to fire the pyros. Similarly, AD2ARM provides the arm function for the four bridgewires of pyros 3 and 4, and AD2FIRE causes the four bridgewires to fire the pyros. Both fire commands are required to release the array retention devices prior to deploying the solar array.

Figure 8.6-8 is a logic diagram indicating prerequisites for firing the array deploy pyros. The diagram illustrates that all pyros can be fired from either the SC&CU A or B side.

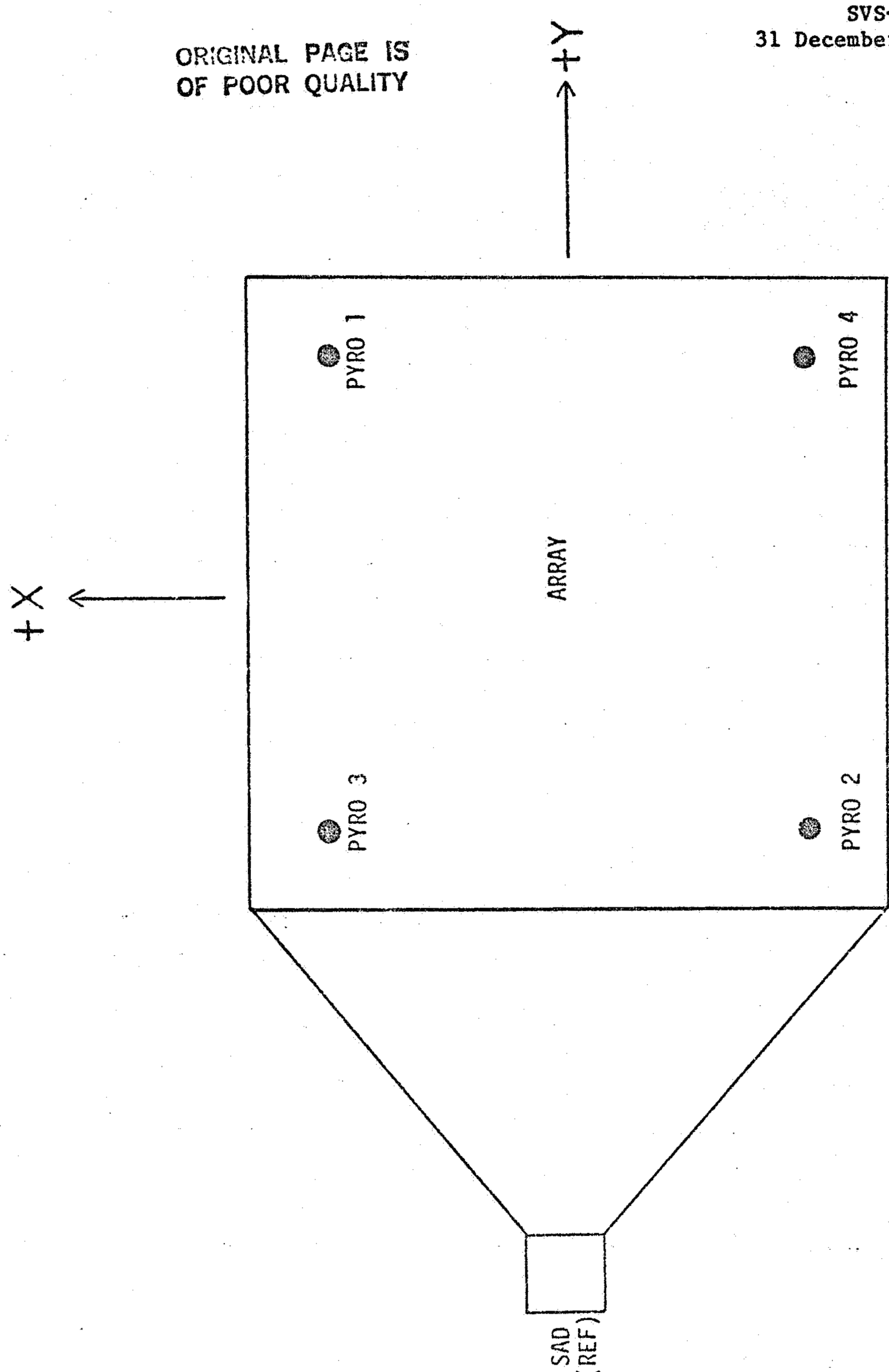

Figure 8.6-7. Solar Array Retention/Release Device Locations

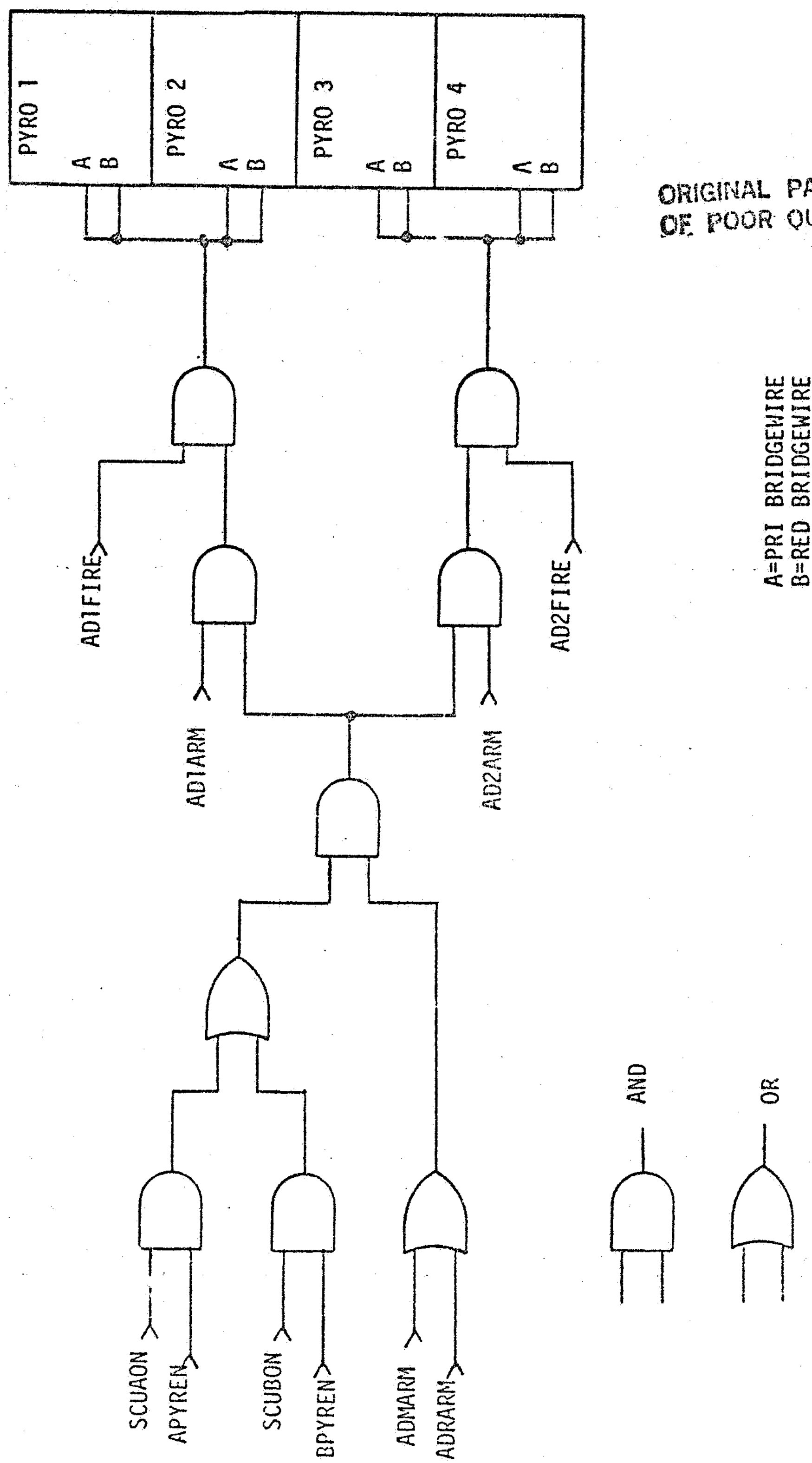

Figure 8.6-8. Solar Array Deploy Pyro Logic Diagram

8.6.1.5.3 Antenna Deploy Pyro Commands

The stowed TDRSS antenna boom is secured during launch by a retention/release pyro device identified as the boom unlatch pyro. In addition, the antenna gimbal drive assembly (GDA) is secured by two devices identified as GDA launch lock pyros 1 and 2. The boom unlatch pyro must be fired to allow deployment of the antenna boom, and the GDA launch lock pyros must be fired to release the antenna gimbal assembly before initiating antenna positioning maneuvers. The primary bridgewires of each pyro device can be fired only from the SC&CU A side, and the redundant bridgewires only from the SC&CU B side. SCUAON and APYREN are prerequisites for arming/firing pyros from the A side, and SCUBON and BPYREN are prerequisites for arming/firing from the B side.

The master arm function for the antenna deploy pyro group is provided by either the BDMARM or BDRARM command, where BDRARM is a backup command for use in the event BDMARM does not execute. Either command sets relay K9 in Figure 8.6-5.

The master safe function is provided by either the BDMSAF or BDRSAF (backup safe) command which resets K9, placing all arm relays in the group in the safe condition.

BUNLARM provides the arm function for one bridgewire of the boom unlatch pyro as described for the ARM N command in Paragraph 8.6.1.5.1, and BUNFIRE causes the bridgewire to fire the pyro. Similarly, GIM1ARM and GIM1FIRE arm and fire GDA launch lock pyro 1, and GIM2ARM and GIM2FIRE arm and fire GDA launch lock pyro 2. The antenna deploy pyro group has provisions for control of a spare pyro device which is not connected on Landsat but the commands, BSPARM and BSPFIRE, can be executed by the SC&CU.

Figure 8.6-9 is a logic diagram indicating prerequisites for firing the antenna deploy pyros. Note that primary (A) bridgewires are fired from the SC&CU A side and redundant bridgewires from the B side.

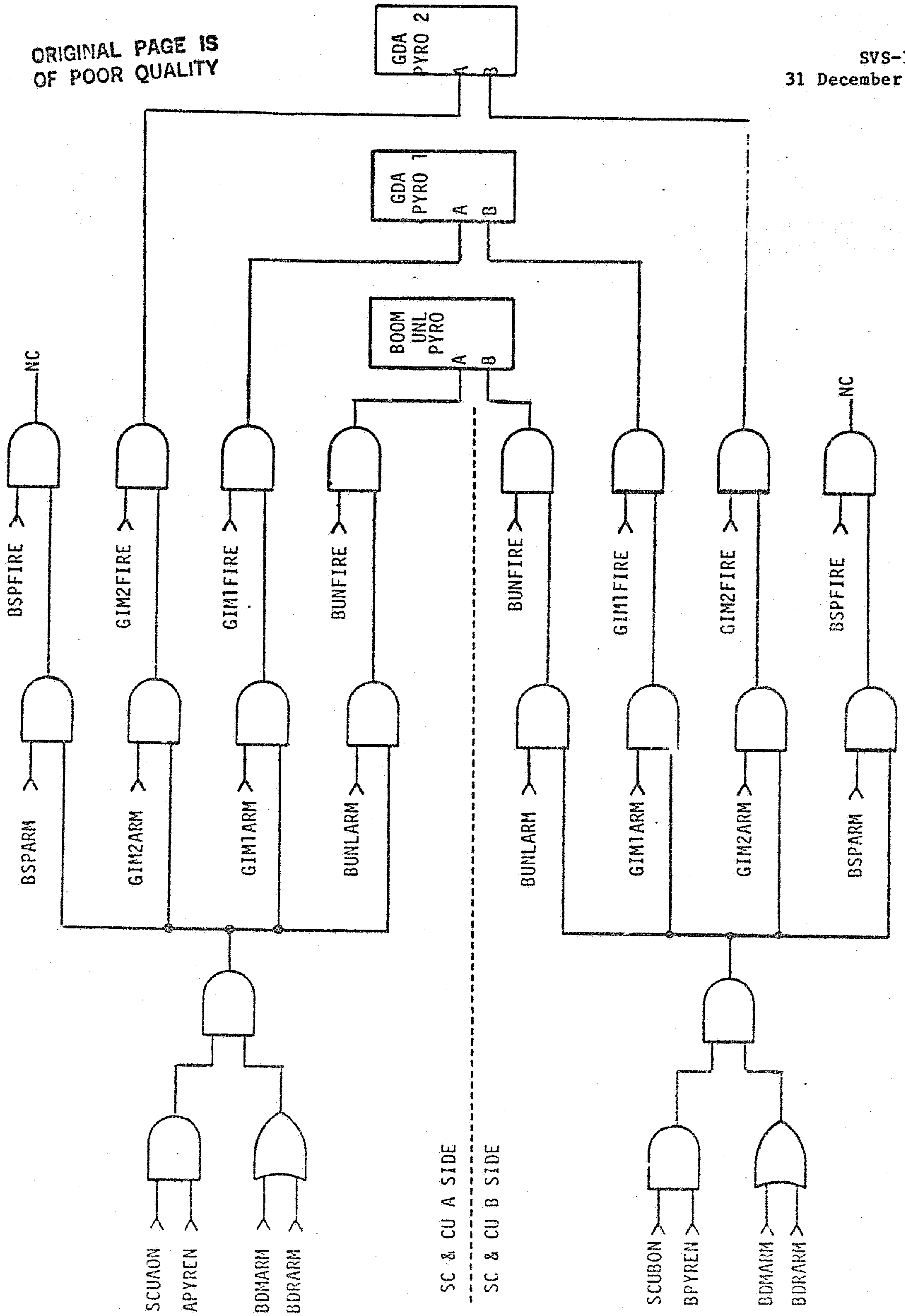

Figure 8.6-9. Antenna Deploy Pyro Logic Diagram

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8.6.1.5.4 Antenna Jettison Pyro Commands

The TDRSS antenna boom with its appendages can be jettisoned in preparation for recovery of the spacecraft by the Space Shuttle. Mechanical and electrical separation of the boom from the spacecraft is accomplished by a pyro device identified as the boom jettison pyro. Wires to the GDA launch lock pyros (Paragraph 8.6.1.5.3) are not routed through the boom disconnect connector in order to assure the safety and integrity of these devices. These wires must be severed, prior to firing the boom jettison pyro, by the cable cutter pyro device.

The master arm function for the antenna jettison pyro group is provided by either the BJMARM or BJRARM command, where BJRARM is a backup command for use in the event BJMARM fails to execute. Either command sets relay K9 in Figure 8.6-5.

The master safe function is provided by either the BJMSAF or BJRSAF (backup safe) command which resets K9, placing all arm relays in the group in the safe condition.

CCUTARM provides the arm function for one bridgewire of the cable cutter pyro as described for the ARM N command in Paragraph 8.6.1.5.1, and CCUTFIRE causes the pyro to fire. These commands should be executed before arming and firing the boom jettison pyro. JETARM and JETFIRE arm and fire the boom jettison pyro initiating separation of the antenna boom from the spacecraft. The antenna jettison pyro group has provisions for control of two spare pyro devices which are not connected on Landsat but the commands JSP1ARM, JSP1FIRE, JSP2ARM and JSP2FIRE can be executed by the SC&CU.

Figure 8.6-10 is a logic diagram indicating prerequisites for firing the antenna jettison pyros. Note that primary bridgewires are fired from the SC&CU A side and redundant bridgewires from the B side.

8.6.1.5.5 Hardline Jettison Control

Recovery of the Landsat spacecraft by the Space Shuttle requires that the TDRSS antenna boom and the solar array be jettisoned from the spacecraft. The Shuttle is equipped to fire three jettison pyro devices via a Landsat/Shuttle interface connector. The three devices are the cable cutter and boom jettison pyros (Paragraph 8.6.1.5.4) and a solar array jettison pyro.

These hardline jettison control signals are routed through relays in the SC&CU to the pyros. Each pyro is individually fired by the Shuttle by either a primary fire signal which fires the pyro primary bridgewire, or a redundant fire signal which fires the redundant bridgewire. Figure 8.6-11 is a simplified schematic depicting a typical hardline jettison signal interface for one pyro device.

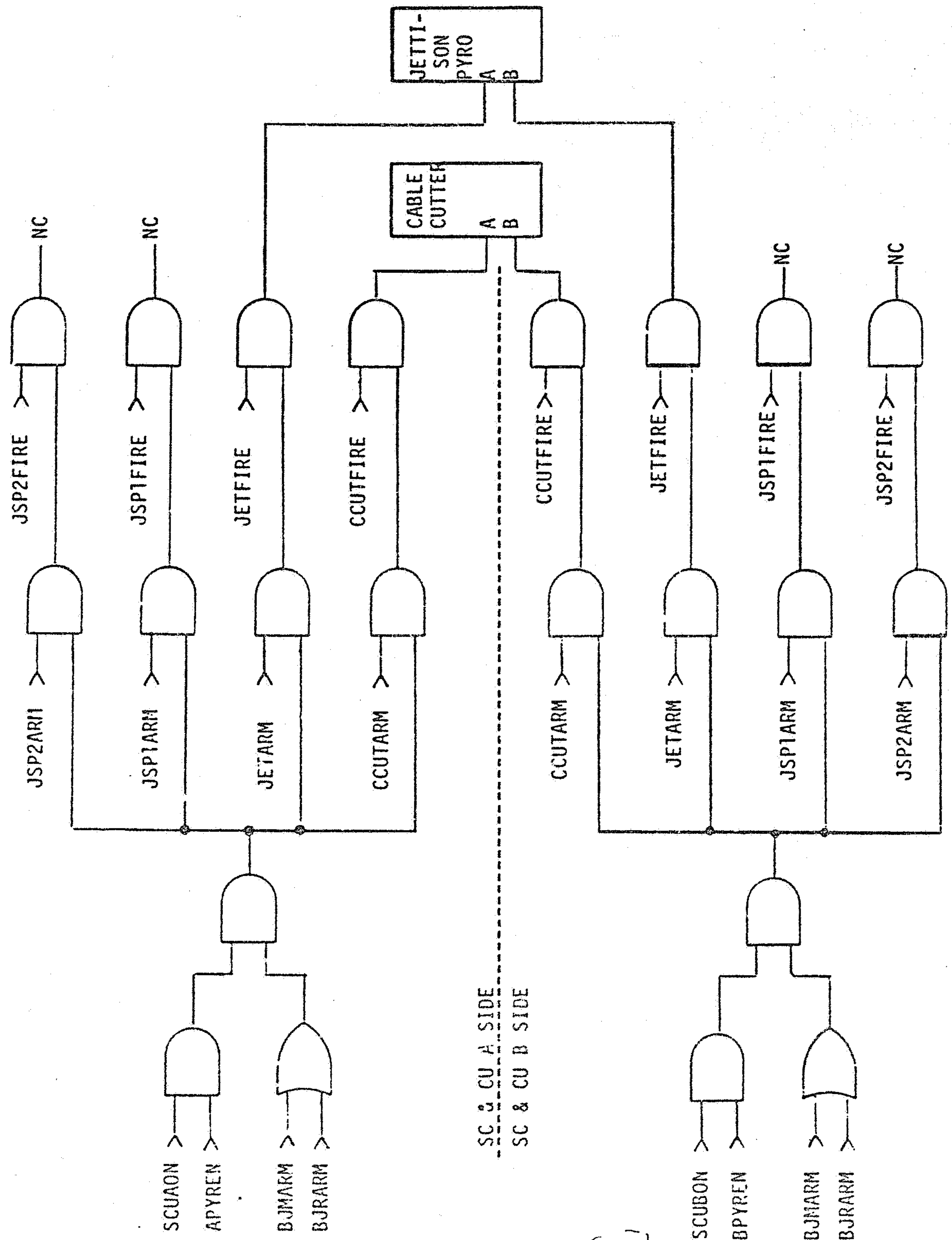

Figure 8.6-10. Antenna Jettison Pyro Logic Diagram

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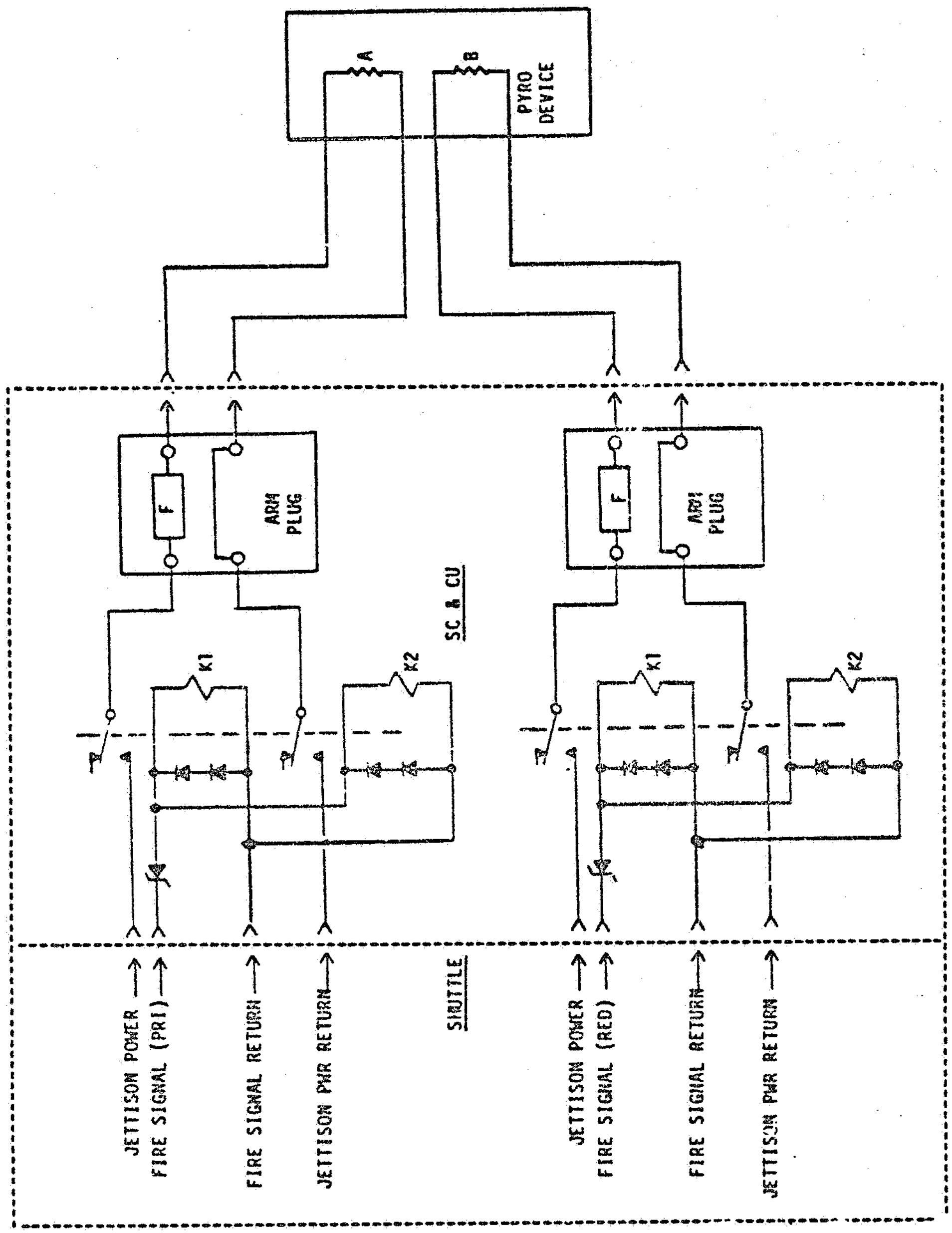

Figure 8.6-11. Simplified Hardline Jettison Pyro Control Circuit

The cable cutter and antenna jettison pyros controlled by Shuttle commands are the same pyros which are fired using the spacecraft commands in Paragraph 8.6.1.5.4. The Shuttle commands are intended for use only if the spacecraft commands fail to jettison the antenna boom prior to spacecraft capture by the Shuttle.

The solar array jettison pyro can only be fired by the Shuttle. This precludes inadvertent jettisoning of the solar array by spacecraft commands, which would be catastrophic to the Landsat mission.

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8.6.2 COMMAND SEQUENCES

8.6.2.1 RIU Switchover

To switch from the active RIU to its mate, the following commands should be sent to the off RIU:

SRIUEN
RIUSB2

8.6.2.2 Pyro Firing Sequences

In general, pyro devices are fired as part of deployment sequences. The planned sequence of events after spacecraft separation from the booster is listed below.

Fire array deploy pyros
Deploy array
Fire boom unlatch pyro
Deploy boom
Fire GDA launch lock pyros

The planned sequence of events for a Shuttle recovery of the spacecraft is listed below:

Fire cable cutter pyro
Fire boom jettison pyro
Spacecraft capture by Shuttle
Shuttle fire array jettison pyro

8.6.2.2.1 Solar Array Deploy Pyros

- If SC&CU A is on
  APYREN
- If SC&CU B is on
  BPYREN
  ADMARM or ADRARM
  AD1ARM
  AD1FIRE
  AD2ARM
  AD2FIRE
  ADMSAF or ADRSAF
- If SC&CU A is on
  APYRDI
- If SC&CU B is on
  BPYRDI
- Deploy solar array

8.6.2.2.2 Antenna Deploy Pyros

- If SC&CU A is on
  APYREN
- If SC&CU B is on
  BPYREN
  BDMARM or BDRARM
  BUNLARM
  BUNFIRE
  BDMSAF or BDRSAF
- If SC&CU A is on
  APYRDI
- If SC&CU B is on
  BPYRDI
- Deploy TDRSS antenna boom

After the boom is deployed:

- If SC&CU A is on
  APYREN
- If SC&CU B is on
  BPYREN
  BDMARM or BDRARM
  GIM1ARM
  GIM1FIRE
  GIM2ARM
  GIM2FIRE
  BDMSAF or BDRSAF
- If SC&CU A is on
  APYRDI
- If SC&CU B is on
  BPYRDI

TDRSS antenna positioning maneuvers can now be initiated.

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8.6.2.2.3 Antenna Jettison Pyros

- If SC&CU A is on
  APYREN
- If SC&CU B is on
  BPYREN
  BJMARM or BJRARM
  CCUTARM
  CCUTFIRE
  JETARM
  JETFIRE
  BJMSAF or BJRSAF
- If SC&CU A is on
  APYRDI
- If SC&CU B is on
  BPYRDI

8.6.3 COMMAND RESTRAINTS

8.6.3.1 Serial Magnitude Command Restraints

The time between execution of SC&CU serial commands should be 128 milliseconds or greater.

8.6.3.2 Pyro Command Restraints

Pyros will not fire unless all prerequisites are satisfied. The command sequences in Paragraph 8.6.2.2 have been chosen to ensure that prerequisite commands are executed in the correct order.

When jettisoning the TDRSS antenna boom, the cable cutter pyro should be fired before the boom jettison pyro is fired.

8.6.3.3 RIU Restraints

The backup mate off command (MRIUDI) should be addressed only to a RIU in the Standby 2 state.

8.7 SC&CU TELEMETRY

Operation of the SC&CU is monitored via 32 telemetry channels from RIU 4 of which 4 are active analog, 9 are passive (conditioned) analog requiring a 1 milliampere source from the RIU, 10 are bilevel digital, and 9 are serial digital. In addition, RIU 4 provides 16 active analog channels for ESAM telemetry function, and 1 serial digital and 13 passive analog channels for PM-1A telemetry functions.

All telemetry monitors are listed in Table 8.7-1 by function name and acronym. The ESAM and PM-1A monitors are included for information only. Descriptions for those functions are provided in Sections 3.7 and 7.7 respectively.

In Table 8.7-1 signal types are designated ALOG for active analog, PASS for passive analog, S for serial digital, and B for bilevel digital functions. The numbers associated with the S and B notations indicate bit numbers of the 8-bit digital word (where bit 0 is the MSB). SMPL RATE defines the number of times a function is sampled in a telemetry major frame. Telemetry matrix locations for all functions are the same in both the Mission and Engineering telemetry formats.

Telemetry function descriptions are shown in Paragraph 8.7.1 and 8.7.2; telemetry derivation circuits for selected functions are presented in Paragraph 8.7.3.

8.7.1 ANALOG TELEMETRY FUNCTIONS

The SC&CU utilizes 13 analog telemetry channels of which 9 are passive outputs providing temperature indications. Passive analog outputs are unpowered except during sampling, at which time the RIU provides a 1 milliampere current source to the passive channel as the output is sampled. Active analog channels are energized by the SC&CU power supplies, rather than the RIU.

This section presents analog telemetry descriptions using the acronyms in Table 8.7-1. Where possible, monitors have been collected into functional groups for ease in understanding.

Operating limits appear in Table 8.7-2. The limits shown were selected for warning of potential problems during ground test environments. In orbital operation, the telemetry functions should remain well within these limits.

Telemetry derivation circuits for selected analog functions are presented in Paragraph 8.7.3. For information regarding calibration curves for the telemetered functions, see Appendix A 3.

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Table 8.7-1. SC&CU Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
	PAYLOAD HEATER STATUS:						
SC/CU-01	NOT USED (DIGITAL 1)	---	SO-1	96,04	1	04-00	8.7.2.2.1
	USS HEATER 1 A ENA/DISA	USS1AHTR	S--2	96,04	1		
	USS HEATER 1 B ENA/DISA	USS1BHTR	S--3	96,04	1		
	USS HEATER 1 THERMOSTAT BYPASS/ENA	USS1THT	S--4	96,04	1		
	DASB RAD PRIMARY HTR ENA/DISA	USBHTRA	S--5	96,04	1		
	DASB RAD REDUNDANT HTR ENA/DISA	USBHTRB	S--6	96,04	1		
	DASB RAD HTR THERMOSTAT BYPASS/ENA	USBTHT	S--7	96,04	1		
SC/CU-02	NOT USED (DIGITAL 1)	---	SO-1	97,04	1	04-01	8.7.2.2.1
	TM/MA PRIMARY HTR ENA/DISA	UTMMAHA	S--2	97,04	1		
	TM/MA REDUNDANT HTR ENA/DISA	UTMMAHB	S--3	97,04	1		
	TM/MA HTR THERMOSTAT BYPASS/ENA	UTMMATH	S--4	97,04	1		
	MSS I/F A PRIMARY HTR ENA/DISA	UMSAHTA	S--5	97,04	1		
	MSS I/F A REDUNDANT HTR ENA/DISA	UMSAHTB	S--6	97,04	1		
	MSS I/F A HTR THERMOSTAT BYPASS/ENA	UMSATHT	S--7	97,04	1		
SC/CU-03	NOT USED (DIGITAL 1)	---	SO-1	98,04	1	04-02	8.7.2.2.1
	WB MOD I/F PRIMARY HTR ENA/DISA	UWBHTRA	S--2	98,04	1		
	WB MOD I/F REDUNDANT HTR ENA/DISA	UWBHTRB	S--3	98,04	1		
	WB MOD I/F HTR THERMOSTAT BYPASS/ENA	UWBTHT	S--4	98,04	1		
	USS HEATER 2 A ENA/DISA	USS2AHTR	S--5	98,04	1		
	USS HEATER 2 B ENA/DISA	USS2BHTR	S--6	98,04	1		
	USS HEATER 2 THERMOSTAT BYPASS/ENA	USS2THT	S--7	98,04	1		
SC/CU-04	NOT USED (DIGITAL 1)	---	SO-1	96,71	1	04-04	8.7.2.2.1
	TM SAFEHOLD HTR 1 ENA/DISA	UTMHTR1	S--2	96,71	1		
	TM SAFEHOLD HTR 2 ENA/DISA	UTMHTR2	S--3	96,71	1		
	TM S/H HTR THERMOSTAT BYPASS/ENA	UTMTHT	S--4	96,71	1		
	PAYLOAD HTR 8 PRIMARY ENA/DISA	UPL8AHTR	S--5	96,71	1		
	PAYLOAD HTR 8 REDUNDANT ENA/DISA	UPL8BHTR	S--6	96,71	1		
	PAYLOAD HTR 8 THERMOSTAT BYPASS/ENA	UPL8THT	S--7	96,71	1		

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Table 8./-1. SC&CU Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
	S/C HEATER STATUS:						
SC/CU-05	NOT USED (DIGITAL 1)	---	S0-1	97,71	1	04-05	8.7.2.2.1
	S/C HEATER 1 ENA/DISA	USCHTR1	S--2	97,71	1		
	S/C HEATER 1 THERMOSTAT BYPASS/ENA	USC1THT	S--3	97,71	1		
	S/C HEATER 2 ENA/DISA	USCHTR2	S--4	97.71	1		
	S/C HEATER 2 THERMOSTAT BYPASS/ENA	USC2THT	S--5	97.71	1		
	S/C HEATER 3 ENA/DISA	USCHTR3	S--6	97.71	1		
	S/C HEATER 3 THERMOSTAT BYPASS/ENA	USC3THT	S--7	97,71	1		
SC/CU-06	NOT USED (DIGITAL 1)	---	S0-1	98,71	1	04-06	8.7.2.2.1
	S/C HEATER 4 ENA/DISA	USCHTR4	S--2	98,71	1		
	S/C HEATER 4 THERMOSTAT BYPASS/ENA	USC4THT	S--3	98,71	1		
	S/C HEATER 5 ENA/DISA	USCHTR5	S--4	98,71	1		
	S/C HEATER 5 THERMOSTAT BYPASS/ENA	USC5THT	S--5	98,71	1		
	S/C HEATER 6 ENA/DISA	USCHTR6	S--6	98,71	1		
	S/C HEATER 6 THERMOSTAT BYPASS/ENA	USC6THT	S--7	98,71	1		
SC/CU-07	ANTENNA DEPLOY PYRO STATUS:						
	NOT USED (DIGITAL 1)	---	S--0	96,125	1	04-08	8.7.2.2.2
	UNPOWERED SIDE MASTER ARM-ARM/SAFE	UBDUMAS	S--1	96,125	1		
	POWERED SIDE MASTER ARM-ARM/SAFE	UBDPMAS	S--2	96,125	1		
	ANTENNA BOOM UNLATCH PYRO ARM/SAFE	UBDUNL	S--3	96,125	1		
	GIMBAL LOCK RELEASE PYRO 1 ARM/SAFE	UBDGIM1	S--4	96,125	1		
	GIMBAL LOCK RELEASE PYRO 2 ARM/SAFE	UBDGIM2	S--5	96,125	1		
	SPARE PYRO ARM/SAFE	UBDSPAR	S--6	96,125	1		
	ARM PLUG CONTINUITY NO/YES	UBDPLUG	S--7	96,125	1		
SC/CU-08	ARRAY DEPLOY PYRO STATUS:						
	NOT USED (DIGITAL 1)	---	S--0	97,125	1	04-09	8.7.2.2.2
	UNPOWERED SIDE MASTER ARM-ARM/SAFE	UADUMAS	S--1	97,125	1		
	POWERED SIDE MASTER ARM-ARM/SAFE	UADPMAS	S--2	97,125	1		
	SET 1 PYROS 1A & 2B ARM/SAFE	UADST1A	S--3	97,125	1		
	SET 1 PYROS 2A & 1B ARM/SAFE	UADST1B	S--4	97,125	1		
	SET 2 PYROS 3A & 4B ARM/SAFE	UADST2A	S--5	97,125	1		
	SET 2 PYROS 4A & 3B ARM/SAFE	UADST2B	S--6	97,125	1		
	ARM PLUG CONTINUITY NO/YES	UADPLUG	S--7	97,125	1		

Table 8.7-1. SC&CU Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
SC/CU-09	COMMANDABLE JETTISON PYRO STATUS:						
	NOT USED (DIGITAL 1)	---	S--0	98,125	1	04-10	8.7.2.2.2
	UNPOWERED SIDE MASTER ARM-ARM/SAFE	UBJUMAS	S--1	98,125	1		
	POWERED SIDE MASTER ARM-ARM/SAFE	UBJPMAS	S--2	98,125	1		
	GDA CABLE CUTTER PYRO ARM/SAFE	UBJCCUT	S--3	98,125	1		
	BOOM JETTISON PYRO ARM/SAFE	UBJPYRO	S--4	98,125	1		
	SPARE PYRO ARM/SAFE	UBJSPR1	S--5	98,125	1		
	SPARE PYRO ARM/SAFE	UBJSPR2	S--6	98,126	1		
	ARM PLUG CONTINUITY NO/YES	UBJPLUG	S--7	98,125	1		
SC/CU-10	BILEVEL WORD 01:	---					
	SC&CU A ON/OFF	UBOFFAON	B--0	96,17	1	04-32	8.7.2.1.1
	SC&CU B ON/OFF	UAOFFBON	B--1	96,17	1	04-33	8.7.2.1.1
	A SIDE PYROS ENABLED/DISABLED	UASPYRED	B--2	96,17	1	04-34	8.7.2.1.2
	B SIDE PYROS ENABLED/DISABLED	UBSPYRED	B--3	96,17	1	04-35	8.7.2.1.2
	SC&CU HEATER A ENABLED/DISABLED	UHTRAED	B--4	96,17	1	04-36	8.7.2.1.3
	SC&CU THERMOSTAT A BYPASSED/ENABLED	UTHTABE	B--5	96,17	1	04-37	8.7.2.1.3
	SC&CU HEATER B ENABLED/DISABLED	UHTRBED	B--6	96,17	1	04-38	8.7.2.1.3
	SC&CU THERMOSTAT B BYPASSED/ENABLED	UTHTBBE	B--7	96,17	1	04-39	8.7.2.1.3
SC/CU-11	BILEVEL WORD 02:	---					
	RIU 04 B ON/A ON	URIUSBA	B--0	96,18	1	04-40	8.7.2.1.4
	RIU 04 MATE STANDBY 1/OFF	UMATENF	B--1	96,18	1	04-41	8.7.2.1.4
SC/CU-12	SC&CU TEMPERATURE	UTSCCU	PASS	96,12	1	04-22	8.7.1.2
SC/CU-13	SPACECRAFT STRUCTURE TEMP 1	UT1MMS	PASS	96,48	1	04-16	8.7.1.3
SC/CU-14	SPACECRAFT STRUCTURE TEMP 2	UT2MMS	PASS	97,48	1	04-17	8.7.1.3
SC/CU-15	SPACECRAFT STRUCTURE TEMP 3	UT3MMS	PASS	98,48	1	04-18	8.7.1.3
SC/CU-16	SPACECRAFT STRUCTURE TEMP 4	UT4MMS	PASS	96,49	1	04-19	8.7.1.3
SC/CU-17	SPACECRAFT STRUCTURE TEMP 5	UT5MMS	PASS	97,49	1	04-20	8.7.1.3
SC/CU-18	SPACECRAFT STRUCTURE TEMP 6	UT6MMS	PASS	98,49	1	04-21	8.7.1.3
SC/CU-19	RIU 04A TEMPERATURE	UTRIUA	PASS	96,89	1	04-24	8.7.1.2
SC/CU-20	RIU 04B TEMPERATURE	UTRIUB	PASS	96,90	1	04-25	8.7.1.2
SC/CU-21	SC&CU +5 V A POWER	U5VAPWR	ALOG	98,15	1	04-42	8.7.1.1
SC/CU-22	SC&CU +25 V A POWER	U25VAPW	ALOG	98,79	1	04-43	8.7.1.1
SC/CU-23	SC&CU +5V B POWER	U5VBPWR	ALOG	97,46	1	04-44	8.7.1.1
SC/CU-24	SC&CU +25V B POWER	U25VBPW	ALOG	96,94	1	04-45	8.7.1.1

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Table 8.7-1. SC&CU Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
	PM-1A TELEMETRY FUNCTIONS:						
PM-45	PM-1A HEATER STATUS:					04-03	8.7.2.2.1
	NOT USED (DIGITAL 1)	---	S--0	32,64	1		
	NOT USED (DIGITAL 1)	---	S--1	32,64	1		
	PM-1A PRI TANK HTR ENA/DISA	ZPRTKHT	S--2	32,64	1		
	PM-1A PRI LINE HTR ENA/DISA	ZPRLNHT	S--3	32,64	1		
	PM-1A LINE HTR THMSTAT BYP/ENA	ZPRLNTH	S--4	32,64	1		
	PM-1A RED TANK HTR ENA/DISA	ZBUTKHT	S--5	32,64	1		
	PM-1A RED LINE HTR ENA/DISA	ZBULNHT	S--6	32,64	1		
	PM-1A TANK HTR THMSTAT BYP/ENA	ZBULNTH	S--7	32,64	1		
PM-48	PM-1A TANK TEMPERATURE	ZT1ATNK	PASS	96,64	1	04-26	7.7
PM-49	PM-1A FUEL TEMPERATURE	ZT1AFUL	PASS	97,64	1	04-27	7.7
PM-50	PM-1A LINE TEMPERATURE	ZT1ALIN	PASS	98,70	1	04-28	7.7
	ESAM TELEMETRY FUNCTIONS:						
ESAM-01	ESA-1 PITCH FINE ERROR	EES1YF	ALOG	8	128	04-48	3.7
ESAM-05	ESA-2 PITCH FINE ERROR	EES2YF	ALOG	9	128	04-52	3.7
ESAM-02	ESA-1 PITCH COARSE ERROR	EES1YC	ALOG	40	128	04-49	3.7
ESAM-06	ESA-2 PITCH COARSE ERROR	EES2YC	ALOG	41	128	04-53	3.7
ESAM-03	ESA-1 ROLL FINE ERROR	EES1XF	ALOG	72	128	04-50	3.7
ESAM-07	ESA-2 ROLL FINE ERROR	EES2XF	ALOG	73	128	04-54	3.7
ESAM-04	ESA-1 ROLL COARSE ERROR	EES1XC	ALOG	104	128	04-51	3.7
ESAM-08	ESA-2 ROLL COARSE ERROR	EES2XC	ALOG	105	128	04-55	3.7
ESAM-09	ESA-1 SIGNAL STATUS	EES1SIG	ALOG	38	128	04-59	3.7
ESAM-10	ESA-2 SIGNAL STATUS	EES2SIG	ALOG	102	128	04-62	3.7
ESAM-11	ESA-1 SENSOR STATUS	EES1SEN	ALOG	99,06	4	04-57	3.7
ESAM-12	ESA-2 SENSOR STATUS	EES2SEN	ALOG	99,22	4	04-58	3.7
ESAM-13	ESA-1 TEMPERATURE	EES1TMP	ALOG	33,44	1	04-56	3.7
ESAM-14	ESA-2 TEMPERATURE	EES2TMP	ALOG	33,46	1	04-63	3.7
ESAM-15	ESA-1 BOLOMETER TEMPERATURE	EES1BTMP	ALOG	33,47	1	04-60	3.7
ESAM-16	ESA-2 BOLOMETER TEMPERATURE	EES2BTMP	ALOG	33,48	1	04-61	3.7

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Table 8.7-2. SC&CU Analog Telemetry Limits

Function	Mode	Limits	Units
UTSCCU	S/C ON	0 TO 35	DEG C
UT1MMS	S/C ON	5 TO 30	DEG C
UT2MMS	S/C ON	5 TO 30	DEG C
UT3MMS	S/C ON	5 TO 30	DEG C
UT4MMS	S/C ON	5 TO 30	DEG C
UT5MMS	S/C ON	5 TO 30	DEG C
UT6MMS	S/C ON	5 TO 30	DEG C
UTRIUA	S/C ON	0 TO 35	DEG C
UTRIUB	S/C ON	0 TO 35	DEG C
U5VAPWR	SCUAON	5.0 TO 5.3	VOLTS
U5VAPWR	SCUBON	0.0 TO 0.9	VOLTS
U25VAPW	SCUAON	24.5 TO 26.5	VOLTS
U5VBPWR	SCUBON	5.0 TO 5.3	VOLTS
U5VBPWR	SCUAON	0.0 TO 0.9	VOLTS
U25VBPW	SCUBON	24.5 TO 26.5	VOLTS

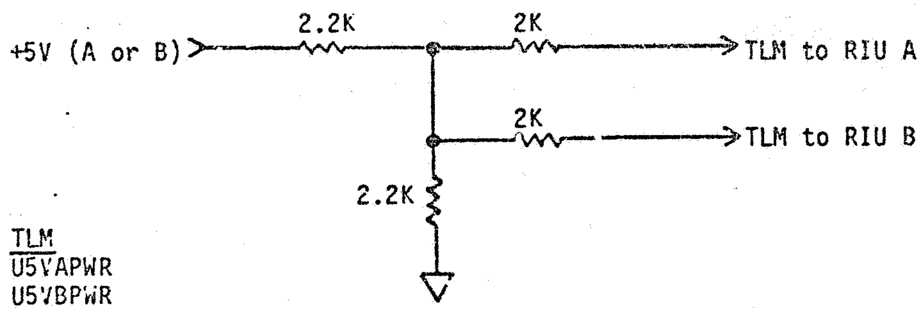

FIGURE 8.7-1. +5V TELEMETRY DERIVATION

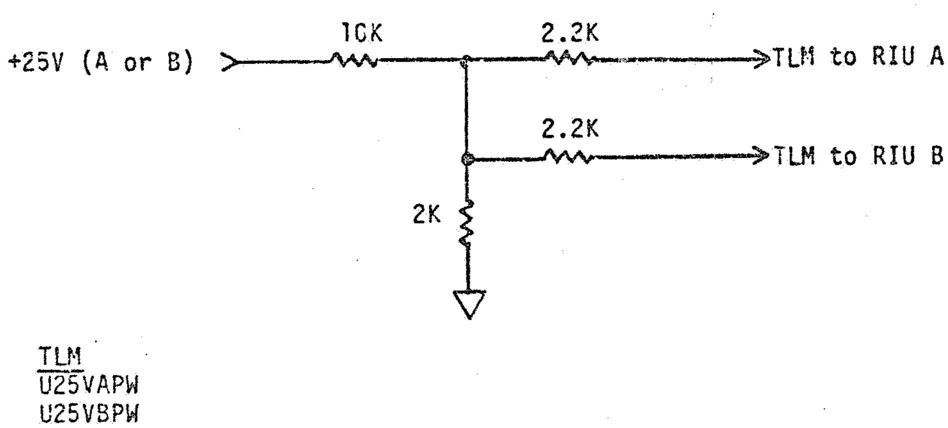

Figure 8.7-2. +25V Telemetry Derivation

8.7.1.1 Power Converter Voltage Monitors

U5VAPWR - SC&CU A +5 V regulated voltage
U25VAPW - SC&CU A +25 V regulated voltage
U5VBPWR - SC&CU B +5 V regulated voltage
U25VBPW - SC&CU B +25 V regulated voltage

These telemetry functions monitor the secondary voltage outputs of the SC&CU A side and B side power converters. The A voltages are present when SC&CU A is on and the B voltages are present when SC&CU B is on. Telemetry voltages for the monitors are derived from resistive dividers as shown in Figures 8.7-1 and 8.7-2.

8.7.1.2 Internal Temperature Monitors

UTSCCU - SC&CU module temperature
UTRIUA - RIU 4A temperature
UTRIUB - RIU 4B temperature

These monitors indicate the temperatures derived from sensors located in the SC&CU module. The RIU temperature sensors are inside each RIU and the SC&CU sensor is mounted on an internal surface of the module. Each temperature is derived as shown in Figure 8.7-3.

8.7.1.3 External Temperature Monitors

Six temperature sensors, UT1MMS through UT6MMS, are located on the MMS structure to indicate spacecraft structure temperatures. Shunt resistors are provided within the SC&CU for each thermistor, as shown in Figure 8.7-4, to condition the signals for RIU telemetry channel inputs.

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8.7.2 DIGITAL TELEMETRY FUNCTIONS

The SC&CU digital monitors provide command verification and subsystem status information. This section presents digital telemetry descriptions using the acronyms in Table 8.7-1. Where possible, monitors are collected into functional groups for ease in understanding.

8.7.2.1 Bilevel Digital Telemetry

Bilevel telemetry functions are utilized to verify SC&CU status resulting from execution of discrete commands. Power for these monitors, with the exception of the RIU status indicators, is derived from the Standby 2 voltage (+5.3 V) generated by the RIU which is on, and is independent of which side of the SC&CU is on. The telemetry derivation circuit, shown in Figure 8.7-5, uses contacts of the latching relays controlled by the discrete commands to change the bilevel state.

8.7.2.1.1 SC&CU On/Off Status Monitors

As described in Section 8.6, one side of the SC&CU is always on when the spacecraft is powered. SCUAON turns the A side on and the B side off; SCUBON turns the B side on and the A side off. Two monitors, UBOFFAON and UAOFFBON are used to determine which side is on. They are decoded as shown below.

UBOFFAON 0 = SC&CU A off
1 = SC&CU A on

UAOFFBON 0 = SC&CU B off
1 = SC&CU B on

8.7.2.1.2 Pyro Enable/Disable Status Monitors

UASPYRED and UBSPYRED indicate the status of the pyro enable/disable latching relays. Pyros can not be fired from the SC&CU A side unless the A side pyros are enabled. Conversely, pyros can not be fired from the SC&CU B side unless the B side pyros are enabled. Both sides should be disabled when no pyro firings are being executed. The monitors are decoded as follows.

UASPYRED 0 = A side pyros disabled
1 = A side pyros enabled

UBSPYRED 0 = B side pyros disabled
1 = B side pyros enabled

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8.7.2.1.3 SC&CU Heater Status Monitors

The status of the latching relays which control the SC&CU module primary (A) and redundant (B) heaters is indicated by the monitors UHTRAED, UTHTABE, UHTRBED and UTHTBBE. The monitors are decoded as shown below.

UHTRAED	0 = SC&CU heater A disabled
	1 = SC&CU heater A enabled
UTHTABE	0 = Heater A thermostat enabled
	1 = Heater A thermostat bypassed
UHTRBED	0 = SC&CU heater B disabled
	1 = SC&CU heater B enabled
UTHTBBE	0 = Heater B thermostat enabled
	1 = Heater B thermostat bypassed

8.7.2.1.4 RIU Status Monitors

URIUSBA and UMATENF indicate RIU 4A and 4B status resulting from the RIU control commands of Paragraph 8.6. The monitors are derived as shown in Figure 8.7-6 and are decoded as follows.

URIUSBA	UMATENF	RIU 4A/4B Status
0	0	A ON, B OFF
0	1	A ON, B STANDBY 1
1	0	B ON, A OFF
1	1	B ON, A STANDBY 1

8.7.2.2 Serial Digital Telemetry

The SC&CU outputs ten 8-bit serial digital telemetry words to RIU 4. Four the the words provide payload heater status, two provide spacecraft (MMS) heater status, three provide pyro control status, and the remaining word provides PM-1A heater status. Each side of the SC&CU has a dedicated serial digital telemetry encoder. Thus, when SC&CU A is on the 5 V(A) logic power energizes the A side telemetry encoder which outputs serial telemetry words to the active RIU. Similarly, when SC&CU B is on the 5 V(B) logic power energizes the B side telemetry encoder. As indicated in Paragraph 8.7.2.1.1, one side of the SC&CU is always on and the other side is off. Both sides can not be on or off at the same time.

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8.7.2.2.1 Heater Status Telemetry

Each of the ten heater status telemetry words is derived as shown in Figure 8.7-7. The relay contacts are shown in the logic "0" position and are additional contacts of the relays in Figure 8.6-4. The two most significant bits (MSB) of every heater status word are fixed at logic "1". The six remaining bits of the word are used as bilevel indicators of relay states resulting from heater control commands. Decoding of each word is presented in the following paragraphs. Bits are numbered S-0 (MSB) through S-7 (LSB).

SC/CU-01. Payload Heaters 1,2 Status

Heater 1 = Upper support structure (USS) heater 1
Heater 2 = Direct Access S-Band (DASB) radiator heater

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1		Always digital "1"
S-2	USS1AHTR	0 = USS htr 1A disabled 1 = USS htr 1A enabled
S-3	USS1BHTR	0 = USS htr 1B disabled 1 = USS htr 1B enabled
S-4	USS1THT	0 = USS htr 1 thermostat enabled 1 = USS htr 1 thermostat bypassed
S-5	USBHTRA	0 = DASB htr A disabled 1 = DASB htr A enabled
S-6	USBHTRB	0 = DASB htr B disabled 1 = DASB htr B enabled
S-7	USBTHT	0 = DASB htr thermostat enabled 1 = DASB htr thermostat bypassed

SC/CU-02. Payload Heaters 3,4 Status

Heater 3 = TM/mission adapter (TM/MA) heater
Heater 4 = MSS interface A (MSS I/F A) heater

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1		Always digital "1"
S-2	UTMMAHA	0 = TM/MA primary heater disabled 1 = TM/MA primary heater enabled
S-3	UTMMAHB	0 = TM/MA redundant htr disabled 1 = TM/MA redundant htr enabled
S-4	UTMMATH	0 = TM/MA htr thermostat enabled 1 = TM/MA htr thermostat bypassed

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S-5	UMSAHTA	0 = MSS I/F A primary heater disabled
		1 = MSS I/F A primary heater enabled
S-6	UMSAHTB	0 = MSS I/F A redundant htr disabled
		1 = MSS I/F A redundant htr enabled
S-7	UMSATHT	0 = MSS I/F A htr thermostat enabled
		1 = MSS I/F A htr thermostat bypassed

SC/CU-03. Payload Heaters 5,6 Status

Heater 5 = Wideband Module Interface (WB I/F) heater
Heater 6 = Upper Support Structure (USS) heater 2

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1		Always digital "1"
S-2	UWBHTRA	0 = WB I/F primary heater disabled
		1 = WB I/F primary heater enabled
S-3	UWBHTRB	0 = WB I/F redundant htr disabled
		1 = WB I/F redundant htr enabled
S-4	UWBTHT	0 = WB I/F htr thermostat enabled
		1 = WB I/F htr thermostat bypassed
S-5	USS2AHTR	0 = USS heater 2A disabled
		1 = USS heater 2A enabled
S-6	USS2BHTR	0 = USS heater 2B disabled
		1 = USS heater 2B enabled
S-7	USS2THT	0 = USS htr 2 thermostat enabled
		1 = USS htr 2 thermostat bypassed

SC/CU-04. Payload Heaters 7,8 Status

Heater 7 = Thematic Mapper Safehold (TM S/H) heater
Heater 8 = Not connected to any heater (spare)

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1		Always digital "1"
S-2	UTMHTR1	0 = TM S/H heater 1 disabled
		1 = TM S/H heater 1 enabled
S-3	UTMHTR2	0 = TM S/H heater 2 disabled
		1 = TM S/H heater 2 enabled
S-4	UTMTHT	0 = TM S/H htr thermostat enabled
		1 = TM S/H htr thermostat bypassed
S-5	UPL8AHTR	0 = Heater 8 primary disabled
		1 = Heater 8 primary enabled
S-6	UPL8BHTR	0 = Heater 8 redundant disabled
		1 = Heater 8 redundant enabled

S-7	UPL8THT	0 = Heater 8 thermostat enabled 1 = Heater 8 thermostat bypassed

SC/CU-05. Spacecraft (MMS) Structure Heaters 1,2,3

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1		Always digital "1"
S-2	USCHTR1	0 = MMS heater 1 disabled 1 = MMS heater 1 enabled
S-3	USC1THT	0 = MMS heater 1 thermostat enabled 1 = MMS heater 1 thermostat bypassed
S-4	USCHTR2	0 = MMS heater 2 disabled 1 = MMS heater 2 enabled
S-5	USC2THT	0 = MMS heater 2 thermostat enabled 1 = MMS heater 2 thermostat bypassed
S-6	USCHTR3	0 = MMS heater 3 disabled 1 = MMS heater 3 enabled
S-7	USC3THT	0 = MMS heater 3 thermostat enabled 1 = MMS heater 3 thermostat bypassed

SC/CU-06. Spacecraft Structure Heaters 4,5,6

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1		Always digital "1"
S-2	USCHTR4	0 = MMS heater 4 disabled 1 = MMS heater 4 enabled
S-3	USC4THT	0 = MMS heater 4 thermostat enabled 1 = MMS heater 4 thermostat bypassed
S-4	USCHTR5	0 = MMS heater 5 disabled 1 = MMS heater 5 enabled
S-5	USC5THT	0 = MMS heater 5 thermostat enabled 1 = MMS heater 5 thermostat bypassed
S-6	USCHTR6	0 = MMS heater 6 disabled 1 = MMS heater 6 enabled
S-7	USC6THT	0 = MMS heater 6 thermostat enabled 1 = MMS heater 6 thermostat bypassed

PM-45. PM-1A Heater Status

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1		Always digital "1"
S-2	ZPRTKHT	0 = Primary tank heater disabled 1 = Primary tank heater enabled
S-3	ZPRLNHT	0 = Primary line heater disabled 1 = Primary line heater enabled
S-4	ZPRLNTH	0 = Line heater thermostat enabled 1 = Line heater thermostat bypassed
S-5	ZBUTKHT	0 = Redundant tank heater disabled 1 = Redundant tank heater enabled
S-6	ZBULNHT	0 = Redundant line heater disabled 1 = Redundant line heater enabled
S-7	ZBULNTH	0 = Tank heater thermostat enabled 1 = Tank heater thermostat bypassed

8.7.2.2.2 Pyro Status Telemetry

Each of the three pyro status words is derived as shown in Figure 8.7-8. All relay contacts in the figure are shown in the safe position. The most significant bit (S-0) of every word is fixed at logic "1". Bit S-1 indicates the state of the master safe/arm latching relay on the SC&CU side which is off. Thus if SC&CU A is on bit S-0 indicates the state of the B side master arm/safe relay, and vice versa. The state of the master arm/safe relay of the on side is determined by the level of bit S-2. Bits S-3 through S-6 indicate the position of individual arm relays. Bit S-7 provides a continuity check indicating whether a pyro arm plug, necessary for pyro firing, has been installed. This bit is valid only for the SC&CU side which is on; if SC&CU A is on it indicates the status of the A side pyro arm plug, and if SC&CU B is on it indicates the status of the B side pyro arm plug. Unlike master arm/safe relay status, arm plug status is not transferred between the A and B sides for monitoring purposes. Decoding of each pyro status word is presented in the following paragraphs.

SC/CU-07. Antenna Deploy Pyro Status

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1	UBDUMAS	0 = Unpowered side master safe 1 = Unpowered side master armed
S-2	UBDPMAS	0 = Powered side master safe 1 = Powered side master armed
S-3	UBDUNL	0 = Boom unlatch pyro safe 1 = Boom unlatch pyro armed

S-4	UBDGIM1	0 = GDA launch lock pyro 1 safe 1 = GDA launch lock pyro 1 armed
S-5	UBDGIM2	0 = GDA launch lock pyro 2 safe 1 = GDA launch lock pyro 2 armed
S-6	UBDSPAR	0 = Spare (unused) pyro safe 1 = Spare (unused) pyro armed
S-7	UBDPLUG	0 = Arm plug continuity YES 1 = Arm plug continuity NO

Note that digital "0" indicates SAFE. Therefore when SC/CU-07 = 10000000, all pyro relays are in a safe mode and the arm plug is installed. This is also true for pyro status words SC/CU-08 and SC/CU-09.

SC/CU-08. Solar Array Deploy Pyro Status

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1	UADUMAS	0 = Unpowered side master safe 1 = Unpowered side master armed
S-2	UADPMAS	0 = Powered side master safe 1 = Powered side master armed
S-3	UADST1A	0 = Set 1 pyros 1A & 2B safe 1 = Set 1 pyros 1A & 2B armed
S-4	UADST1B	0 = Set 1 pyros 2A & 1B safe 1 = Set 1 pyros 2A & 1B armed
S-5	UADST2A	0 = Set 2 pyros 3A & 4B safe 1 = Set 2 pyros 3A & 4B armed
S-6	UADST2B	0 = Set 2 pyros 4A & 3B safe 1 = Set 2 pyros 4A & 3B armed
S-7	UADPLUG	0 = Arm plug continuity YES 1 = Arm plug continuity NO

SC/CU -09. Antenna Jettison Pyro Status

Bit	Acronym	Bit State Definition
S-0		Always digital "1"
S-1	UBJUMAS	0 = Unpowered side master safe 1 = Unpowered side master armed
S-2	UBJPMAS	0 = Powered side master safe 1 = Powered side master armed
S-3	UBJCCUT	0 = GDA cable cutter pyro safe 1 = GDA cable cutter pyro armed
S-4	UBJPYRO	0 = Boom jettison pyro safe 1 = Boom jettison pyro armed

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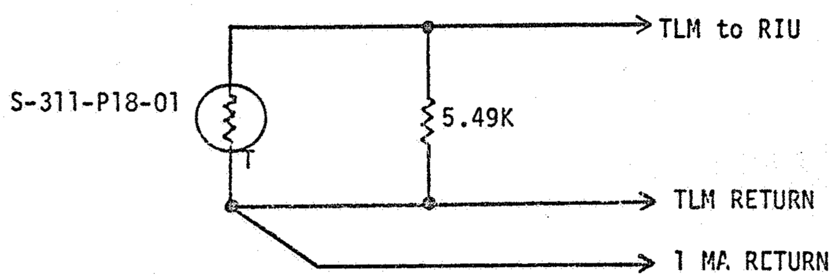
S-5	UBJSPR1	0 = Spare (unused) pyro 1 safe 1 = Spare (unused) pyro 1 armed
S-6	UBJSPR2	0 = Spare (unused) pyro 2 safe 1 = Spare (unused) pyro 2 armed
S-7	UBJPLUG	0 = Arm plug continuity YES 1 = Arm plug continuity NO

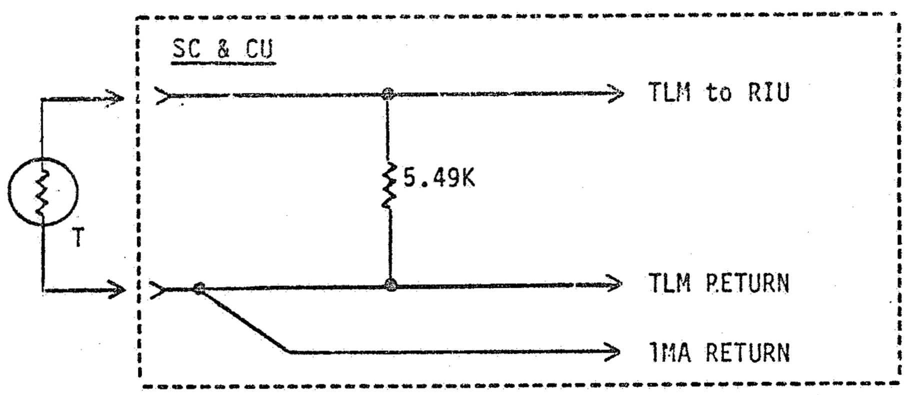
8.7.3 TELEMETRY DERIVATION SCHEMATICS

This section provides functional schematics showing the derivation of the telemetry functions as an aid to understanding the telemetry interface. These functional schematics are provided as information only and are superseded by the exact circuits defined on SC&CU drawings.



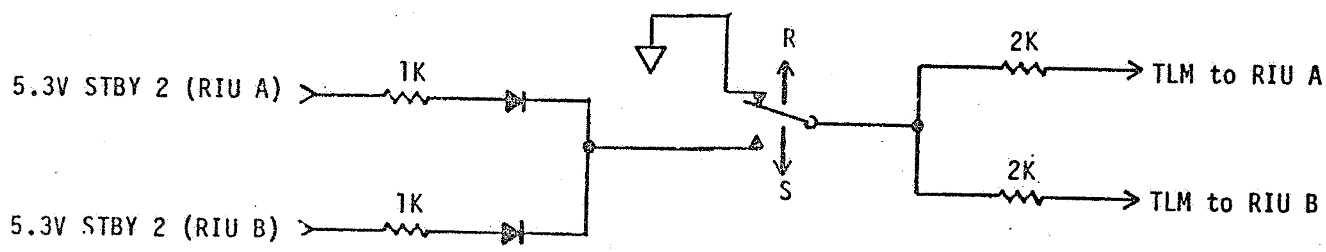
<u>TLM</u>
UTSCCU
UTRIUA
UTRIUB

FIGURE 8.7-3. INTERNAL TEMPERATURE MONITOR DERIVATION



<u>TLM</u>
UT1MMS
UT2MMS
UT3MMS
UT4MMS
UT5MMS
UT6MMS

Figure 8.7-4. External Temperature Monitor Derivation



R = RESET = LOGIC "0"
S = SET = LOGIC "1"

TLM	S	R
UBOFFAON	A ON	A OFF
UAOFFBON	B ON	B OFF
UASPYRED	ENA	DISA
UBSPYRED	ENA	DISA
UHTRAED	ENA	DISA
UTHTABE	BYP	ENA
UHTRBED	ENA	DISA
UTHTBBE	BYP	ENA

Figure 8.7-5. Discrete Command Telemetry Verification

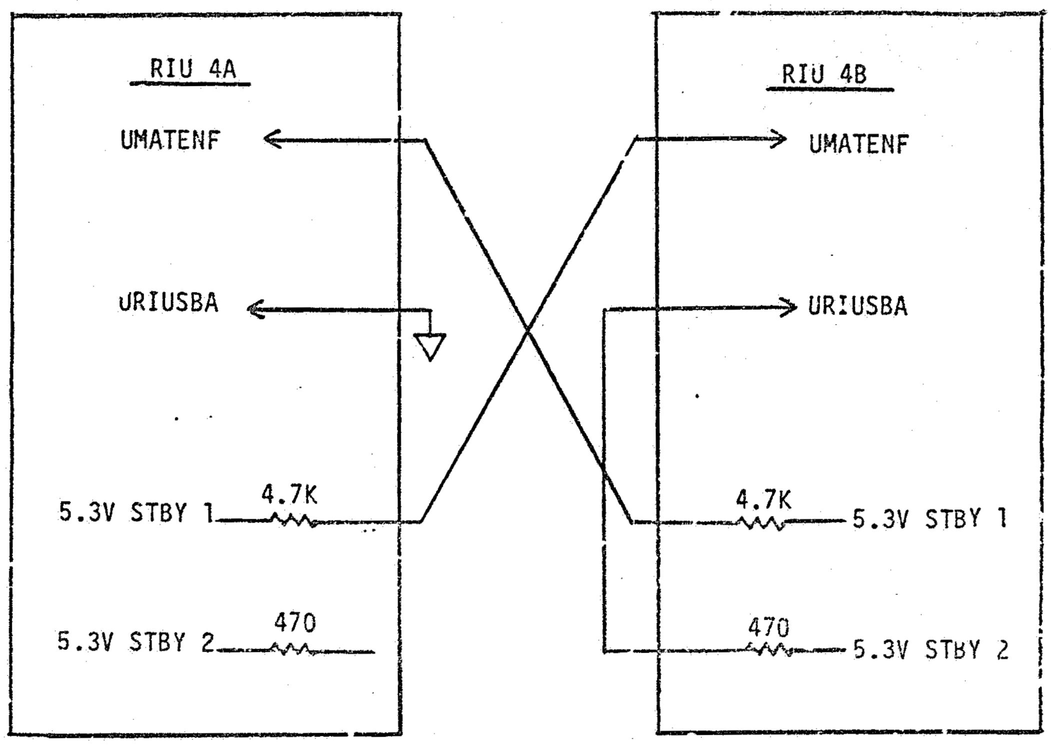


Figure 8.7-6. RIU Status Monitor Derivation

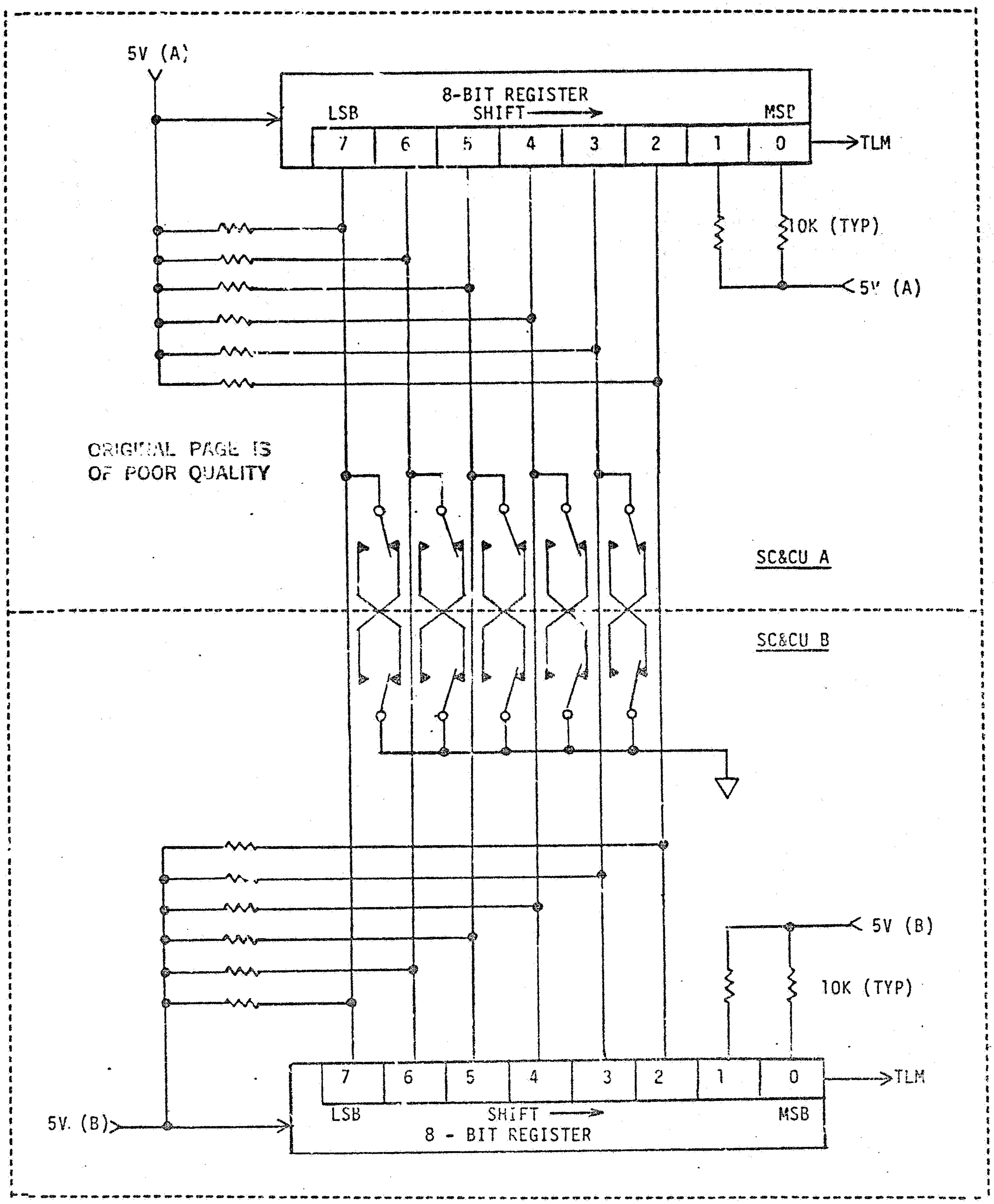


Figure 8.7-7. Heater Status Telemetry Word Derivation

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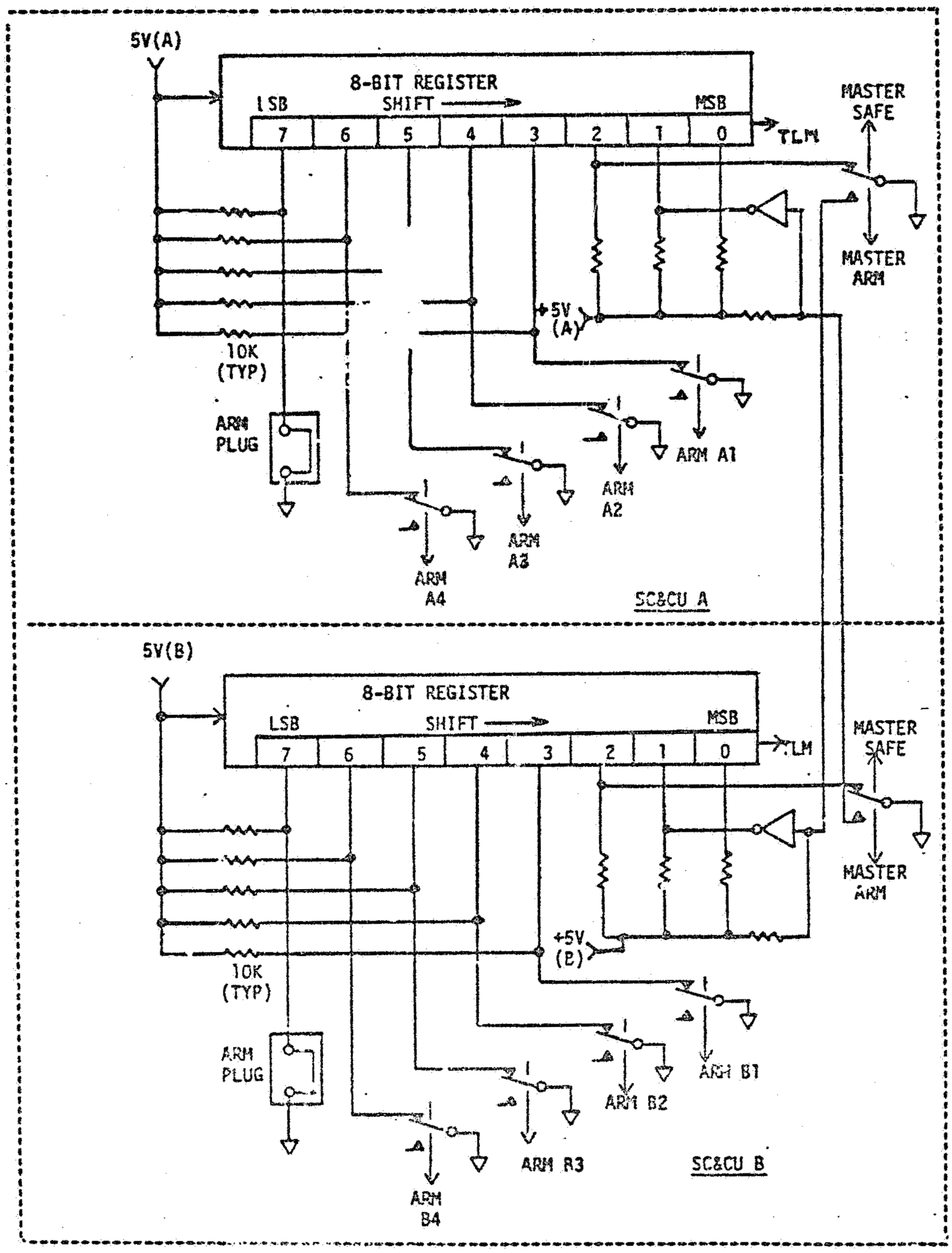

Figure 8.7-8. Pyro Status Telemetry Word Derivation

9.0 MODULAR POWER SUBSYSTEM

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SECTION 9.0

MODULAR POWER SUBSYSTEM

The Modular Power Subsystem (MPS) is one of three functional modules comprising a basic modularized spacecraft referred herein as a Multimission Modular Spacecraft (MMS). The three MMS modules (Figure 9-1), Modular Power Subsystem (MPS), Communication and Data Handling (C&DH) and Modular Attitude Control Subsystem (MACS) are of similar dimensions and construction and are mounted to the module support structure. A smaller module, the Signal Conditioning and Control Unit (SC&CU) provides mission unique circuitry for Landsat-D referred to as spacecraft in this section.

The MMS is configured for the Landsat-D mission by adding an Instrument Module (IM), composed of a payload, a Solar Array (SA), and a high gain antenna.

The MPS receives electrical power from the solar array and conditions, regulates and controls this power for use by the spacecraft. During periods when the solar array is not illuminated, MPS batteries supply spacecraft power. The batteries also supplement solar array power during periods of peak power demand. Spacecraft electrical power requirements vary with each mission (i.e., Thematic Mapper and/or Multispectral Scanner).

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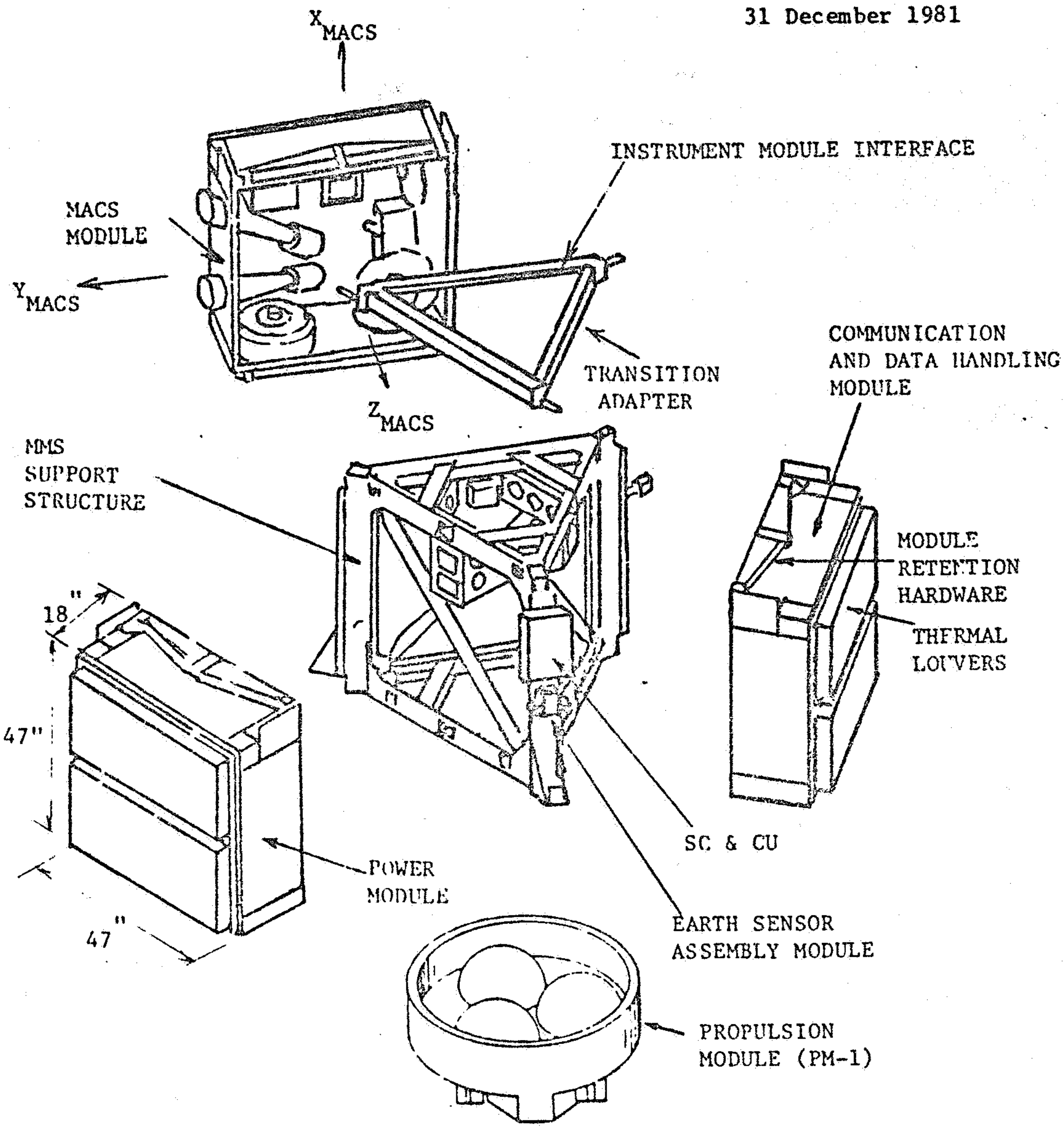

Figure 9-1. MMS Subsystems

9.1 MPS FUNCTIONAL DESCRIPTION

The primary function of the MPS is to provide power to the MMS and its payload. Power is supplied by the MPS through the MPS Module/Spacecraft interface connectors and MMS harness. This harness routes each of the following MPS power outputs to MMS modules and Instrument Module:

1. MACS Module Power
2. C&DH Module Power
3. SC&CU Module Power
4. Propulsion/Actuation Module Power
5. Instrument Module Power (Payload)

Figure 9-2 is a functional description of the modules.

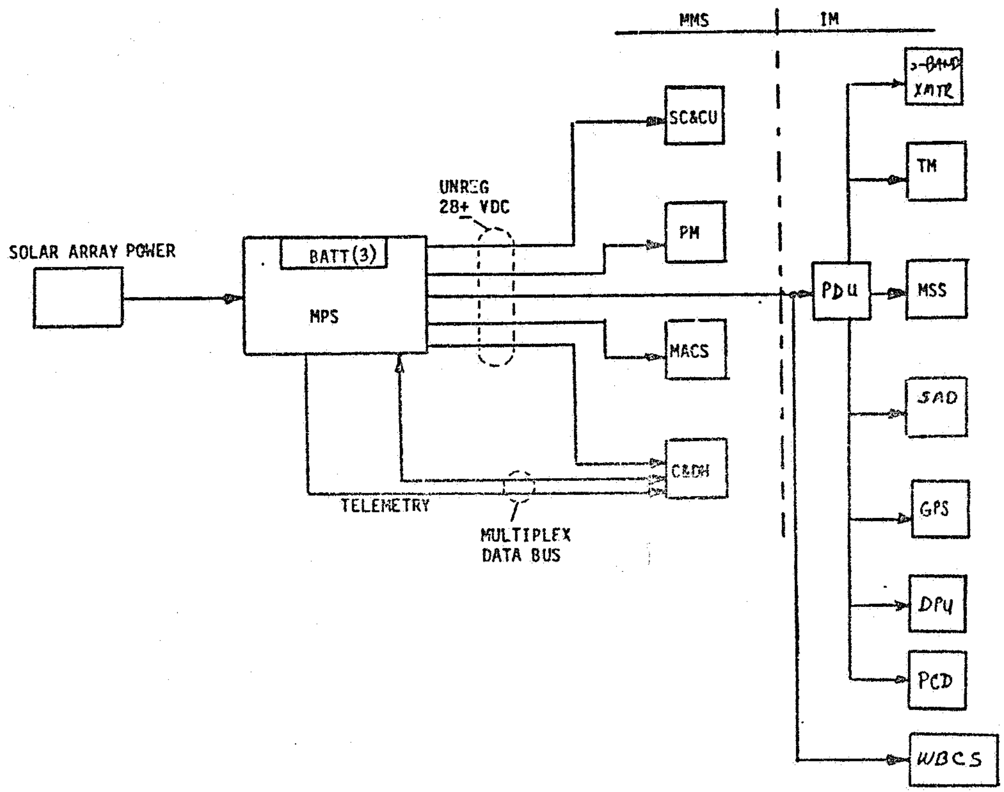

Figure 9-2. MPS General Interfaces

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External power sources available to the MPS during different mission phases are routed to the MPS through the MMS harness. These sources, discussed in detail in the Power Sources description, Section 9.2.1, provide the MPS with the following power inputs:

1. Main Array Power
2. GND/Shuttle Power Direct
3. GND/Shuttle Power Main
4. Ground Charge
5. Hardline Resupply Heater Power

Primary MPS functions are conditioning, controlling, monitoring and distributing power received by the MPS from the various sources. In block diagram form, Figure 9-3 shows power distribution throughout the MPS with power control provided by relays and fuses, power monitoring by current sensors (with data supplied to the SCA), and power conditioning provided by the PRU.

Voltage on the unregulated bus is distributed by the MPS as follows: Unregulated bus voltage is applied to the PCU load bus. The load bus distributes this voltage to MPS internal and external loads. Power for the MPS internal load, Power Regulation Unit (PRU) and for one external load (SC&CU) is provided directly from the MPS load bus. Power for current sensors and heaters is provided to the Bus Protection Assembly (BPA) where each load is protected by redundant fuses. Power provided to the BPA for heater circuits may be interrupted by the heater ON/OFF relays. One current sensor monitors both the MPS internal load current and the SC&CU current. For external MPS power distribution, the load bus voltage is applied to the instrument load bus through redundant PDR's (Power Disconnect Relays) which provide for removal of the MPS external loads.

The instrument load bus provides power distribution to the following MPS external loads; C&DH module power, ACS module power, propulsion/actuation module power and Instrument Module Power (Payload). Loads are monitored by current sensors, and the two instrument module busses are fused to protect the load bus.

For MPS control by the C&DH ON-Board Computer (OBC), command and data handling circuits are required. Two redundant RIU's (A&B) provide MPS interface with the MMS multiplex data bus (MDB). Commands from the OBC are received by the RIU's via the MDB and MPS module/spacecraft interface connectors. The RIU's format these commands for use by the SCA. Circuits in the SCA condition the commands for use throughout the MPS. Monitor and status data from points throughout the MPS is conditioned by SCA circuits and routed to the RIU's. The RIU's format this data for sending via the MDB to the C&DH module. The C&DH module distributes the data to the OBC and to the IM for telemetry transmission.

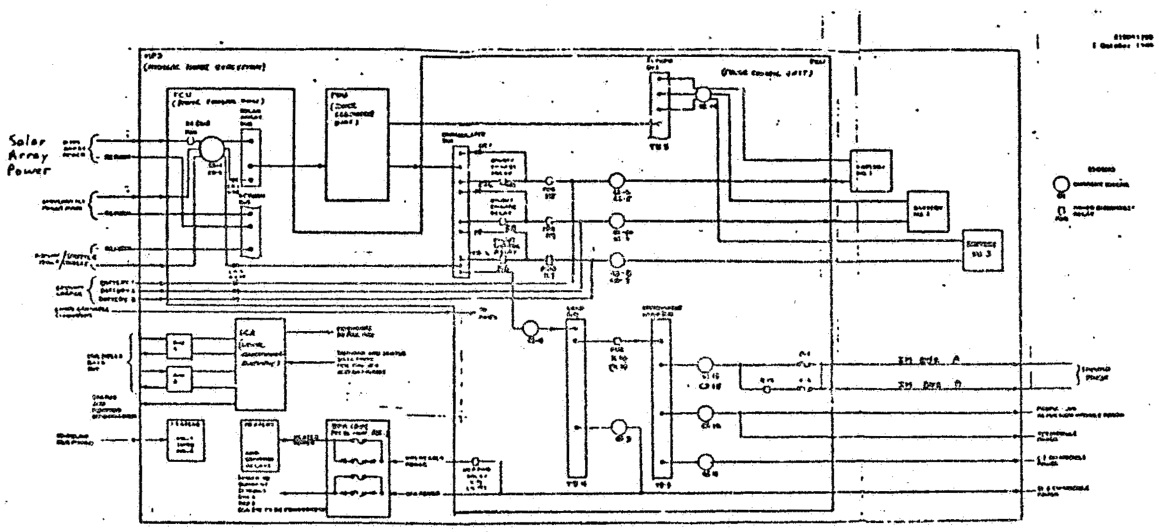

Figure 9-3. MPS Block Diagram

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9.1.1 POWER SOURCES

Depending on the phase of the spacecraft mission, various sources of electrical energy are available to the MPS. The sources, when they are used, when they are available, and their routing to the MPS, are discussed in the following paragraphs:

9.1.1.1 Solar Array

During orbital flight, the primary source of electrical energy for the MPS is the spacecraft solar array. It is designed to satisfy the maximum electrical load of the spacecraft. MPS solar array input power has the following requirements:

Open Circuit Volts	-	Min Volts: 55 VDC (0 volts at eclipse) Max Volts: 125 VDC
Short Circuit Current	-	72 Amps Max 1.7 Amps Min (0 amps at eclipse)

Electrical energy generated by the solar array is routed from the array through the spacecraft harness to the MPS. The solar energy is applied to the MPS through redundant inputs and referred to as Main Array Power.

9.1.1.2 Battery Power

During eclipse periods of the spacecraft orbital flight, no sunlight strikes the solar array and the solar array provides no electrical energy. MPS batteries provide the only source of electrical energy for spacecraft power requirements during an eclipse period. Battery power is also available to supplement solar array power during periods of peak power load. Battery voltage is routed from battery terminals through MPS cables to the PCU. Then through high and low range current sensors, through a power disconnects relay (PDR), and through a diode onto the PCU unregulated bus as shown in Figure 9-3. During battery charging, array power output is routed to the battery terminals in a similar manner except the diode is bypassed with the ON/OFF charge relay.

9.1.1.3 Ground/Shuttle Charge Power

In addition to the solar array power input, the MPS is provided with three additional power inputs to be used potentially at various times during the spacecraft mission. These inputs are GND/Shuttle PWR MAIN, GND/Shuttle PWR Direct, and Ground Charge for batteries

9.1.1.4 GND/Shuttle Pwr Main

This power input may be used during ground testing, prelaunch and spacecraft retrieval and resupply in orbit by the shuttle craft to provide electrical power for the complete spacecraft. This power is applied to the spacecraft through the spacecraft umbilical connector and routed through the spacecraft harness to the MPS module/spacecraft interface connectors. Within the MPS this power is routed onto the solar array bus through the solar array current sensor. A diode in each power input line isolates the MPS from faults that may occur on the external supply lines.

9.1.1.5 GND/Shuttle Pwr Direct

This is the second type of MPS power input routed through the spacecraft umbilical connectors to the MPS. Within the MPS, the difference between this input and the GND/Shuttle Power Main input, described above, is that GND/Shuttle Pwr Direct input bypasses the solar array and the PRU, applying voltage directly onto the MPS unregulated bus. The GND/Shuttle Pwr Direct input is isolated by diodes. This power input may be used during ground testing, prelaunch, and spacecraft retrieval and resupply in orbit by the shuttle craft.

9.1.1.6 Ground Charge

The MPS batteries can be charged from an external power source without powering up the total MPS. A ground charge provides the third type of MPS power input routed through the spacecraft umbilical connectors to the MPS. Within the MPS these inputs are routed through current sensors in the PCU and then directly to the MPS battery terminals. These inputs are used to supply voltage for battery charging and are isolated by diodes. The voltage supplied by these inputs is not controlled by MPS circuits and the current sensors are not used for ground charge control or monitoring.

9.1.2 POWER REGULATION AND CONTROL

9.1.2.1 PRU Functions

The PRU provides three main functions: conditioning of power applied to the PCU solar array bus (Main Array Power and GND/Shuttle Pwr Main), supplying conditioned power to the PCU unregulated bus, and controlling the charging of batteries. The PRU will function in one of three modes: 1) Standby, 2) Peak Power Tracking, and 3) Voltage Limit. (See Section 9.3 for detailed explanation of modes of operation.) In performing its function, the PRU provides the most efficient use of available solar array power when operating in the peak power tracking mode.

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PRU output voltage (22-35 volts) is determined by the battery terminal voltage. Additional PRU characteristics are as follows:

PRU INPUT

Voltage	-	125 Volts Maximum 40 Volts Minimum
Current	-	72 Amperes Maximum 4 Amperes Minimum
Power	-	4500 Watts Maximum 0.0 Watts Minimum (Eclipse) 160 Watts minimum ((Operation)
Reflected Ripple	-	Less than 7.5 Amperes Peak to Peak, All operating modes

PRU OUTPUT

Voltage	-	22-35 Volts
Current	-	108 Amperes Maximum
Power	-	3600 Watts Maximum
Current Ripple	-	Less than 7.5 Amperes Peak to Peak, all operating modes 1 Hz to 15 KHz

9.1.2.2 PCU Functions

Power from the PRU or GND/Shuttle Pwr Direct input is applied to the PCU for control and monitor functions in preparation for distribution by the PCU load bus. In the following paragraph, control and monitor functions are described for each MPS power source, with distribution described in the Power Distribution paragraph 9.1.3.

9.1.2.3 Main Array Power

The spacecraft solar array power is applied to the PCU solar array bus after being routed through the power disconnect relays (PDR) and current sensors (CS) as shown in Figure 9-3. Main array power is routed to the PCU by the MPS internal cabling and then routed to a PDR. When enabled, the PDR applies Main Array Power to the solar array bus. Disabling this PDR removes the power.

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9.1.2.4 Ground/Shuttle Power Main

Power from this source is applied to the PCU solar array bus after being routed from the PCU input connectors through a current sensor and an isolation diode. The isolation diode protects the MPS circuits from a fault external to the MPS. The Ground/Shuttle Power Main returns are routed directly to the PCU return bus.

Power applied to the PCU solar array bus from either of the above sources is routed directly to the PRU input. The PRU conditions and regulates the power as described in Section 9.1.2.1 PRU Functions. Conditioned power from the PRU output is routed onto the PCU unregulated bus. This is one of three sources of power supplied to the unregulated bus. The second source is GND/Shuttle Power Direct which is routed through a current sensor and a diode and onto the unregulated bus. The diode protects MPS circuits from a fault external to the MPS. The third regulated bus power source is battery power. Power applied to the unregulated bus is routed directly to the PCU load bus for distribution as described in paragraph 9.1.3, Power Distribution.

9.1.2.5 Battery Power

The third source of unregulated bus power, battery power, is used when the Main Array Power is not available (eclipse period) or during periods of peak power demand if the solar array output is insufficient. Each batteries voltage is applied to the unregulated bus by routing battery positive voltage through two current sensors (CS), a power disconnect relay (PDR), and an ON/OFF charge relay as shown in Figure 9-3. Battery returns are routed through a current sensor to the PCU return bus.

9.1.3 POWER DISTRIBUTION

MPS power distribution to internal and external loads is provided by the PCU load bus and the PCU instrument load bus. Returns are to the PCU load bus with a current sensor monitoring current. The current sensor monitors the total current drawn by MPS internal and external loads.

9.1.3.1 Internal Power Distribution

Power requirements within the MPS include MPS heater power and BPA power. A current sensor monitors current drawn by BPA power, HTR power, and SC&CU module power. The power for the BPA power and SC&CU module is provided through redundant wiring from the PCU load bus.

Two independent power inputs are provided the BPA by the PCU Load Bus, i.e., MPS heater power and BPA power. The heater power is routed through redundant PCU power disconnect relays which are controlled by a command from the SCA relay driver circuits (Figure 9-7).

The BPA provides distribution of its two power inputs through redundant fused circuits to non-critical MPS interval loads as follows: The BPA provides redundant fuse circuits of three ratings; 1 Amp, 2 Amp and 3 Amp, with test points supplied for the monitoring of each fuse status. The fuse circuits are on replaceable printed circuit cards with the primary and redundant fuses on separate boards. Figure 9-4 shows a typical BPA redundant fuse circuit. MPS Heater Power input to the BPA is routed through two 3 Amp fuse redundant circuits providing HTR Pwr A & B outputs from the BPA to heaters HR A1; A2 and HR B1, B2 (Figure 9-3). The second BPA input (BPA Power) is routed through the BPA 3 Amp, 2 Amp or 1 Amp fuse circuits providing the following BPA outputs:

1. Power A and B to RIU-A (2 Amp)
2. Power A and B to RIU-B (2 Amp)
3. SCA DC to DC Converter Power A and B (3 Amp)

9.1.3.2 External Power Distribution

Spacecraft power requirements include the following:

1. SC&CU Module Power
2. C&DH Module Power
3. ACS Module Power
4. Propulsion/Actuation Module Power
9. Payload Power

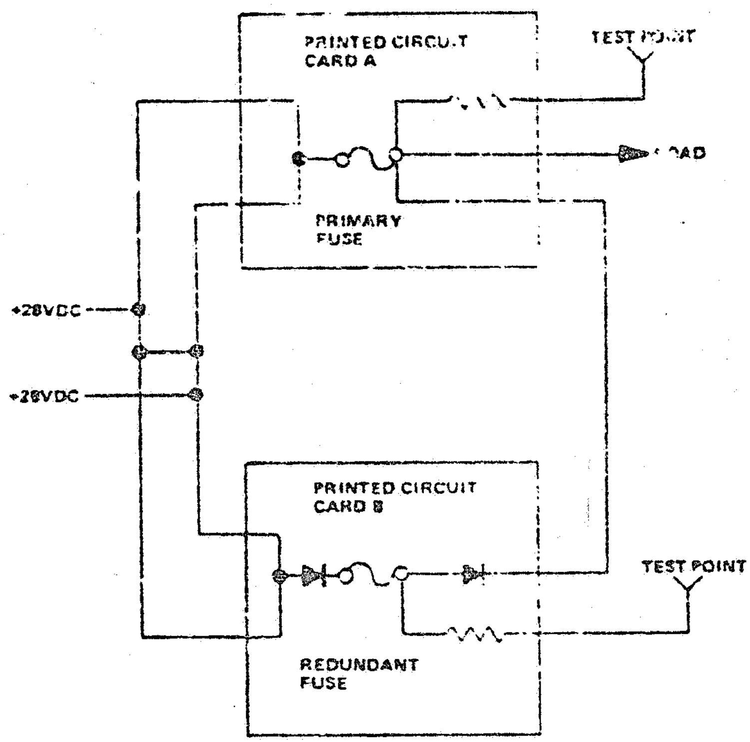

Figure 9-4. Typical BPA Redundant Fuse Circuit

The SC&CU module power provided by the PCU Load Bus, and monitored by the same circuit sensor as MPS internal loads, is discussed in the Internal Power Distribution paragraph. The PCU Instrument Load Bus distributes for each MPS external load except the SC&CU Module power. The voltage on the PCU Load Bus is applied through redundant PCU power disconnect relays Instrument Load Power Disconnect to the Instrument Load Bus. These relays are each controlled by hardline commands Load PD Enable CMD A and CMD B and a Load PD, disable CMD A and CMD B and by redundant enable commands from the SCA. The Instrument Load Pwr Disconnect (PDR) provide a method of removing external loads from the MPS. The Instrument Load Bus voltage is routed through a current sensor and PCU connectors for distribution by the spacecraft harness to the ACS Module power and Propulsion/Activation module as shown in Figure 9-3. C&DH module power has a similar routing through a current sensor and the MPS Module/Spacecraft interface connecter to the C&DH module via the spacecraft harness.

9.1.3.3 Payload Power

Instrument Module Bus A & Bus B is supplied by the voltage from the PCU instrument load bus as shown in Figure 9-3. High and low range current sensors monitor the payload power. Two 150 amp replaceable fuses located in the PCU provide instrument load bus power protection. Fuse F1 is in series with payload BUS A. BUS B, including Fuse F2 can be commanded open by the from the SCA relay drivers: INSTR FUSE SELECT relay located in the PCU. The INSTR FUSE SELECT relay is controlled by two commands from the SCA relay drivers: INSTR FUSE SELECT 1 (CMD 36) and INSTR FUSE SELECT 1 and 2 (CMD 37) (refer to Figure 9-14). After passing through the fuse circuit, payload power is routed through PCU connectors INSTR BUS A and INSTR BUS B. The spacecraft harness then routes IM BUS A and IM BUS B to the spacecraft payload.

9.1.4 Signal Conditioning Assembly (SCA)

The SCA provides the interface circuits required to match the RIU command and data circuits with the MPS circuits The SCA circuits include: 1) regulators, 2) command relay drivers, and 3) monitor circuits.

9.1.4.1 Power Circuits

The power circuits consist of two redundant DC to DC converters as shown in Figure 9-9. Each DC to DC converter supplies regulated voltages of +12VDC, -12VDC, +14VDC, -5VDC and filtered +28VDC as required for use within the SCA. These voltages are derived from a +28VDC input applied to each DC to DC converter. The DC to DC converter input +28VDC is applied to a filter circuit with the filter circuit output (28VDC Filter) being fused and available for use within the SCA. The 28VDC filtered output is also converted to AC voltage, applied to a transformer and stepped down.

The stepped down AC voltages are applied to regulator circuits to obtain +5VDC, +12VDC, -12VDC and +14VDC converter outputs for use within the SCA. Both DC to DC converters are identical and operate in the same modes.

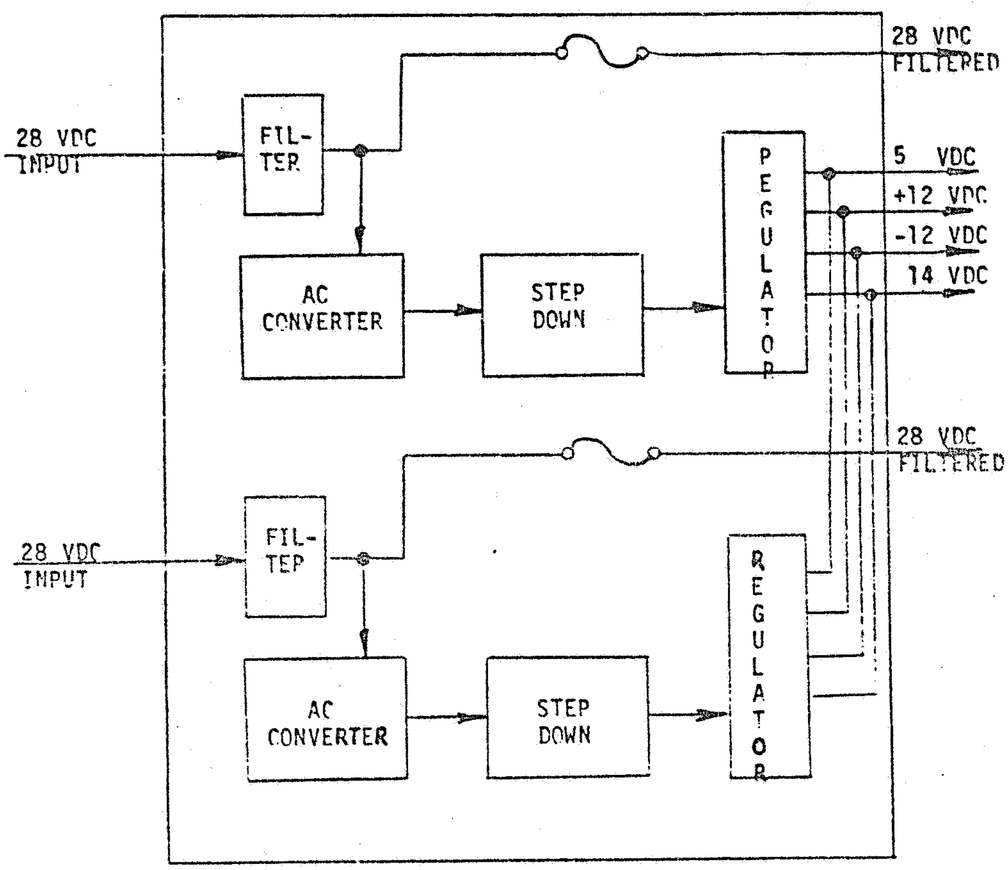

Figure 9-5. Functional Block Diagram D/C to D/C Converter

9.1.4.2 Command Circuits

The command circuits consist of relay driver circuits, required to control magnetic latching relays located throughout the MPS, and command signal wiring. The SCA module contains six circuit boards; with six relay driver circuits per board for a total of 36 circuits. All relay driver circuits are identical. Relay driver circuits are triggered by two types of signals: RIU discrete commands or internal SCA logic signals. The RIU discrete command is a high to low transition of approximately six milliseconds duration, which is generated by a single ended switch closure to signal ground. The SCA logic signal is a high to low level transition of internal SCA logic circuit output. The RIU's also output relay driver commands of 28VDC capable of driving small relays without a relay driver circuit. A high to low transition of the relay driver circuit input triggers the pulse stretcher logic device. Figure 9-6 shows a simplified diagram of a discrete pulse relay driver circuit. The pulse stretch device output is a signal ground pulse of longer duration than the command input. This signal ground provides a return for the +5VDC applied to the photocoupler diode causing the diode to emit light and turn on the phototransistor in the photocoupler. When turned on, the photocoupler applies +14VDC to the output transistor causing it to conduct, thereby applying +28VDC on the relay driver circuit output. This 28VDC is the signal routed to the magnetic latching relay which circuit it is intended to drive.

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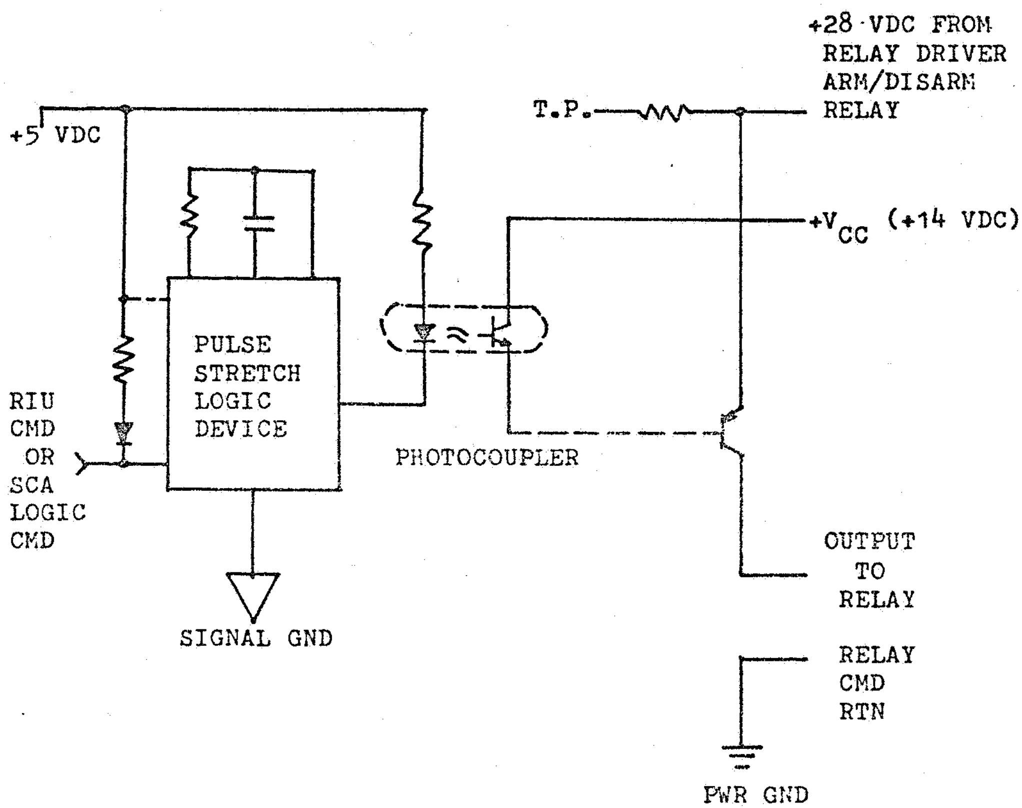

Figure 9-6. Discrete Pulse Relay Driver Simplified Diagram

Command signal wiring routes commands received from the RIU's directly through the SCA and on to the recipient control circuit. Each command and its redundant command is routed in parallel to its destination with each routed to test points on the SCA test connector. Two PRU commands "Set M" (11) and "Reset, VA, VB" (12) are not routed directly to the PRU. These two commands provide control of the MPS Safe Mode and are applied to safe mode logic in the SCA.

9.1.4.3 Control Circuits

There are three types of control circuits contained in the SCA: ARM/DISARM, BATTERY CHARGE INHIBIT, and computer status monitor.

9.1.4.3.1 ARM/DISARM Control Circuit.

The arm/disarm control circuit is used for three types of commands; battery ON/OFF charge, instrument fuse/power disconnect and heater control. An arm/disarm control circuit consists of a latching relay which operates directly on RIU 28VDC pulse commands from the RIU. The relay receives separate arm and disarm commands from the RIU's. The redundant relay is commanded by the redundant RIU. Figure 9-7 shows a simplified diagram of an arm/disarm control circuit. One set of contacts in each relay provides arm/disarm status of the relay by providing a digital "0" signal when the relay is in the armed (SET) state.

9.1.4.3.2 Battery Charge Inhibit Control Circuit.

The battery charge inhibit control circuit consists of three identical circuits. Internal logic will prevent all batteries from being simultaneously OFF charge. The output of the logic circuits controls the relay drivers in the SCA. Automatic charging is inhibited when discrete BATT OFF charge CMDS are sent or when battery charge inhibit circuits activate BATT OFF CHG relay drivers. The charge inhibit circuit prevents battery charging when indicated battery temperatures are above 35°C. If a thermal switch malfunctions, indicated by Therm Switch (closed <35°C) input, automatic control of charging is also inhibited. Logic circuits receive BATTERY ON/OFF CHG STATUS's and uses this information to maintain at least one battery on charge at all times.

If the solar array power output is equal to or less than the total load demand (including payload, electronics and battery) the feedback loop of the regulator will be the peak power tracker, i.e. full array power output is employed. When the batteries reach full charge, the battery voltage/temperature control of the Power Regulator will take over from the peak power tracker loop in order to reduce the battery charging rate. This feedback loop will force the solar array operating point to a higher voltage, thus lowering the operating power level sufficiently to meet the decreasing charge rate requirements.

9.1.4.3.3 Computer Status Monitor/Safe Mode Logic.

The computer status monitor and safe mode logic ciecuit of the SCA monitors the status of the computer for the purpose of transferring the MPS to a safe mode in the event of a sensed computer anomaly. The computer status is evaluated by monitoring the COMPUTER PULSE TRAIN "A"/"B" signal for the absence of a pulse within a 3.3 $\pm$0.30 second period. COMPUTER PULSE TRAIN "A"/"B" is normally a series of pulses with a rate of one pulse every 1.0 $\pm$ 0.10 seconds, unless priority interrupt occurs in which case two pulses will be skipped. The SCA interprets the detected absent pulse as a computer anomaly. When a computer anomaly is detected, SCA logic commands the MPS into a safe mode of operation. When control has been transferred to a safe mode, the MPS remains in the Safe Mode until reset by a separate command COMPUTER MONITOR RESET CMD "A"/"B" CMD (44). The MPS remains in the safe mode even if the COMPUTER PULSE TRAIN (CMD 40) is reestablished after interruptions. The computer status monitor function may be disabled and enabled by separate set and reset commands received from either RIU.

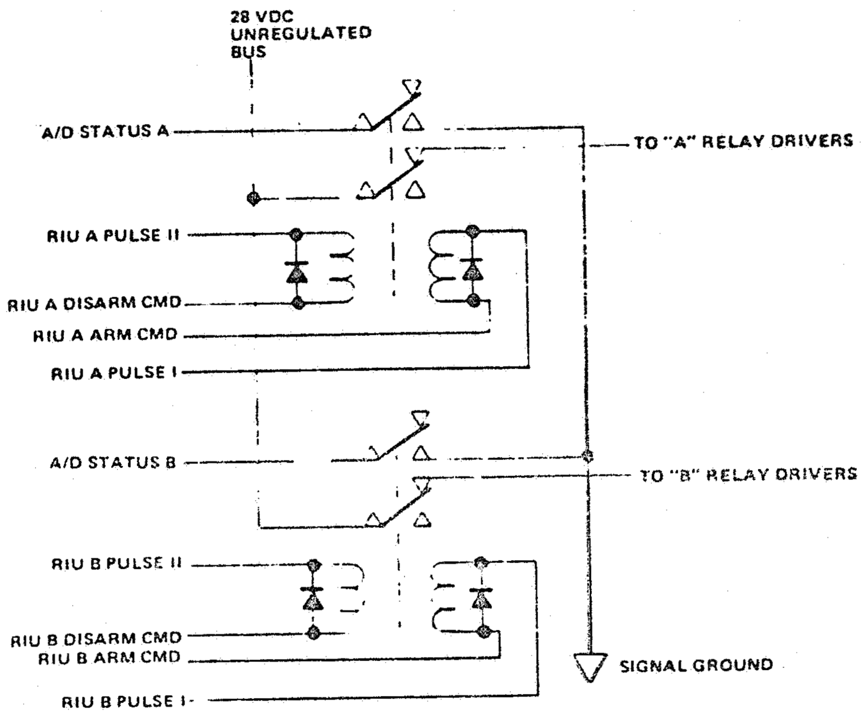

Figure 9-7. Arm/Disarm Control Circuit Simplified Diagram

9.1.4.3.4 SCA Monitor Circuits.

The SCA monitor circuit receives data from points throughout the MPS. This data is conditioned and routed to RIU A or B, which sends the data to the C&DH module for use by the OBC and TLM units. SCA monitor circuits consist of bi-level status monitors and four types of voltage monitors. The bi-level status monitor circuit accepts eight single-ended bi-level inputs and shifts this data into an eight bit serial digital word for transfer to the RIU. See Figure 9-8 for a simplified circuit. Each bi-level monitor circuit consists of redundant circuitry which supplies two data words DATA A1 OUTPUT and DATA B1 to RIU A or RIU B.

Voltage monitor circuits consist of circuitry that converts input signals of various levels to proportionate 0 to 5 VDC signals compatible with RIU inputs. Four types of circuits are required to handle the different input signals. Two types are resistive networks and two types are differential amplifier circuits. The first type of monitoring circuit is used for BATT #1, BATT #2 and BATT #3 Voltages and UNREGULATED BUS VOLTAGE. This circuit provides a 0 to 5 VDC output voltage proportional to the 0 to 40 VDC input. The second type of circuit monitors the SOLAR ARRAY BUS VOLTAGE and accepts a 0 to 125 VDC input. The output is 1/25 the input voltage or 0 to 5 VDC. The third type of circuit monitors the 3rd electrode voltage for the 3rd electrode cell in each of the MPS batteries. For a simplified diagram see Figure 9-9. The differential amplifier circuit provides a gain of approximately 10. The amplifier output is directly proportional to the 3rd electrode voltage input and is between 0 and 5 VDC. The fourth type of circuit monitors the battery balance voltage. Battery balance voltage is determined by monitoring the voltage difference between two groups of eleven cells in the same battery. The output of the differential amplifier is proportional to the voltage difference between the two cell groups. The amplifier output voltage range is 0 to 5 VDC with a differential input range of $\pm$0.7 volts dc. Each of the voltage monitor circuits supply output data to RIUA and RIU. to the spacecraft umbilical connectors.

Signals from thermistors monitoring local temperatures of the PCU; PRU; BATTERIES; BPA; SCA; and MPS baseplate are routed to the SCA and conditioned by the SCA. The thermistor conditioning circuit consists of a resistor network which provides outputs to RIUA, RIUB and a test point. Signals from the current sensors located in the PCU are routed to the SCA where a resistive network provides buffered parallel outputs for routing to RIU A and RIU B. Current sensor output test points are also routed to the SCA test conductor. Hardline outputs for some current sensors are routed to the spacecraft umbilical connectors.

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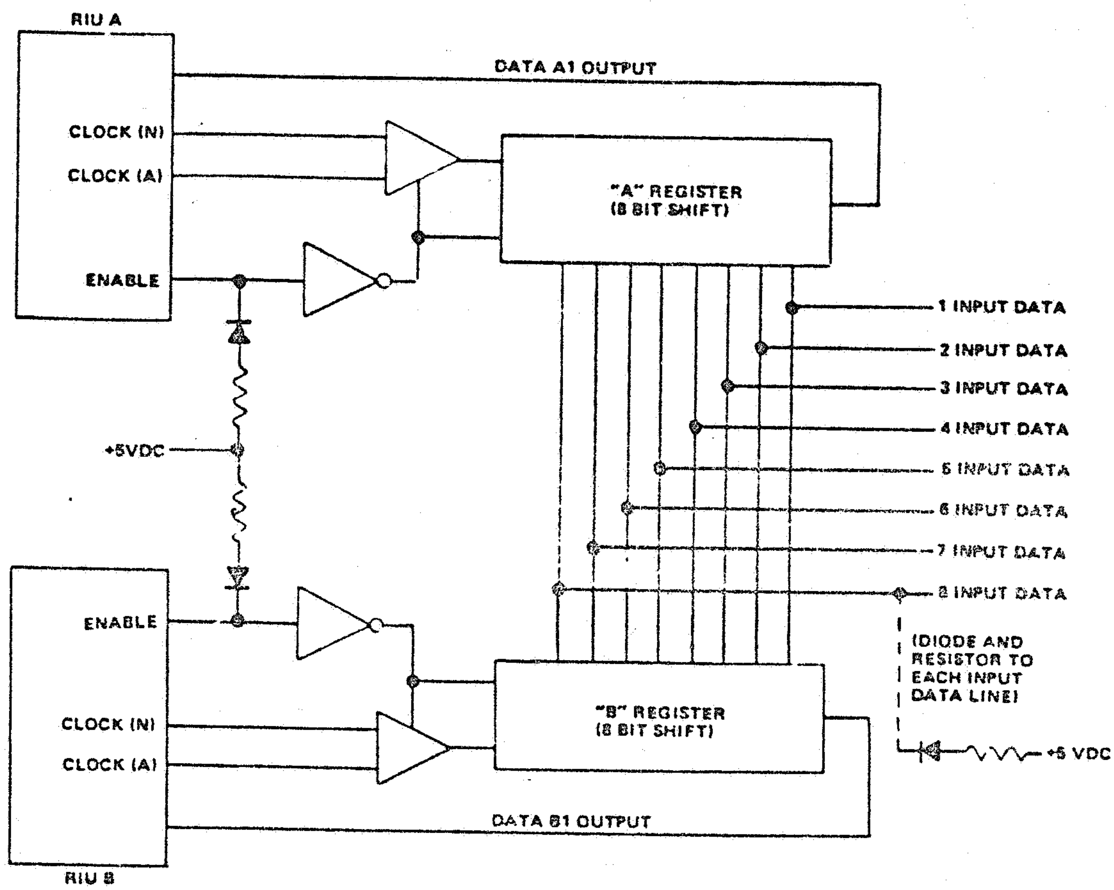

Figure 9-8. Bilevel Status Monitor Simplified Diagram

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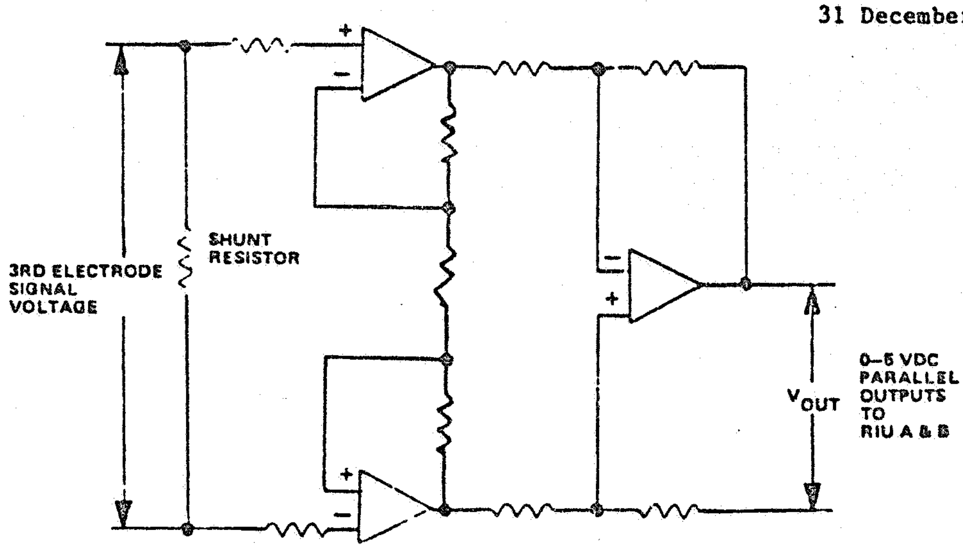
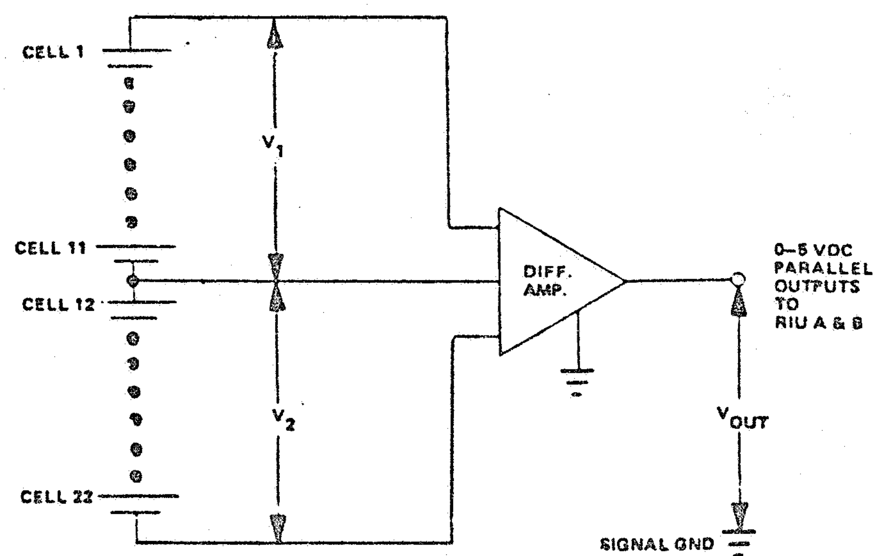


BATTERY 3RD ELECTRODE VOLTAGE MONITOR



BATTERY BALANCE VOLTAGE MONITOR

Figure 9-9. Voltage Monitor Circuits Simplified Diagrams (BATT #3 not shown)

9.2 PERFORMANCE CAPABILITIES

The Modular Power Subsytem (MPS) will be capable of satisfying the following requirements throughout the full duration of the mission when matched to a suitable mission unique solar array and an appropriate battery complement for the mission.

Function	Capability
Voltage	The average value of the MPS output bus voltage will be within the range 22-35 VDC (negative grounded to structure at CGP).
Ripple	The ripple voltage impressed on the average value of the MPS bus voltasge will be less than 1.5 volts peak-to-peak over the frequency range of 1 Hz to 10 MHz.
Power Output	
Orbital Average	1200 watts max. (including peaks) 850 watts max. available to users 250 watts min.
Peak	2.0 KW above the operating load (3.0 KW absolute maximum) for 10 minutes, day or night, once per orbit.
Source Impedance	The maximum source impedance, not including harness impedance will be: 0.10 ohms - 1 Hz to 1 KHz 0.15 ohms - 1 KHz to 20 KHz 0.30 ohms - 20 KHz to 100 KHz
Voltage Transients	Load switching transients on the power bus will not exceed the following values:
0 to 10 micro sec	3.0 volts, max.
10 micro sec to 1.0 msec	1.0 volts, max.
>1.0 ms*	$\pm$0.5 volts, max. (within the 22 to 35 volt operation range)
Rate of Rise*	$\leq$0.5 volts/micro sec
Rate of Fall	$\leq$5.0 volts/msec
Fault Induced Transient	During abnormal transients, the spacecraft bus voltage will remain within the range of zero to 40 VDC. The duration of abnormal transients should not exceed 500 msec.

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Energy Storage	Capable of providing nominal energy storage of 150 ampere hours for LS-D.
PRU Input	
Voltage	125 voltas max 40 volts min.
Current	72 amperes max. 4 amperes min.
Power	4500 watts max. 160 watts min. 0.0 watts min. (eclipse)
Reflected Ripple	Less than 7.5 amperes Peak-to-Peak, all operating modes
PRU Output	
Voltage	22-35 volts
Current	108 amperes max.
Power	3600 watts max.
Current Ripple	Less than 7.5 amperes Peak-to-Peak, all operating modes 1 Hz to 15 KHz

9.3 MPS MODES OF OPERATION

The MPS mode of operation is dependent upon the source of power available to the MPS, the state of charge of MPS batteries and the mission phase of the spacecraft (ground, flight or resupply operations). MPS operation is controlled by the ON-BOARD COMPUTER (OBC) located in the spacecraft C&DH module. The MPS receives commands from the OBC through RIU and SCA interface circuits. These commands control relays which in turn control which of the following modes the MPS operates in.

9.3.1 POWER REGULATION MODE

In the power regulation mode the MPS receives power through one of two inputs, MAIN ARRAY POWER or GND/SHUTTLE POWER MAIN, depending on the mission phase. Both power inputs are routed onto the PCU solar array bus and to the PRU input, see Figure 9-3, MPS Block Diagram. During MPS power regulation mode, the PRU operates in the peak power tracking mode, voltage limited mode; or current limited mode and provides power to the PCU unregulated bus for distribution.

9.3.2 STANDBY AND PEAK POWER TRACKING MODES

When no solar array power is available, the PRU operates in a standby mode and MPS power is supplied by batteries. When solar array power is available, but not adequate to supply the load bus the PRU operates in a peak power tracking mode and the depict is satisfied by the battery. When the load demand is satisfied any excess power is used for battery charging. In this mode the PRU draws at least 95% of the power available from the solar array. When GND/SHUTTLE PWR MAIN input is a source of MPS power, the PRU also conditions this power as it does solar array power.

9.3.3 VOLTAGE LIMITED MODE

During battery charging periods, the battery voltage limit is determined by one of eight preselected commandable voltage-temperature (V/T) limits as shown in Table 9-3. When the battery terminal voltage reaches the limit corresponding to the battery operating temperature for the chosen level, the battery charge current is reduced (tapered) to maintain the battery voltage at this limit. A temperature sensor located on each battery, along with SCA monitor circuits, provide temperature information to the charge control logic. The highest battery voltage and highest battery temperature is used by the control logic to determine the battery voltage limit.

9.3.4 BATTERY POWER MODE

When the PRU is operating in the standby mode, the MPS batteries provide power to the PCU unregulated bus for distribution. The battery power mode is used during eclipse periods of spacecraft flight. During periods of peak power demand, battery power is also used to supplement available solar array derived power.

9.3.5 BATTERY CHARGE MODES

MPS power inputs from four sources may be used in charging the MPS batteries. When the charging voltage source is the Main Array Power or GND/Shuttle PWR Main, the PRU controls the charging of the battery. If the PRU power output applied to the PCU unregulated bus exceeds the load bus power demands, the batteries may be charged. The PRU controls the battery charging in the voltage limited mode. Two other sources of battery charge voltage are GND/SHUTTLE PWR DIRECT and GROUND CHARGE. These two sources are not controlled by the PRU. GND/SHUTTLE PWR DIRECT voltage is routed directly to the unregulated bus and may be used for battery charging and/or distribution by the MPS. The GROUND CHARGE source is used for battery charging only and is routed directly to the batteries. Using the GROUND CHARGE input, the MPS batteries may be charged without powering up the total MPS.

9.3.5.1 Ground/Shuttle Charge Mode

During this charge mode the MPS receives power from one of three inputs, GND/SHUTTLE PWR MAIN, GND/SHUTTLE PWR DIRECT, or GROUND CHARGE. Both GND/SHUTTLE PWR MAIN and GND SHUTTLE PWR DIRECT voltage are available only when the MPS is on the ground or in the shuttle. When the GND/SHUTTLE PWR MAIN input is used the PRU controls battery charging. The GND/SHUTTLE PWR DIRECT input is not controlled by the PRU but this voltage is routed to the batteries the same manner as the PRU output voltage. The GROUND CHARGE input voltage is available only when the MPS is on the ground. This voltge is applied directly to the battery terminals and is used only for battery charging. The GROUND CHARGE voltage is not controlled by circuits in the MPS and may be used to charge the batteries without powering up the total MPS.

9.3.6 SAFE/HOLD MODE

When the computer status monitor circuit indicates a computer anomaly, logic circuits, located in the SCA, command the MPS into a Safe/Hold mode of operation. The MPS Safe/Hold mode consists of the battery charge control logic being commanded to the voltage mode, both power trackers ON, the current mode inhibited, and V/T Level 1 selected (for a previously commanded V/T Level of 4 or less) or V/T Level 5 selected (for a previously commanded V/T Level $\geq$5).

9.4 CONSTRAINTS

9.4.1 MPS INITIALIZATION CONSTRAINTS

Voltage/Temperature (V/T) curve for initial MPS operation must be Level 9.

9.4.2 MPS TELEMETRY CONSTRAINTS

TBD

9.4.3 MPS COMMAND CONSTRAINTS

TBD

9.4.4 MPS TEMPERATURE CONSTRAINTS

Battery temperature shall not be allowed to exceed 35 degrees centigrade

9.4.5 MPS OPERATION MODE CONSTRAINTS

1. If any battery terminal voltage is less than a ground programmable reference voltage (recommended 1.10 volts per cell = 24.2 volts) for 24 seconds, the OBC commands off all non-essential loads.

2. If any battery differential voltage is greater than 0.5 volts for 24 consecutive seconds, command that battery OFF charge (requires enable).

3. Command off all non-essential loads and set flag (computer) if both battery capabilities are less than 25 ampere-hours.

4. Minimum allowable unregulated bus voltage must be 29.0 Vdc.

5. Minimum allowable end of night battery voltage must be 29.4 Vdc.

6. Depth of discharge must be limited to 50 percent of rated capacity (50 AH per battery).

7. Initial Voltage Temperature (V/T) curve for normal operations will be either number 5 or 6.

9.4.6 MPS SAFE HOLD CONSTRAINTS

1. Battery charge control logic is set to V/T level 3 (for a previously commanded V/T level of 4 or less) or set to V/T level 5 (when the level had been at a level 5 or above).

2. If Peak Power Tracker #2 or any of the 3 V/T board circuits have been disabled due to a failure, the Safe Mode circuit shall be disabled. This is done with the Computer Status Monitor Set or Reset commands to obtain a 0 and 1 or a 1 and 0 readout for Computer MON ENA DISA Status A and Status B, respectively.

9.5 REDUNDANCY CROSS-STRAPPING

There are three types of cross-strapping: dedicated, active and passive. Active (A) cross-strapping is where primary and redundant components feed a third unit as shown in Figure 9-10A. Passive (P) cross-strapping involves the selection of a Primary or Redundant component by command switching. There is no passive cross-strapping in the MPS. Dedicated (D) components are used together and cannot be cross-strapped as in the MPS regulators, command drivers or, status monitors.

The MPS has redundancy in the following major areas:

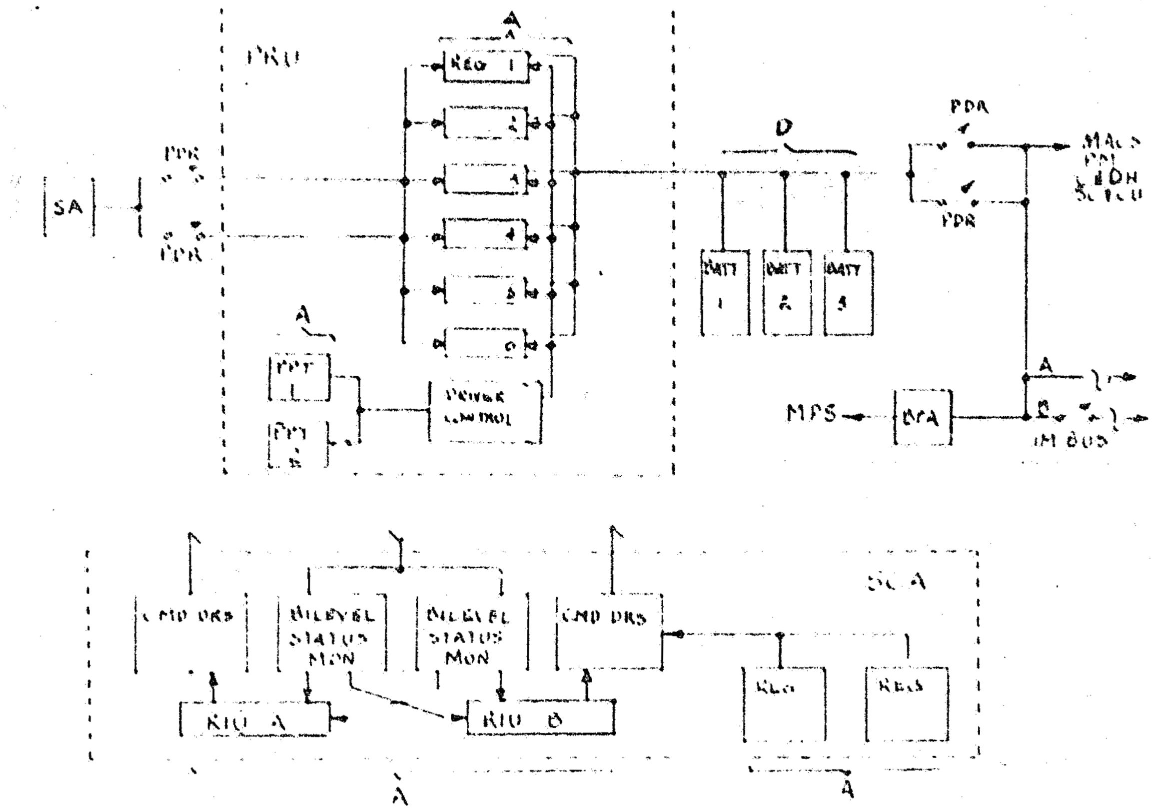

Figure 9-10A. MPS Cross Strapping/Redundancy

9.5.1 REGULATORS

There are six switching power modules, each with two paralleled elements within the regulator. The system can suffer the loss of up to two of the elements and still achieve mission duration.

9.5.2 BATTERIES

There are three batteries in the MPS. One battery can be lost and still meet full mission requirements. With one battery functioning, the SC will be operational with limited mission capability.

9.5.3 IM OUTPUT BUS

The IM output power is divided into two power buses (A Bus and B Bus). The A power bus supplies power to the A side of the WBS, TM/MSS and the PDU. The B power bus supplies power to the B side of the WBS, TM/MSS and the PDU, Figure 9-10.

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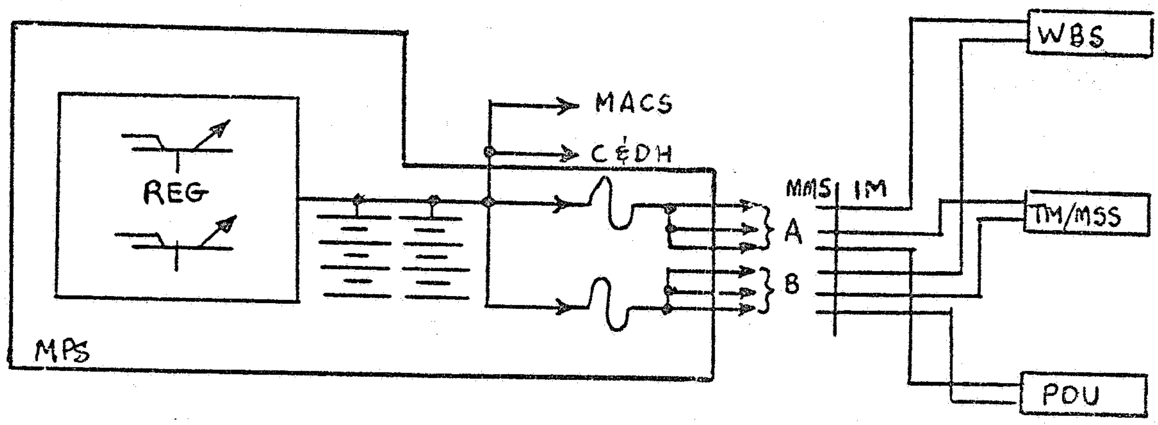

Figure 9-10. IM Output Bus

9.6 COMMAND

MPS commands and data are sent to/from the MPS using two methods, hardline and multiplex data bus (MDB). Spacecraft mission phase determines which method is used. Hardline commands and data are used to control the MPS during testing, pre-launch, and supply and retrieval operations. During spacecraft flight, commands and data transmitted via telemetry are received/transmitted by the spacecraft C&DH module and sent to/from the MPS over the multiplex data bus (MDB). The hardline commands and data take the place of command and data transmitted by telemetry. In the hardline method, each piece of data and each command has an independent wire routed from the MPS module/spacecraft interface connector through the MMS harness to the MMS umbilical connectors. Communications with the C&DH module over the MDB provides the second method of sending/receiving commands and data. RIU #3 provides the MPS interface with the MDB as described in the following paragraphs. In-flight telemetry data is primarily limited to those functions necessary to determine subsystem configuration and abnormal or emergency MPS conditions and to commands required for MPS control and operation.

9.6.1 RIU INTERFACE

The RIU's provide a two direction interface for command and Telemetry data transfer between the MPS and C&DH module. The MPS RIU interfaces with the multiplex data bus (MDB), which is routed through the MMS harness to the C&DH module where the central unit (CU) provides access to the on-board computer. The MDB consists of two pairs of redundant party lines, supervisory and reply. Information is sent from the CU to the MPS RIU's over redundant supervisory lines, and information is sent from the MPS RIU's to the CU over redundant reply lines. Each MPS RIU has its own unique address. Upon recognition of its address, the RIU switches from standby to operational mode and receives data. The RIU converts this data into discrete relay and logic circuit commands. Each RIU provides 64 discrete commands. RIU's receive various types of data which are acquired from throughout the MPS and conditioned by the SCA.

The RIU's process this data and send it in a nine bit reply word format over the redundant reply lines to the CU. Sending of data to the CU is controlled by the CU with information sent over the supervisory line to the RIU's. The CU distributes data for transmitting via telemetry and use by the OBC. For detailed information on the RIU refer to the Data Format Control Book Volume II and III (Telemetry and Command) respectively.

9.6.2 DISCRETE COMMANDS

Discrete commands are transmitted from the ground or by the OBC via RIU #3. The commands are listed in Table 9-1 along with RIU channel number, complementary and prerequisit commands, and the telemetry verification points. The telemetry verification is listed by User ID, matrix location (column, row), bit location and bit state. Data Format Control Books II (telemetry) and III (command) contain more specific information on command and telemetry format. Figures 9-11 through 9-15 show the commands in logic diagram form. Note that for the logic diagrams in this section the switching points are not necessarily relay controls but may be Transistor-Transistor Logic circuit or other solid state devices. The telemetry verification points give the telemetry User ID and its bit position. See section 9.6 for telemetry.

9.6.2.1 Power Regulator V/T Commands

The regulator serves to control the charge current to the batteries. To prevent overcharge, the batteries are allowed to reach a maximum voltage as a function of temperature by tapering the charge current when this voltage is reached. Eight voltage/temperatures curves as shown in Table 9-2, are selectable by command to allow optimization of charge based on battery cell characteristics. This control is accomplished by converting the voltage and temperature parameters to a signal voltage which is used to regulate the battery voltage limit.

A "safe-mode" configuration is implemented through the use of internally generated signals having the same effect as commands "RESET M, VA, VB" and "RESET IA, IB". To illustrate the effect of these commands, refer to list of commands and the logic (Table 9-2).

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Table 9-1. Discrete Commands (MPS)

RIU SA/SB CMD CH NO.	COMMAND NAME	COMMAND [illegible]	COMMAND CMD	PWR REQ	FUNCTION PERFORMED	TELEMETRY VERIF USER I.D.	C	R	B	BIT ST	[illegible]	PRIME RETURN
00	RIU SELF ON (STANDBY)	RIU	65		PWR ON TO ENABLE DISCRETE COMMAND	MPS 07	96	56	0,1			
01	BATTERY 1 ON CHARGE		02	55	SUPPLIES +28V SOURCE TO CHARGE BATTERY 1	MPS 02	97	50	5	0		
02	BATTERY 1 OFF CHARGE		01	35	REMOVES +28V SOURCE FROM BATTERY 1	MPS 02	97	60	5	1		
03	BATTERY 2 ON CHARGE		04	55	SUPPLIES +28V SOURCE TO CHARGE BATTERY 2	MPS 02	97	50	4	0		
04	BATTERY 2 OFF CHARGE		03	35	REMOVES +28V SOURCE FROM BATTERY 2	MPS 02	97	50	4	1		
05	BATTERY 3 ON CHARGE		06	35		MPS 02	97	50	2	[illegible]		
06	BATTERY 3 OFF CHARGE		05	35		02	97	50	3	1		
07	INSTR FUSE/PWR DISCONNECT ARM		08		ARMS CMDS TO IM BUS "B" & PDR's	MPS [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
08	INSTR FUSE/PWR DISCONNECT DISARM		07		DISARMS CMDS TO IM BUS "B" & PDR's	MPS [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
09	HEATER ARM		10		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
10	HEATER DISARM		09		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
11	PRU 'VT' SET		12		SELECTS PRU V/T FAULT DETECTORS	MPS 01	96	50	4	0		
12	PRU 'VT', VA, VB, RESET		11		SELECTS PRU V/T FAULT DETECTORS	MPS 01	96	50	4,6,7	1		
13	PRU 'VC' SET		19		SELECTS V/T OPERATING LEVEL	MPS 01	96	50	5	0		
14	PRU 'VB' SET		12		SELECTS V/T OPERATING LEVEL	MPS 01	96	50	6	0		
15	PRU 'VA' SET		12		SELECTS V/T OPERATING LEVEL	MPS 01	96	50	7	0		
16	PRU IA, & IB RESET		17,18		SELECTS V/T OPERATING LEVEL	MPS 02	97	50	7,6	[illegible]		
17	PRU 'IB' SET		16		SELECTS PRU V/T FAULT DETECTORS	MPS 02	97	50	6	0		
18	PRU 'IA' SET		16		SELECTS PRU V/T FAULT DETECTORS	MPS 02	97	50	7	0		
19	PRU VC RESET		13		SELECTS PRU V/T FAULT DETECTORS	MPS 01	96	50	5	1		
20	COMPUTER STATUS MONITOR RESET		21		[illegible]	MPS [illegible]	[illegible]	51	[illegible]	1		
21	COMPUTER STATUS MONITOR SET		20		[illegible]	MPS [illegible]	[illegible]	51	[illegible]	0		
22	HTR THERMOSTAT 2 BYPASS RESET		23	09	RETURNS HEATER TO THERMOSTAT CONTROL	MPS [illegible]	[illegible]	[illegible]	[illegible]	1		
23	HTR THERMOSTAT 2 BYPASS SET		22	07	ALLOWS HTR MANUAL CONTROL BY BYPASSING THERMOSTAT	MPS [illegible]	[illegible]	[illegible]	[illegible]	0		
24	HTR THERMOSTAT 1 BYPASS RESET		25	09	RETURNS HEATER TO THERMOSTAT CONTROL	MPS [illegible]	[illegible]	[illegible]	[illegible]	1		
25	HTR THERMOSTAT 1 BYPASS SET		24	07	ALLOWS HTR MANUAL CONTROL BY BYPASSING THERMOSTAT	MPS [illegible]	[illegible]	[illegible]	[illegible]	0		
26	AUTO HEATERS ON/OFF RESET		27	09	REMOVES 28V SOURCE FROM HEATERS	MPS [illegible]	[illegible]	[illegible]	[illegible]	1		
27	AUTO HEATERS ON/OFF SET		26	09	SUPPLIES 28V SOURCE TO HEATERS	MPS [illegible]	[illegible]	[illegible]	[illegible]	0		
28	BATTERY 3 THERMAL SWITCH RESET		29			MPS [illegible]	[illegible]	51	0	1		
29	BATTERY 3 THERMAL SWITCH SET		28			MPS [illegible]	[illegible]	51	0	0		

Table 9-1. Discrete Commands (MPS)

RIU 30/38 CMD CH(ab)	COMMAND NAME	COMMAND LOCATION	COMMAND COMP	PREREQ	FUNCTION PERFORMED	TELEMETRY VERIF USER ID	TELEMETRY VERIF C	TELEMETRY VERIF R	TELEMETRY VERIF B	TELEMETRY VERIF BIT ST	TELEMETRY VERIF MNE	[illegible]
30	BATTERY 2 THERMAL SWITCH RESET	RIU	31			MPS 02/05	97	50/51	0/1	1		
31	BATTERY 2 THERMAL SWITCH SET		30			MPS 02/05	97	50/51	0/1	0		
32	BATTERY 1 THERMAL SWITCH RESET		33			MPS 01/05	96/97	50/51	0/2	1		
33	BATTERY 1 THERMAL SWITCH SET		32			MPS 01/05	96/97	50/51	0/2	0		
34	BATTERY ON/OFF CHARGE DISARM		35		REMOVES 28V FROM BATT CHARGE RELAYS 1 & 2	MPS 02/06	97/98	50/51	2/1	1		
35	BATTERY ON/OFF CHARGE ARM		34			MPS 02/06	97/98	50/51	2/1	0		
36	1M BUS B ENABLE		37	07	SUPPLIES +28V TO ENERGIZE THE "B" BUS	MPS 04	96	51	1	0		
37	1M BUS B DISABLE		36	07	REMOVES +28V FROM THE "B" BUS	MPS 04	96	51	1	1		
38	LOAD POWER DISCONNECT RELAYS CLOSE		— *	07	SUPPLIES POWER TO INSTR LOAD BUS	MPS 05	97	51	6/7	1		K11 STATUS K10 "
39	SOLAR ARRAY PD RELAYS CLOSE		— *	07	SUPPLIES POWER FROM SOLAR ARRAY TO SA BUS	MPS 03	98	50,111	0/1	1		K6 STATUS K1 STATUS
40	COMPUTER PULSE TRAIN				COMMAND PULSE EVERY 1.10 ± 0.10 SECONDS							
41	BATT 1&3 PD RELAY CLOSE		— *	07	50-100 VDC	MPS 03	98	59,111	2/4	1		K7 STATUS K5 STATUS
42	BATT 2 PD RELAY CLOSE		— *	07	50-100 VDC	MPS 03	98	50,111	3	1		K9
43												
44	COMPUTER MONITOR RESET				RETURNS MPS TO NORMAL OPERATION FROM SAFE HOLD MODE							
63	RIU STANDBY 2	RIU	00		ENABLES RIU FOR SERIAL DIGITAL CMD & TLM							

* COMPLEMENT IS A HARDLINE COMMAND FOR GROUND TEST ONLY

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Table 9-2. Voltage Control Level Current Control and Fault Detection State Selection Logic

RIU CMD CH*	a. Command List
0312	RESET M, VA, VB
0311	SET M
0315	SET VA
0314	SET VB
0313	SET VC
0319	RESET VC
0316	RESET IA, IB
0318	SET IA
0317	SET IB

Note:
0 = SET
1 = RESET

b. Voltage control level select

VA	VB	VC	CURVE (LEVEL)
1	1	1	1
0	1	1	2
1	0	1	3
0	0	1	4
1	1	0	5
0	1	0	6
1	0	0	7
0	0	0	8

c. Current control level select and fault detector state

STATUS M	I_A	I_B	OPERATIONAL MODE
* 1	1	1	Normal, current mode inhibited
0	0	0	Current mode and tracker 2 inhibited
0	0	1	Current mode and A14 V/T control inhibited
0	1	0	Current mode and A15 V/T control inhibited
0	1	1	Current mode and A17 V/T control inhibited
** 1	0	0	Current mode enabled, current = .75 amps
** 1	0	1	Current mode enabled, current = 1.5 amps
** 1	1	0	Current mode enabled, current = 3.0 amps

* Denotes power up state and safe mode state
**V/T control is operational back-up

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9.7 TELEMETRY

RIU #3 provides the telemetry interface between the MPS subsystem and the C&DH subsystem. Four types of telemetry, serial digital (S), bilevel (B), passive analog (P), and analog (A) are processed by RIU #3 and sent to the C&DH STACC CU via the MDB. Table 9-3 provides a list of telemetry points along with User ID, RIU channel address and message matrix locations. See the Data Format Control Book Vol. II (Telemetry) for specific details about telemetry format. For information regarding calibration curves for the telemetered functions, see Appendix A.9.

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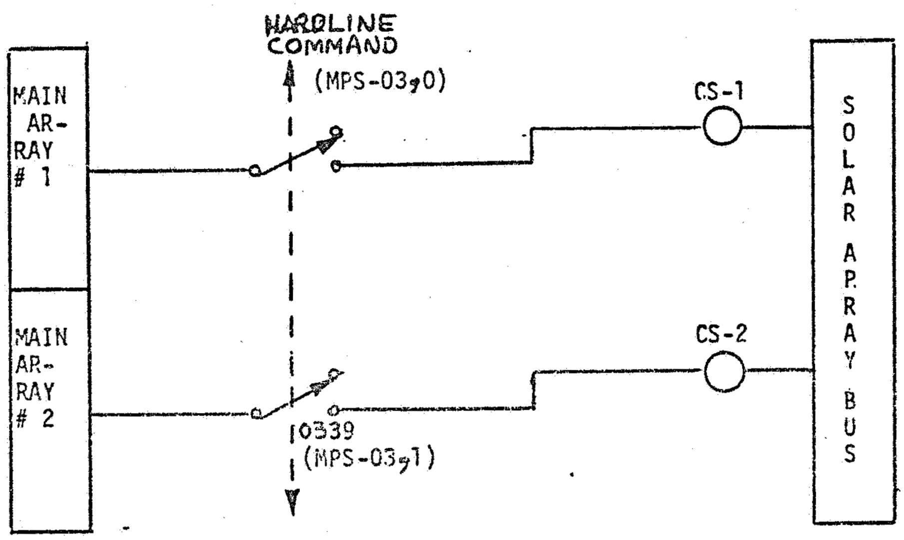
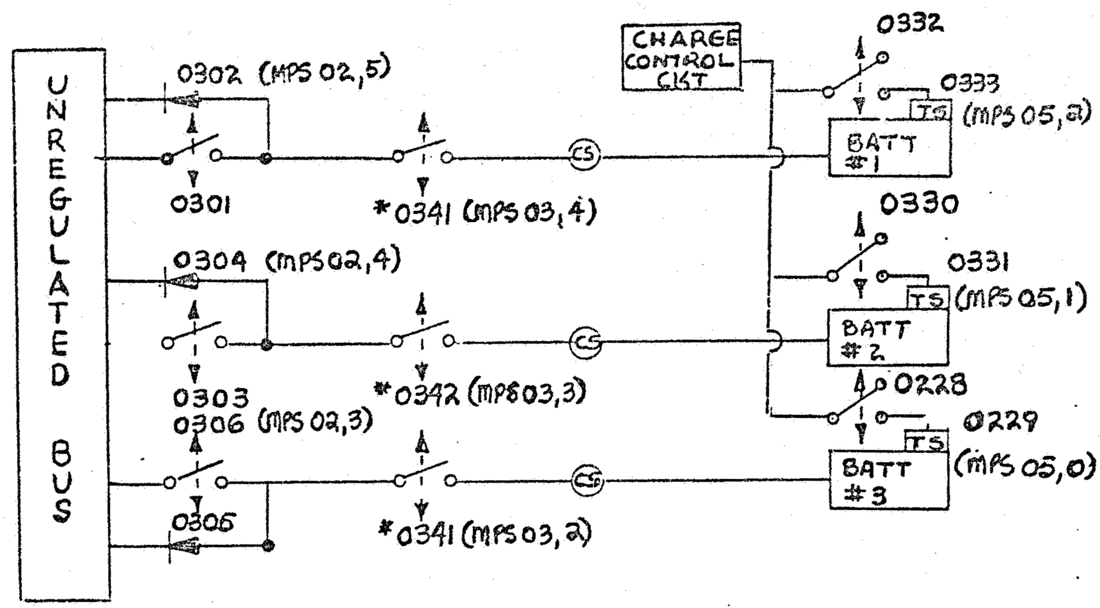


0339 - Solar Array Power Disconnect Relays Close
( ) - TLM Verification (User ID , Bit Number)

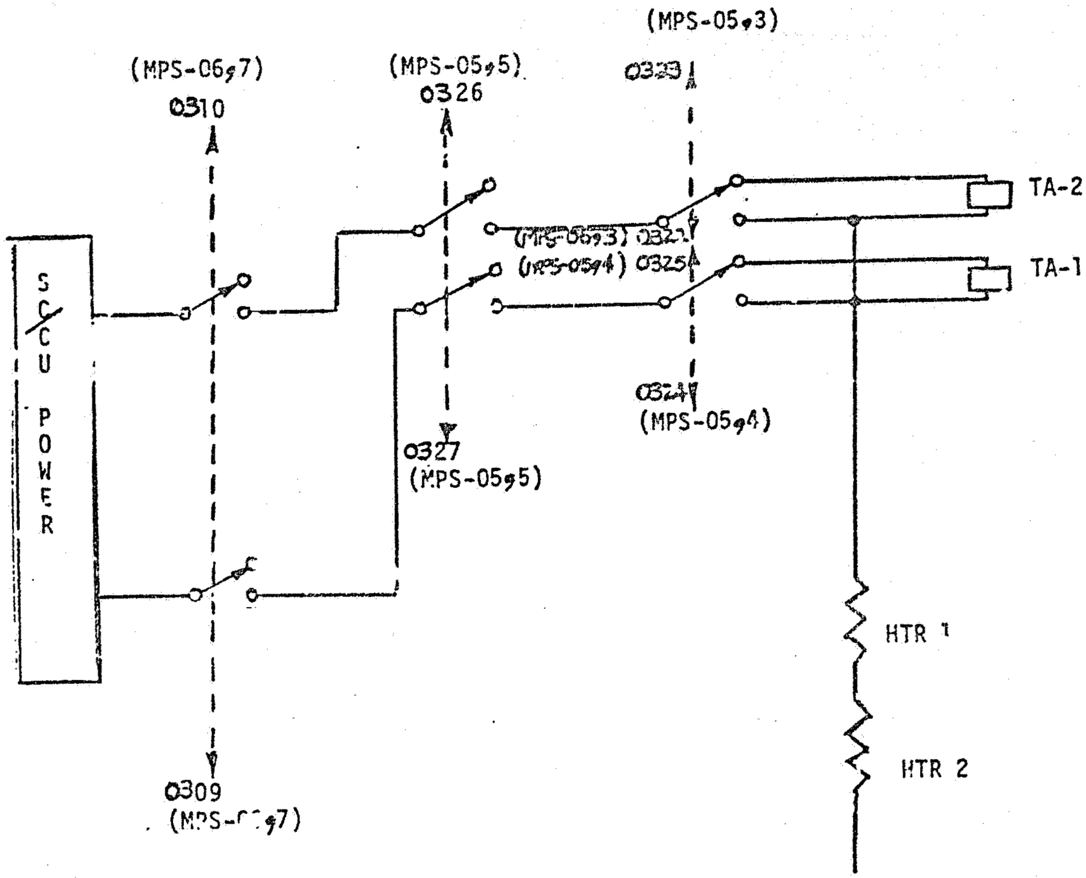
Figure 9-11. Main Array Power Command Control



CHANNEL		CMD
0301	-	Battery 1 On Charge
0302	-	Battery 1 Off Charge
0303	-	Battery 2 On Charge
0304	-	Battery 2 Off Charge
0305	-	Battery 3 On Charge
0306	-	Battery 3 Off Charge
0328	-	Battery 3 Thermal SW Reset
0329	-	Battery 3 Thermal SW Set
0330	-	Battery 2 Thermal SW Reset
0331	-	Battery 2 Thermal SW Set
0332	-	Battery 1 Thermal SW Reset
0333	-	Battery 1 Thermal SW Set
0341	-	Battery 1 & 3 PD Relay Close
0342	-	Battery 2 PD Relay Close
( )	-	TLM Verification (User ID, Bit #)

* HARDLINE CMD

Figure 9-12. Battery Charge Circuit Commands



0309 - Heater Arm
0310 - Heater Disarm
0326 - Auto Heaters On/Off Reset
0327 - Auto Heaters On/Off Set
0322 - Heater Thermostat 2 Bypass Reset
0323 - Heater Thermostat 2 Bypass Set
0324 - Heater Thermostat 1 Bypass Reset
0325 - Heater Thermostat 1 Bypass Set
( ) - TLM Verification (User ID,Bit #)

Figure 9-13. Heater Power Circuit Commands

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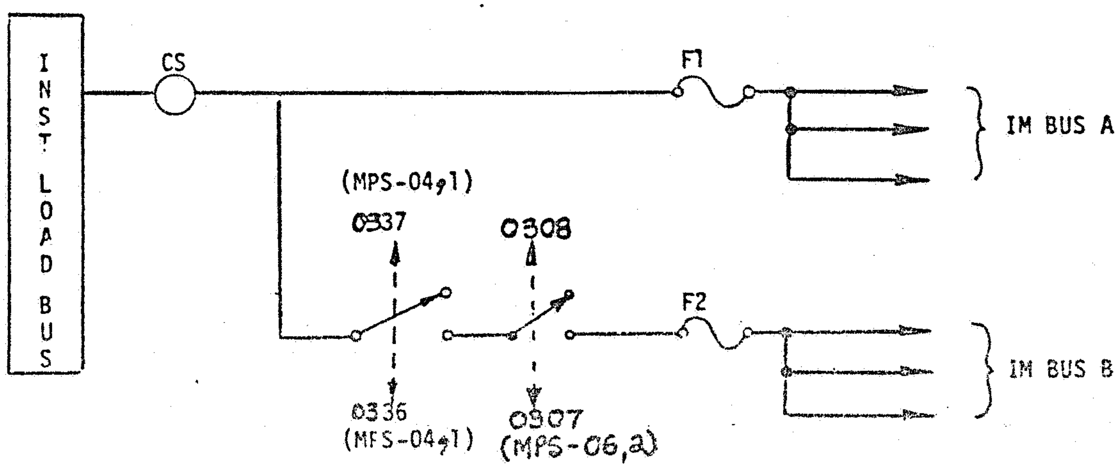

0307 - Instrument Fuse/Power Disconnect RIU B Armed
0308 - Instrument Fuse/Power Disconnect RIU B Disarmed
0336 - Instrument Module Bus B Enable
0337 - Instrument Module Bus B Disable
( ) - TLM Verification (User ID , Bit Number)

Figure 9-14. Payload Power Commands

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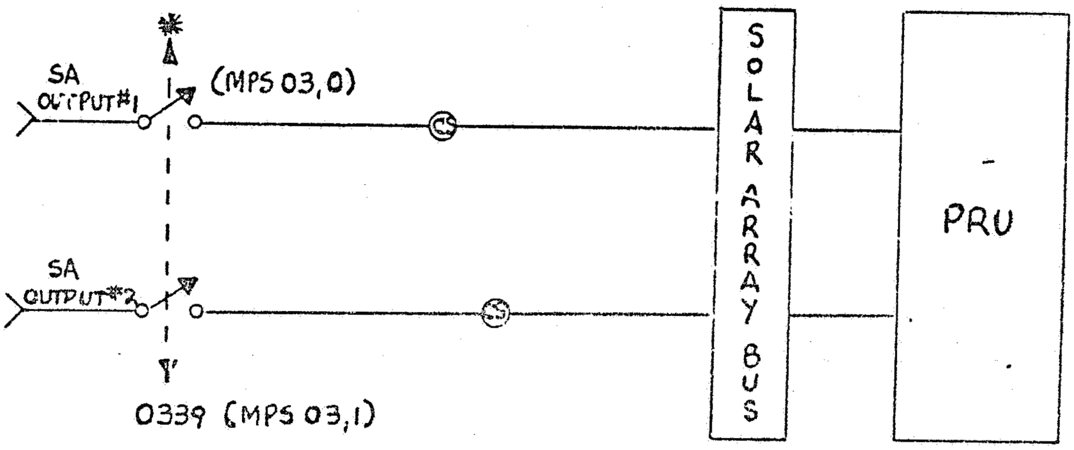

Figure 9-15. Solar Array Power Disconnect CKT

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Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

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MNEMONIC	USER ID	TLM FUNCTION DESCRIPTION	SGNL TYPE	MTX LOC COL, ROW	SMPL RATE	ADDRESS RIU-CH	REMARKS
	MPS-01	STATUS WORD	S	96,50		03-00	SEE SHEET 3
	-02	STATUS WORD 2	S	97,50		03-01	SEE SHEET 4
	-03	STATUS WORD 3	S	98,50-98,119		03-02	SEE SHEET 5
	-04	STATUS WORD 4	S	96,51		03-03	SEE SHEET 6
	-05	STATUS WORD 5	S	97,51		03-04	SEE SHEET 7
	-06	STATUS WORD 6	S	98,51		03-05	SEE SHEET 8
	-07	RIU STATUS	B	98,56		03-08	SEE SHEET 9
	-08	BATT 1 TEMP (PRIMARY)	P	96,20		03-29	
	-42	BATT 1 TEMP (REDUNDANT)	P	96,89		03-21	
	-09	BATT 2 TEMP (PRIMARY)	P	97,20		03-30	
	-43	BATT 2 TEMP (REDUNDANT)	P	97,89		03-22	
	-10	PCU TEMP 1	P	96,19		03-25	
	-11	PCU TEMP 2	P	97,19		03-24	
	-12	PCU TEMP 3	P	98,19		03-20	
	-13	BPA TEMP	P	96,27		03-26	
	-14	PRU TEMP	P	98,27		03-28	
	-15	SCA TEMP	P	97,27		03-27	
	-16	MOD TEMP 1	P	96,25		03-19	
	-17	MOD TEMP 2	P	97,25		03-18	
	-18	MOD TEMP 3	P	98,55		03-17	
	-19	MOD TEMP 4	P	96,26		03-16	
	-20	BATT 1 VOLTAGE	A	96,28		03-32	
	-21	BATT 2 VOLTAGE	A	96,29		03-33	
	-22	LOAD BUS VOLTAGE	A	97,26		03-35	
	-23	BATT 1 3RD ELECTRODE VOLTAGE	A	97,28		03-45	
	-24	BATT 2 3RD ELECTRODE VOLTAGE	A	97,29		03-44	
	-25	BATT 1 DIFFERENTIAL VOLTAGE	A	98,28		03-42	
	-26	BATT 2 DIFFERENTIAL VOLTAGE	A	98,29		03-41	
	-27	SCA DC/DC CONVERTER A VOLTAGE	A	97,18		03-56	
	-28	SCA DC/DC CONVERTER B VOLTAGE	A	98,18		03-48	
	-29	BATT 1 HIGH CURRENT	A	16		03-52	

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Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

2 of 9

NEMONIC	USER ID	TLM FUNCTION DESCRIPTION	SGNL TYPE	MTX LOC COL, ROW	SMPL RATE	ADDRESS RIU-CH	REMARKS
	MPS-30	BATT 2 HIGH CURRENT	A	15		03-51	
	-31	BATT. 1 LOW CURRENT	A	96,14		03-65	
	-32	BATT 2 LOW CURRENT	A	97,14		03-54	
	-33	CS 1 ARRAY/GND PWR CURRENT	A	97,52 97,116		03-57	
	-34	CS 2 ARRAY/GND PWR CURRENT	A	98,52 98,116		03-63	
	-35	INSTRUMENTS LOW CURRENT	A	96,21 96,53 96,85 96,117 59		03-61	
	-36	INSTRUMENTS HIGH CURRENT	A	98,14 60		03-62	
	-37	MACS, PM CURRENT	A	98,05 98,37 98,69 98,101 63		03-58	
	-38	C/OH CURRENT	A	96,22 96,54 96,86 96,118 61		03-59	
	-39	SC/CU, MPS CURRENT	A	97,22 97,54 97,86 97,118 62		03-60	
	-40	TOTAL LOAD CURRENT	A	7 39 71 103		03-49	
	-41	SOLAR ARRAY BUS VOLTAGE	A	96,52 96,116		03-36	

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Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

3 of 9

USER ID	BIT NUMB.	BIT STATE	MEANING/DEFINITION
MPS-D1 STATUS WORD 1	0	0	BATT 1 THML. SW. ENA/DISA. STATUS A SET
		1	BATT. 1 THML. SW. E/D. STATUS A RESET
	1	0	HTR THERMOSTAT 2 BYPASS STATUS. B SET
		1	HTR. THERMOSTAT 2 BYPASS STATUS B RESET
	2	0	HTR THERMOSTAT 1. BYPASS STATUS B SET
		1	HTR THERMOSTAT 1. BYPASS STATUS B RESET
	3	0	AUTO HTR ON/OFF. STATUS B SET
		1	AUTO HTR ON/OFF STATUS B RESET.
	4	0	PRU "M" SET
		1	PRU "M" RESET
	5	0	PRU "VC" SET
		1	PRU "VC" RESET
	6	0	PRU "VB" SET
		1	PRU "VB" RESET
	7	0	PRU "VA" SET
		1	PRU "VA" RESET

Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

USER ID	BIT NUMB	BIT STATE	MEANING/DEFINITION
MPS-02 STATUS WORD 2	0	0	BATT 2 TIML SW ENA/DISA STATUS A SET
		1	BATT 2 TIML SW E/D STATUS A RESET
	1	–	UNUSED BIT
	2	0	BATT CHG RELAY DRVR RIU A ARMED
		1	BATT CHG RELAY DRVR RIU A DISARMED
	3	0	BATT 3 ON CHARGE } NOT USED ON LSD
		1	BATT 3 OFF CHARGE } NOT USED ON LSD
	4	0	BATT 2 ON CHARGE
		1	BATT 2 OFF CHARGE
	5	0	BATT 1 ON CHARGE
		1	BATT 1 OFF CHARGE
	6	0	PRU "IB" SET
		1	PRU "IB" RESET
	7	0	PRU "IA" SET
		1	PRU "IA" RESET

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Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

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USER ID	BIT NUMB	BIT STATE	MEANING/DEFINITION
MPS-03 STATUS WORD 3	0	0	PD RELAY ARRAY 2 OPEN
		1	PD RELAY ARRAY 2 CLOSED
	1	0	PD RELAY ARRAY 1 OPEN
		1	PD RELAY ARRAY 1 CLOSED
	2	0	PD RELAY BATT 3 OPEN } SHOULD BE "OPEN" ALWAYS FOR LSD
		1	PD RELAY BATT 3 CLOSED }
	3	0	PD RELAY BATT 2 OPEN
		1	PD RELAY BATT 2 CLOSED
	4	0	PD RELAY BATT 1 OPEN
		1	PD RELAY BATT 1 CLOSED
	5	—	BATT 3 TEMP MON (NOT USED ON LSD)
	6	0	BATT 2 TEMP OVER LIMIT
		1	BATT 2 TEMP NORMAL
	7	0	BATT 1 TEMP OVER LIMIT
		1	BATT 1 TEMP NORMAL

Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

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USER ID	BIT NUMB.	BIT STATE	MEANING/DEFINITION
MPS.-04 STATUS WORD 4	0	-	BATT. B THML SW STATUS A
	1	0	INSTR MODULE 28V BUS B ENABLED
		1	INSTR. MODULE 28V BUS B DISABLED
	2	0	SAFE MODE COMMAND NORMAL
		1	SAFE MODE COMMAND SENT
	3	0	COMPUTER MON ENA/DISA STATUS A SET
		1	COMPUTER MON E/D STATUS A RESET
	4	0	COMPUTER PULSE TIMER NORMAL
		1	COMPUTER PULSE TIMER FAILURE
	5	0	INSTR FUSE/PD RELAY DRVR RIU A ARMED
		1	INSTR. FUSE/PD RELAY DRVR RIU A DISARMED
	6	0	HEATER RELAY DRIVER RIU A ARMED
		1	HEATER RELAY DRIVER RIU A DISARMED
	7	-	UNUSED BIT

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Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

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USER ID	BIT NUMB	BIT STATE	MEANING/DEFINITION
MPS-05 STATUS WORD 5	0	—	BATT. 3 THML SW STATUS B (
	1	0	BATT. 2 THML SW ENA/DISA STATUS B SET
		1	BATT. 2 THML SW E/D STATUS B RESET
	2	0	BATT 1 THML SW E/D STATUS B SET
		1	BATT 1 THML SW E/D STATUS B RESET
	3	0	HTR THERMOSTAT 2 BYPASS STATUS A SET
		1	HTR THERMOSTAT 2 BYPASS STATUS A RESET
	4	0	HTR THERMOSTAT 1 BYPASS STATUS A SET
		1	HTR THERMOSTAT 1 BYPASS STATUS A RESET
	5	0	AUTO HTR ON/OFF STATUS A SET
		1	AUTO HTR ON/OFF STATUS A RESET
	6	0	PD RELAY LOAD 2 OPEN
		1	PD RELAY LOAD 2 CLOSED
	7	0	PD RELAY LOAD 1 OPEN
		1	PD RELAY LOAD 1 CLOSED

Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

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USER ID	BIT NUMB	BIT STATE	MEANING/DEFINITION
MPS-26 STATUS WORD 6	0-3	-	UNUSED BITS
	4	0	COMPUTER MON ENA/DISA STATUS B SET
		1	COMPUTER MON E/D STATUS B RESET
	5	0	BATT CHG RELAY DRVR RIU B ARMED
		1	BATT CHG RELAY DRVR RIU B DISARMED
	6	0	INSTR FUSE/PD RELAY DRVR RIU B ARMED
		1	INSTR FUSE/PD RELAY DRVR RIU B DISARMED
	7	0	HEATER RELAY DRIVER RIU B ARMED
		1	HEATER RELAY DRIVER RIU B DISARMED

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Table 9-3. Landsat-D Modular Power Subsystem Telemetry List Summary

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USER ID	BIT NUMB	BIT STATE	MEANING/DEFINITION
MPS-07 RIU STATUS	0-1		RIU STATUS
		00	RIU: A ON, B OFF
		01	RIU: A ON, B STANDBY 1
		10	RIU: B ON, A OFF
		11	RIU: B ON, A STANDBY 1
	2-7		NOT USED

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10.0 SOLAR ARRAY DRIVE AND POWER TRANSMISSION SYSTEM

SECTION 10.0

SOLAR ARRAY DRIVE AND POWER TRANSMISSION ASSEMBLY (SADAPTA)

10.1 FUNCTIONAL DESCRIPTION

The SADAPTA provides the following functions:

1. Retain the rotatable solar array to the Instrumentation Module. A solar array shaft supports the slip rings, and provides the interface with solar array jettison assembly. A housing assembly supports the drive modules, the slip ring assembly, the solar array shaft, and provides the interface with the Instrument Module structure.

2. Rotate the solar array. Two redundant drive modules interface with the PDU. They rotate the solar array at 0, 1, 2 or 3 times orbital rate (3.70°/minute).

3. Transfer electrical power and signals. A slip ring assembly transmits electrical power and signals across the rotary joint, and provides shaft position signals. The slip ring assembly interfaces with the subsystems defined in Paragraph 10.1.2.

4. Indicate angular position of the solar array (position potentiometers and switches interface with the PDU and define angular position).

Each drive module consists of a stepper motor, a speed reducer, a spring clutch, and a spur gear pinion in mesh with a common gear of the two drive modules (see Figure 10.1-1). Figure 10.1-2 shows the Solar Array Drive Logic Block Diagram.

The slip ring assembly consists of a slip ring rotor mounted on the solar array shaft, two redundant position indicators mounted on the shaft, and brush and wiper blocks mounted on the housing.

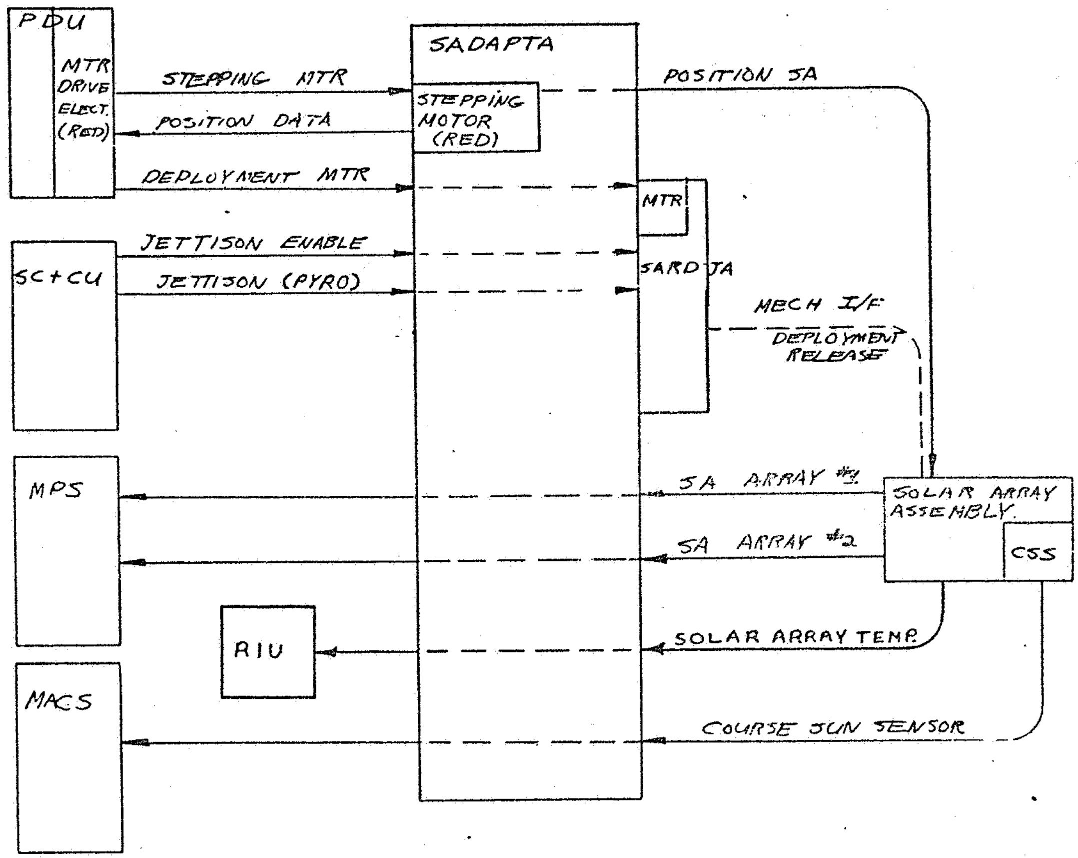

Figure 10.1-1. SADAPTA Functional Block Diagram

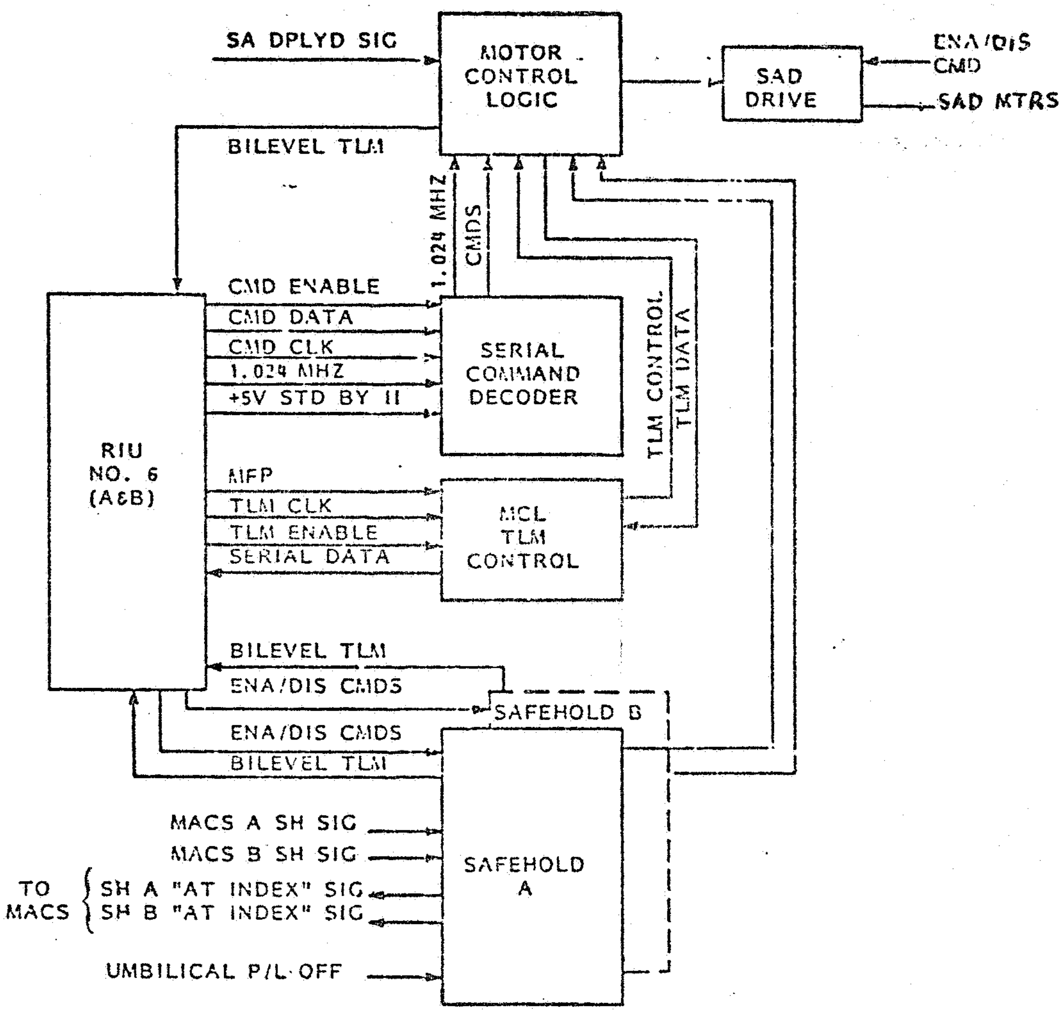

Figure 10.1-2. SAD Logic Block Diagram

10.1.1 MECHANICAL INTERFACES

The SADAPTA interfaces mechanically with the Instrument Module (IM) structure and the solar array jettison assembly.

10.1.2 ELECTRICAL INTERFACES

The SADAPTA interfaces electrically with the following Flight Segment subsystems, assemblies and components:

1. Power Distribution Unit (PDU)
2. Solar Array Retention, Deployment, Jettison Assembly (SARDJA)
3. Solar Array Assembly
4. Coarse Sun Sensor (CSS) Assembly
5. Signal Conditioning & Control Unit (SC&CU)
6. Modular Power Subsystem (MPS)
7. Modular Attitude Control Subsystem (MACS)
8. Remote Interface Unit (RIU7)

10.2 PERFORMANCE CAPABILITIES

10.2.1 ROTATION AND STEP ANGLE

1. The SADAPTA direction of rotation is CLOCKWISE when viewed from the Solar Array.

2. The SADAPTA shaft step angle is $0.0030857^{\circ} \pm 5$ percent non-cumulative per input pulse, and 116, 666 $+400/-100$ pulses for a full 360° rotation after the first 12000 pulses have fully engaged the wrap spring clutch.

10.2.2 STEP RATE, PULSE WIDTH AND SEQUENCING

The step rate of the SADAPTA is approximately 20, 40, or 60 pulses per second (pps) with pulse width of 0.015 second and detent current of 23.5 ma minimum when full current is removed. Change of step rate is in increments of approximately 20 pps with a minimum of 60 steps at each step rate. The DC supply to the drive electronics is 28 +5, -6.5 VDC.

10.2.3 SLIP RING ELECTRICAL CIRCUITS

The SADAPTA has 40 slip ring circuits.

10.2.4 ARRAY POSITION INDICATOR

The SADAPTA provides two redundant position indicators each consisting of a conductive plastic type potentiometer and a segmented switch. The output of the potentiometer and segmented switch is as shown in Figure 10.2-1.

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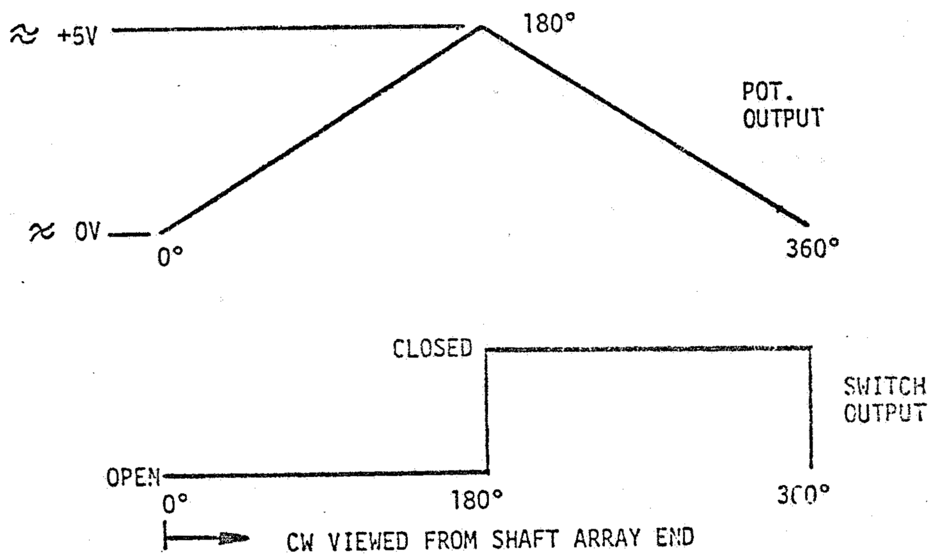

Figure 10.2-1. Potentiometer & Segmented Switch Outputs

10.2.4.1 Potentiometer

The indicator position potentiometer has the following characteristics:

1.	Mechanical Range -	360° continuous
2.	Electrical Range -	360° continuous
3.	Excitation -	0V & +5V $\pm$ 0.005V
4.	Linearity - (360° Base)	$\pm$0.4% from 10° to 170° and from 190° to 350° $\pm$0.7% from 170° to 190° and from 350° to 10° Including alignment tolerance between potentiometers.

10.2.4.2 Segmented Switch

The segmented switch has the following characteristics:

1.	Switch Open -	From 0° to 180°
2.	Switch Closed -	From 180° to 360°
3.	Switching Accuracy -	$\pm$1.5°
4.	Input Voltage -	+5V

10.3 MODES OF OPERATIONS

The SADAPTA modes are selected according to the following mission phases:

Launch Phase -	Zero rotation rate
In-Orbit Phase -	Zero, Wo*, 2XWo, and 3xWo rates can be commanded in an open loop mode, or controlled by the PDU in a closed loop mode using the coarse sun sensors (pointing accuracy = $\pm$7°).
Orbit Adjust -	Zero rate during the orbit adjust, and 3xWo rate during array slews after the orbit adjust will be commanded.

*Orbit Rate approx. 3.6°/min

Safehold -

a) Inertial - drive at 2 Wo until the index position is obtained, then remain at zero. (Not planned for use on Landsat-D but is available if command selected.

b) Earth Sensor - zero, Wo and 2xWo, using the coarse sun sensors.

10.4 CONSTRAINTS

1. Solar array release is to be initiated by the OBC. After separation, telemetry is sampled two consecutive times and the SA is released by the OBC via the SC&CU. Confirmation of the Solar Array deployment must be received in 20 minutes or the OBC will reinitiate the deployment sequence over the "B" link.

2. During Orbit Adjust rocket firing, the SA must be aligned in the plane of the thrust vector, $278^{\circ} \pm 5^{\circ}$ (approximately noon position).

3. The SAD operation is to be constrained as follows:

   a. The SAD is to be driven open loop at a constant rate when the TM is imaging during the day. The TM jitter caused by a change of the SAD rate will require approximately two minutes for the jitter to be reduced to an acceptable level. Hence, if there is a rate change of the SAD during the day, the imaging with the TM must be discontinued for two minutes beyond the SAD rate change period.

   b. There cannot be any change in the SAD rate within two minutes from the start of the imaging by the TM during the day.

   c. The SAD rates can change by only one times the orbital angular rate within a two minute period TM imaging at night (e.g., 1X to 2X or 2X to 3X but not 1X to 3X).

   d. The SA positioning loop must be closed during slews once per day to eliminate open loop drifts of the solar array to the sun.

10.5 REDUNDANCY

See Figure 10.5-1 for description of the redundancy of SADAPTA interfaces.

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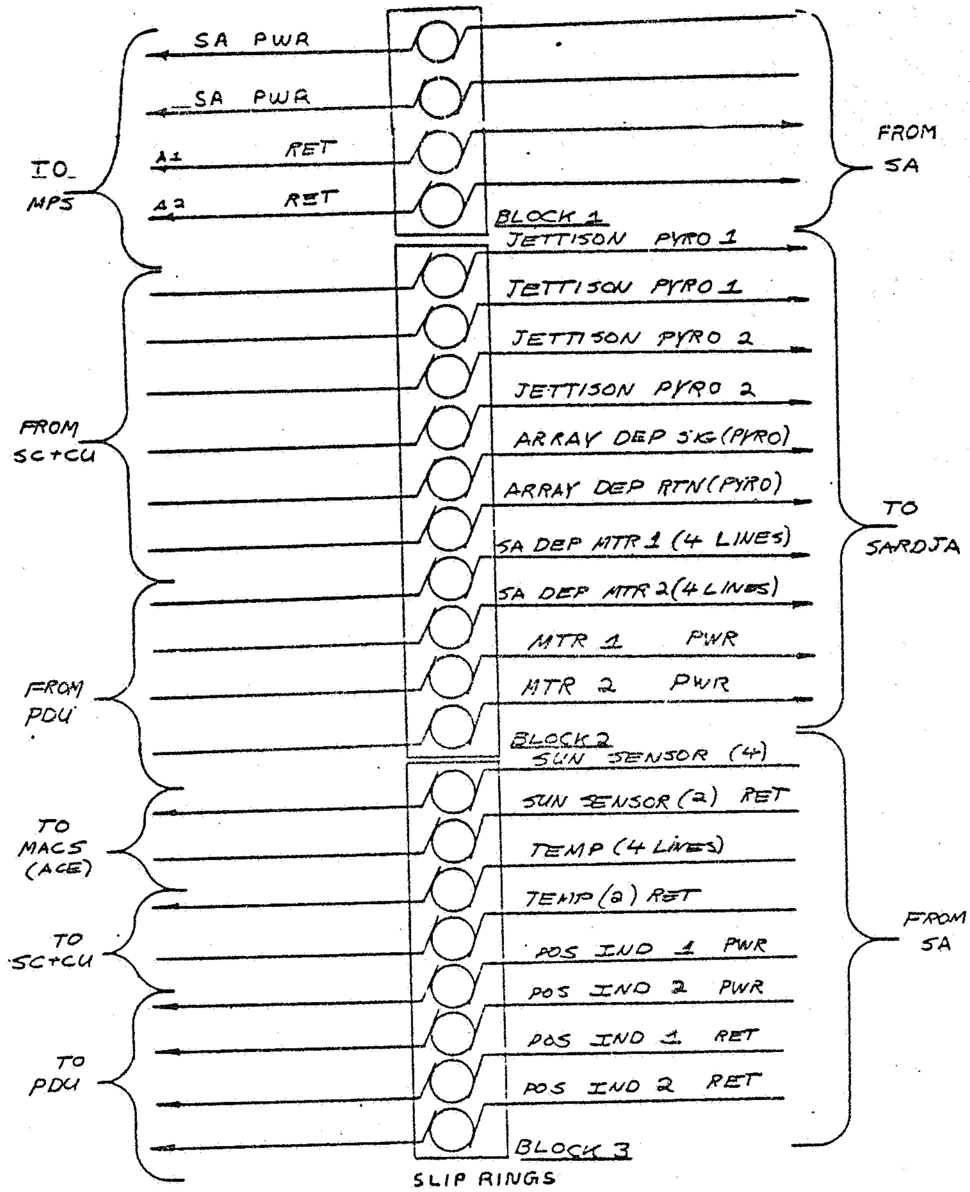

Figure 10.5-1. SADAPTA Redundancy

10.6 COMMANDS

A description of SADAPTA commands will be provided in the PDU Command Directory, Paragraph 11.6.

10.7 TELEMETRY

A description of SADAPTA telemetry will be provided in the PDU Telemetry Directory, Paragraph 11.7.

11.0 POWER DISTRIBUTION UNIT

SECTION 11.0

POWER DISTRIBUTION UNIT

The Power Distribution Unit (PDU) is a component of the electrical system of the Landsat D Instrument Module (IM) and, as such, contains the electronics necessary to provide for the functions of solar array and boom deployment, and solar array drive. The PDU electronics is involved in the satellite operation in all spacecraft operational modes: initial acquisition, orbital and Safe Hold.

11.1 PDU FUNCTIONAL DESCRIPTION

The function of the PDU is to:

1. Distribute and switch power among electrical systems of the IM with the exception of the Wideband Communications Subsystem (WBCS).
2. Protect electrical busses in the IM with the exception of the WBCS.
3. Provide autonomous control and drive electronics for solar array and TDRS mast deployment/retraction and solar array drive motors.
4. Provide IM Safe Hold Mode Control.
5. Switching of heater loads under the control of remote electronic thermostats.
6. Provide regulated voltage power to the internal PDU electronics as well as to specified external electronics.

The PDU also provides block redundancy of the power supplies, motor control and drive circuits, PCD Formatter and SAFE-HOLD Electronics. See Section 20 for Payload Correction Data (PCD) subsystem description.

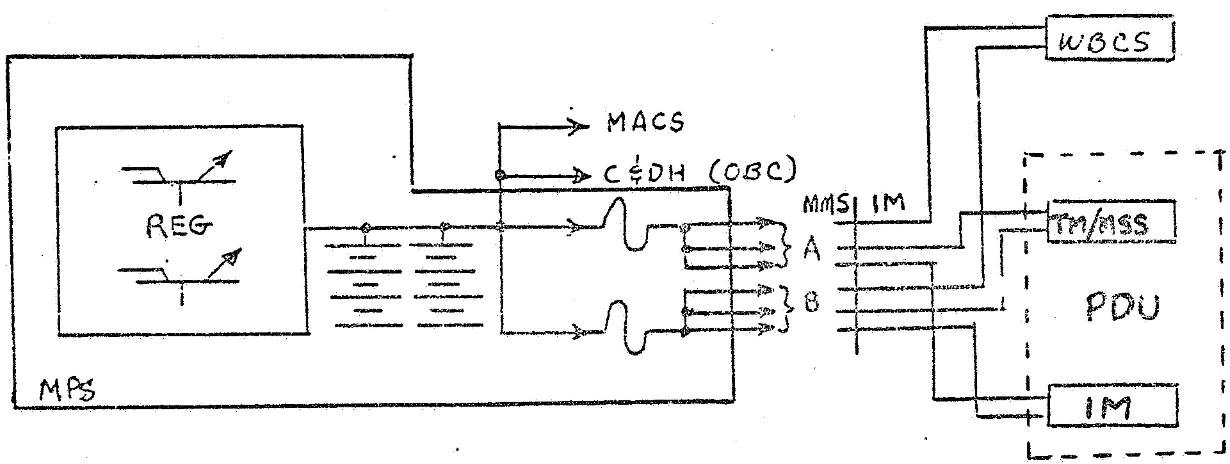

Figure 11.1-1. IM Output Bus

Figure 11.1-1 shows the IM output bus. It supplies 28 Vdc to the P/L bus A1, B1, to the IM bus A2, B2, and to the WBCS. Figure 11.1-2, PDU Block Diagram, shows the PDU component functions and their interfaces.

11.1.1 PRIMARY POWER SWITCHING

Unregulated bus power is distributed by the PDU to the loads identified in Table 11.1-1.

Power for each of these loads is provided with fusing for bus protection. These lines also include switching where indicated, primarily as Enable/Disable control, with the exception of RIU 6, 7 and 8, which remain powered continuously through the PDU. Except for RIU's, where A and B loads are listed, only one of the two outputs will draw power at any one time.

Switching control is exercised by use of ground commands with further control of selected loads by the Safe-Hold electronics and by use of the "Payloads Off" signal (hardline) or command.

The loads checked in the Payloads OFF column of Table 11.1-1 are simultaneously disabled by the receipt of a "Payloads Off" command. The Safe-Hold electronics also has the capability to simultaneously disable these loads.

Telemetry signals indicating status for switching functions are listed in the Telemetry Directory.

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Table 11.1-1. Primary Power Loads

LOAD DESCRIPTION	SOURCE BUS	SWITCHING	PAYLOADS OFF
TM POWER SUPPLY A	A1	EN/DIS	X
TM POWER SUPPLY B	B1	EN/DIS	X
TM SMA HTR	AB1	EN/DIS	
TM FUSE LINKS	AB1	EN/DIS	
MSS POWER SUPPLY A	A1	EN/DIS	X
MSS POWER SUPPLY B	B1	EN/DIS	X
MSS FT TLM	AB1	NONE	
RIU 6 A	A2	NONE	
RIU 6 B	B2	NONE	
RIU 7 A	A2	NONE	
RIU 7 B	B2	NONE	
RIU 8 A	A2	NONE	
RIU 8 B	B2	NONE	
S-BAND A	A2	EN/DIS	X
S-BAND B	B2	EN/DIS	X
USS HTR 2 A	A2	EN/DIS	
USS HTR 2 B	B2	EN/DIS	
GPS	AB2	EN/DIS	X
MSS I/F HTR 2	AB2	EN/DIS	
BOOM HINGE HTRS	AB2	EN/DIS	
TM HTR	AB2	EN/DIS	
PDU PS A	A2	A/B SELECT	
PDU PS B	B2		
SPARE 1	A2 or B2	EN/DIS & BUS SELECT	
SPARE 2	A2 or B2	EN/DIS & BUS SELECT	
SPARE 3	A2 or B2	EN/DIS & BUS SELECT	

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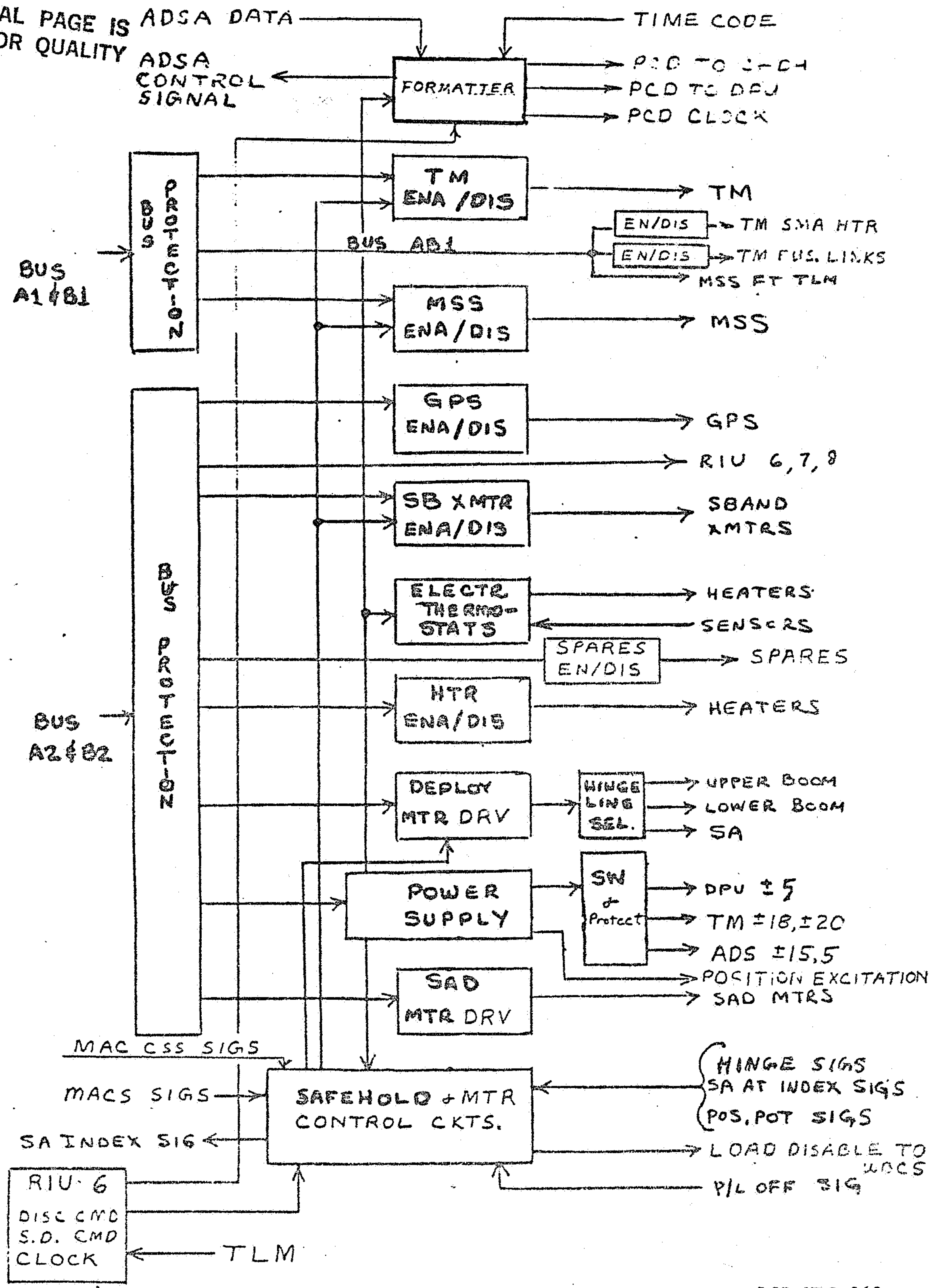

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Figure 11.1-2. PDU Block Diagram

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11.1.2 BUS CONFIGURATION

"Primary" or "A" sections of block redundant subsystems (TM, MSS, RIU, S-Band Xmtrs, Deploy Motors) are powered from a +28 VDC Bus A. "B" sections of block redundant subsystems are powered from a +28 VDC Bus B. The Payload (P/L) Bus is designated as Bus 1 and the IM Bus as Bus 2.

Power return for Bus 1 input and loads are separate from Bus 2 input and loads. Non-redundant outputs (GPS, IM heaters) are powered through diode "OR" gates from both buses (see Figure 11.1-3).

Bus nomenclature is shown in Figure 11.1-3. An output bus created by "ORing" an A or B bus is indicated in Table 11.1-1 by the double prefix AB. The "Spare" loads are connectable to A2 or B2 by a command controlled relay.

+28V, BUS A1	TM A Components MSS A Components
+28V, BUS AB1	Non-redundant TM & MSS Components
+28V, BUS B1	TM B Components MSS B Components
+28V, BUS A2	IM Subsystems, A Components
+28V, BUS AB2	Non-redundant IM subsystems
+28V, BUS B2	IM Subsystems, B Components

Figure 11.1-3. +28 V BUS Nomenclature

11.1.3 SOLAR ARRAY DRIVE (SAD) MOTOR CONTROLS

Redundant SAD motor circuits are provided to pulse redundant stepper motors used for solar array rotation. A 4-coil motor is powered in single phase sequential excitation. The motor control circuit is capable of initiating the sequence by command and is incapable of reversing the sequence. The SAD motor control circuit is capable of pulsing the motor at 3 integer multiple rates (defined as W_o, $2W_o$ and $3W_o$) and is also designed to not pulse (zero rate). These rates are selectable by command. The $3W_o$ rate is 17378 +2, -1 cycles of the 1.024 MHz (RIU) clock per output pulse.

The motor control logic is designed to provide zero rate in the absence of a "SA-Deployed" signal. If this signal is not present, the control logic will execute rate commands if an override has been indicated by the receipt of a specific command provided for this purpose. At initial power turn on, the logic is preset as if the override command had been received. The inhibit logic is designed to be enabled (i.e., hold zero rate in the absence of "SA-Deployed" signal) by a single ground command. Telemetry points to indicate rate and inhibits override status are listed in the Telemetry Directory.

In the Safe Hold mode, the SAD motor control circuits will respond only to the control of the SAFE-HOLD circuits until receipt of a special command which returns the SAD to normal command control and sets zero rate.

11.1.4 DEPLOYMENTS

Redundant deployment motor circuits are provided to pulse redundant stepper motors used for solar array, boom lower (root) hinge and boom upper hinge deployment and retraction. The 4-coil motor is powered in single phase excitation. The motor phases are pulsed at a rate of 8687 $\pm$ 1 pulses of the 1.024 MHz clock per output pulse. The motor control circuit is capable of initiating the same sequence, for each motor, by command. The motor control circuit is capable of initiating a "reverse" sequence, by command or by hardline. Table 11.1-2 lists the sequence control source for the deployment motors.

Table 11.1-2. Normal Sequence Control Source

DEPLOYMENT FUNCTION	CONTROL SOURCE		TERMINATION SIGNAL
	FORWARD	REVERSE	
SOLAR ARRAY	COMMAND	TEST SIGNAL & COMMAND	SOLAR ARRAY DEPLOYED+2048 STEPS
BOOM LOWER HINGE	COMMAND	TEST SIGNAL & COMMAND	L HINGE DEPLOYED+2048 STEPS
BOOM UPPER HINGE	COMMAND	COMMAND (two required)	U HINGE DEPLOYED+2048 STEPS

11.1.5 HEATER CONTROL

The PDU provides electronic heater control circuits for the six (6) sets of IM heaters listed below. One set of heater control circuits is illustrated in Figure 11.1-4.

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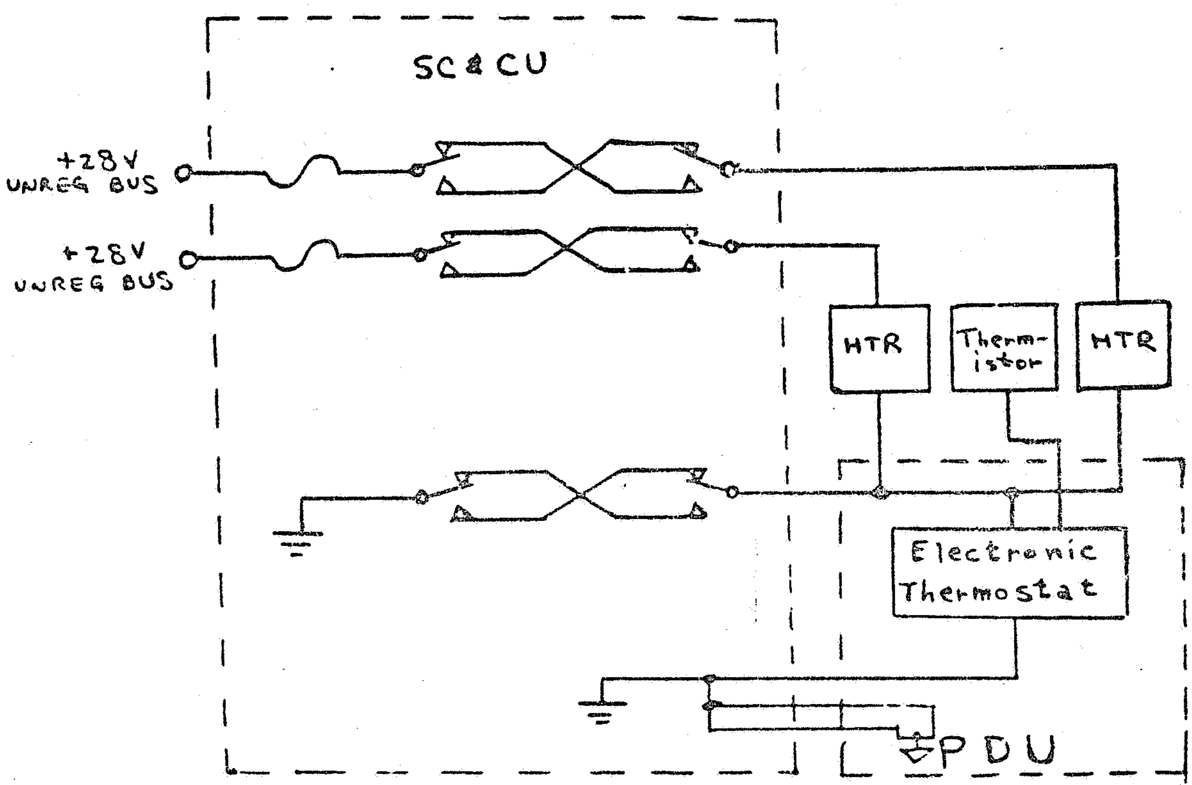

Figure 11.1-4. Electronic Thermostat I/F

HEATER NAME

1. UPPER SUPPORT STRUCTURE HTR #1
2. S-BAND TRANSMITTER RADIATOR HEATER
3. MISSION ADAPTER/TM HEATER
4. MSS INTERFACE HEATER
5. WIDEBAND MODULE I/F HEATER
6. UPPER SUPPORT STRUCTURE HTR #2

Power, power return, bus protection and Enable/Disable control for these heaters is provided by the SC&CU. Thermistors, appropriately placed on the TM structure, provide the temperature sensing for the electronic thermostats. Figure 11.1-4 illustrates the interfaces with the PDU circuits. A power return reference common to all 6 heaters is as shown in Figure 11.1-4. Two (A&B), one (A or B), or none of the heaters can be enabled.

11.1.6 REGULATED VOLTAGE POWER

11.1.6.1 Internal

Power supplies provide regulated voltage as required by the PDU internal circuits. These circuits include, but are not limited to, the SAD and deploy motor control electronics, safe-hold logic, electronic thermostats, and Formatter.

11.1.6.2 External

The PDU supplies the external loads listed in Table 11.1-3. The DC voltage column is the minimum and maximum output voltage over all conditions of life, input line, temperature, and dc load conditions. The peak failure transient column provides the maximum allowable overvoltage resulting from PDU internal failure or load fault clearing on another output.

11.2 PERFORMANCE CAPABILITIES

11.2.1 VOLTAGE DROP

Output Function	Vin-Vout (in Millivolts)
TM Instrument	170
MSS Instrument	130
S-Band Xmtr	130
RIU	130
Other non diode OR'd Outputs	350
Diode OR'd Outputs:	
Heaters	1500
Other	1000

Total voltage drop between PDU input connectors (for MPS unregulated power) and the output connectors which includes both the plus and return wiring is shown above. Voltage drop limit applies when all outputs are fully loaded to worst case low line levels. All outputs means only one block of redundant loads (A or B block).

11.2.2 UNREGULATED POWER BUS Characteristics of the unregulated power bus are shown in Table 11.2-1.

Table 11.2-1. Unregulated Power Bus

- Voltage: Average voltage 21.3 to 35 VDC
- Maximum Dynamic Impedance

  0.10 ohms - 1 Hz to 1 kHz
  0.15 ohms - 1 kHz to 20 kHz
  0.30 ohms - 20 kHz to 100 kHz

- Voltage Transients. The bus voltage will remain within the range 22-35 VDC except for normal Transients or Failure Modes.

  Normal Transient:

  ± 3.0 Volt 0 to 10 usec
  ± 1.0 Volt 10 usec to 1.0 msec

  Step Changes:

  5 volts maximum voltage change
  Rate of Rise ≤ 0.5 Volts/usec

  Rate of Fall ≤ 5.0 Volts/msec

  Abnormal Voltage Transients (Failure Mode):

  Down to 0 Volt or up to 40 Volts per 500 msec.

- Voltage Ripple. Less than 750 mv, peak-to-peak, 1 Hz to 10 MHz.

11.2.3 SECONDARY REGULATED POWER OUTPUTS A description of the secondary regulated power outputs is given in Table 11.2-2.

Table 11.2-2. Secondary Regulated Power Outputs

Output Description	Source	Return Ref.	DC Voltage	Peak Failure Transient	Narrow-band % P-P	Command Switching
DPU A Continuous	PS A					None
DPU B Continuous	PS B		4.65 to 5.5	7.0 Volts	1%	None
DPU A Switched	PS A	PDU/ DPU	(±5)			ON/OFF
DPU B Switched	PS B	SIG	(±5)			
ADS ±15, +5	PS A OR PS B Switch Selected	RTN	15 ±3% 4.65 to 5.5	22V 7V	1% 1%	ON/OFF
TM 18^{-1} +18 -18	PS A or PS B Switch	TM-18	18 +2,-1.9V	(+ or -) 25 volts	.5%	ON/OFF, and A/B select
TM 20^{-2} +20 -20	Selected	TM-20	20 +2,-1.9V			

11.2.4 SAD OUTPUT CHARACTERISTICS

The power for the motor drive will be the 2A and 2B busses. The drive to each motor phase will consist of 15 $\pm$ 1.5 milliseconds of > 111.23.5 volts followed by current drive of 23.5 to 50 milliamps for the time remaining until the next phase pulse.

11.3 MODES OF OPERATION

The Power Distribution Unit (PDU) provides switching to all electrical systems (other than the WBCS) of the IM from the Modular Power Subsystem (MPS) through the MPS Module/Spacecraft interface connectors and MMS harness. Switching control is exercised by ground commands with further control of selected loads by the SAFE-HOLD electronics and by use of a "Payloads OFF" signal. The PDU receives discrete commands from the OBC through RIU interface circuits. These OBC commands position relays fo. the desired operating mode. The PDU operating modes are discussed below:

11.3.1 PRIMARY POWER SWITCHING

Primary power lines identified in Table 11.1-1 can be switched primarily as Enable/Disable control with the exception of RIU's 6, 7 and 8 which are powered continuously through the PDU. Except for the RIU's, where A and B loads are listed, only one of the two outputs will draw power at any particular time. The power loads checked in the Payloads OFF column of Table 11-1 can be simultaneously disabled by receipt of either a "Payloads OFF" command or by the Safe-Hold electronics.

11.3.2 SOLAR ARRAY DRIVE (SAD) MODES

11.3.2.1 Orbit Phase

In this phase, the SAD can be commanded in an open loop or closed loop operating mode. The SAD is normally driven at the $1W_o$ rate, or may be commanded to Stop, $2W_o$, or $3W_o$ as described in Paragraph 11.1.3. Closed loop operation uses the coarse sun sensor to point the array at the sun, accuracy ± 7 degrees.

11.3.2.2 Safe Hold Modes

This mode may be executed by signal from the MACS or by ground command. There are two different Safe Hold modes:

1. Inertial Mode
2. Earth Sensor Mode (closed loop mode)

These modes are selected by command. Upon initiation of Safe Hold inertial mode the Safe Hold logic will initiate a SAD rate of $2W_o$. If the initial SAD rate is zero, a PDU circuit will initiate a SAD rate of W_o for a duration of 3 to 30 seconds prior to stepping up to the $2W_o$ rate. Upon receipt of a SA-at-index position indication (from SADAPTA position indicators), the SAD rate will be set to zero and two signals will be sent to the MACS indicating SA is at the index position, and a telemetry indication provided.

Upon initiation of the Earth Sensor Safehold Mode, the Coarse Sun Sensor (CSS) is utilized to position the SA. The signals from the redundant CSS via the MACS will control the SAD Drive Rate, selecting zero, $_o$, or $2W_o$ rate to point the SA properly.

Normal orbit mode is established by command, if MACS Safe Hold signals are not present.

11.4 CONSTRAINTS

11.4.1 PDU INITIALIZATION CONSTRAINTS

TBD

11.4.2 PDU TELEMETRY CONSTRAINTS

TBD

11.4.3 PDU COMMAND CONSTRAINTS

TBD

11.4.4 PDU TEMPERATURE CONSTRAINTS

TBD

11.4.5 PDU OPERATING MODE CONSTRAINTS

TBD

11.4.6 PDU SAFE HOLD CONSTRAINTS

Once the Safe Hold signal from the MACS has been detected, the PDU must be commanded back to the normal orbital mode for recovery. Even the loss of the Safe-Hold signal from the MACS does not revert the PDU to the orbit normal mode until receipt of the "SOLAR ARRAY DRIVE ORBIT MODE" command.

11.5 REDUNDANCY

The PDU features block redundancy of the power supplies, motor control and drive circuits, Formatter and the SAFE-HOLD electronics.

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11.5.1 FAILURE PROVISIONS

Power distribution, bus protection and switching is devised such that a single failure will prevent the execution of no more than one ON or ENABLE function of the loads in Table 11.1-1. No single part failure will preclude removal of power to the Boom Hinge heaters.

11.5.2 SECONDARY POWER GENERATION AND SWITCHING

Redundant power supplies are provided for the generation of regulated voltages, isolated from chassis and power return. Ground commands are provided to select which of the redundant units is on.

11.5.3 SAD

Redundant SAD circuits are provided to pulse redundant stepper motors used for solar array rotation.

11.5.4 DEPLOYMENTS

Redundant deployment motor circuits are provided to pulse redundant stepper motors used for solar array, boom lower (root) hinge deployment and boom upper hinge deployment and retraction.

11.5.5 SAFE-HOLD

A redundant set of safe hold circuits is provided to perform the following functions:

1. Accept a "Safe-Hold" signal (from the block redundant MACS) and:

   a. Disable payloads.

   b. Drive the solar array to index if in inertial mode.

   c. Indicate to MACS that the solar array is at index if in inertial mode.

   d. Drive Solar Array at desired rate (as determined by CSS input) if in earth sensor mode.

2. Accept ground commands to perform the above.

3. Redundant safe-hold logic electronics will be continuously energized by cross-strapping the outputs of the redundant power supplies to the logic power inputs.

11.5.6 MOTOR CIRCUITS

Motor circuits are completely redundant. The only cross-strapping is the safe-hold logic to SAD motor circuits. This total redundancy is illustrated functionally in Figure 11.5-1.

11.6 COMMANDS

The PDU will provide the circuitry necessary to perform the functions identified in the Command Directory.

11.7 TELEMETRY

The PDU will output to the RIU the telemetry functions detailed in the Telemetry Directory. For information regarding calibration curve coefficients for the telemetered functions, see Appendix A.11.

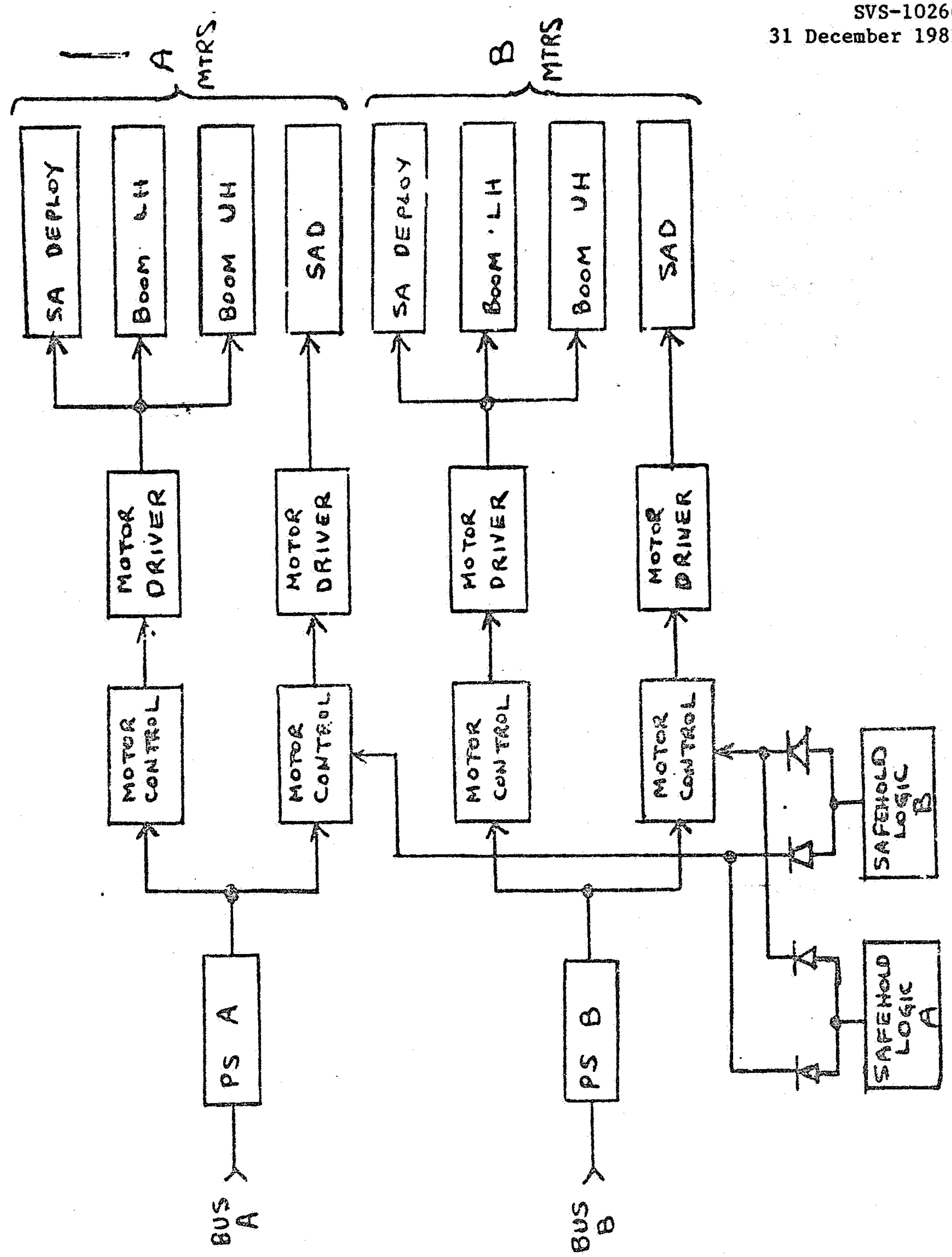

Figure 11.5-1. Motor Circuit Functional Block Diagram

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12.0 DIGITAL PROCESSING UNIT

SECTION 12.0

DIGITAL PROCESSING UNIT

12.1 DPU FUNCTIONAL DESCRIPTION

The Digital Processor Unit (DPU) maintains the time code and formats and distributes the time code to the Thematic Mapper (TM), the Multispectral Scanner (MSS), the Payload Correction Data (PCD) Formatter, and the redundant Remote Interface Units (RIU's). In addition, the DPU converts the data stream from the PCD Formatter (located in the Power Distribution Unit, PDU) into an eight bit word and sends it to the TM. The DPU is block redundant (A and B side) and obtains its power from the Power Distribution Unit (PDU).

Figure 12.1-1, DPU Block Diagram, depicts the component functions.

12.1.1 TIME CODE

The DPU time code is 56 bits in length. Four bits are the spacecraft identification code which identifies the spacecraft, either Landsat-D (1110) or Landsat-D Prime (110?). The remaining 52 bits of the time code represent time. The most significant bits represent hundreds of days of the year down to the 4 least significant bits representing fractions of milliseconds, with the least significant bit representing 1/16th of a millisecond.

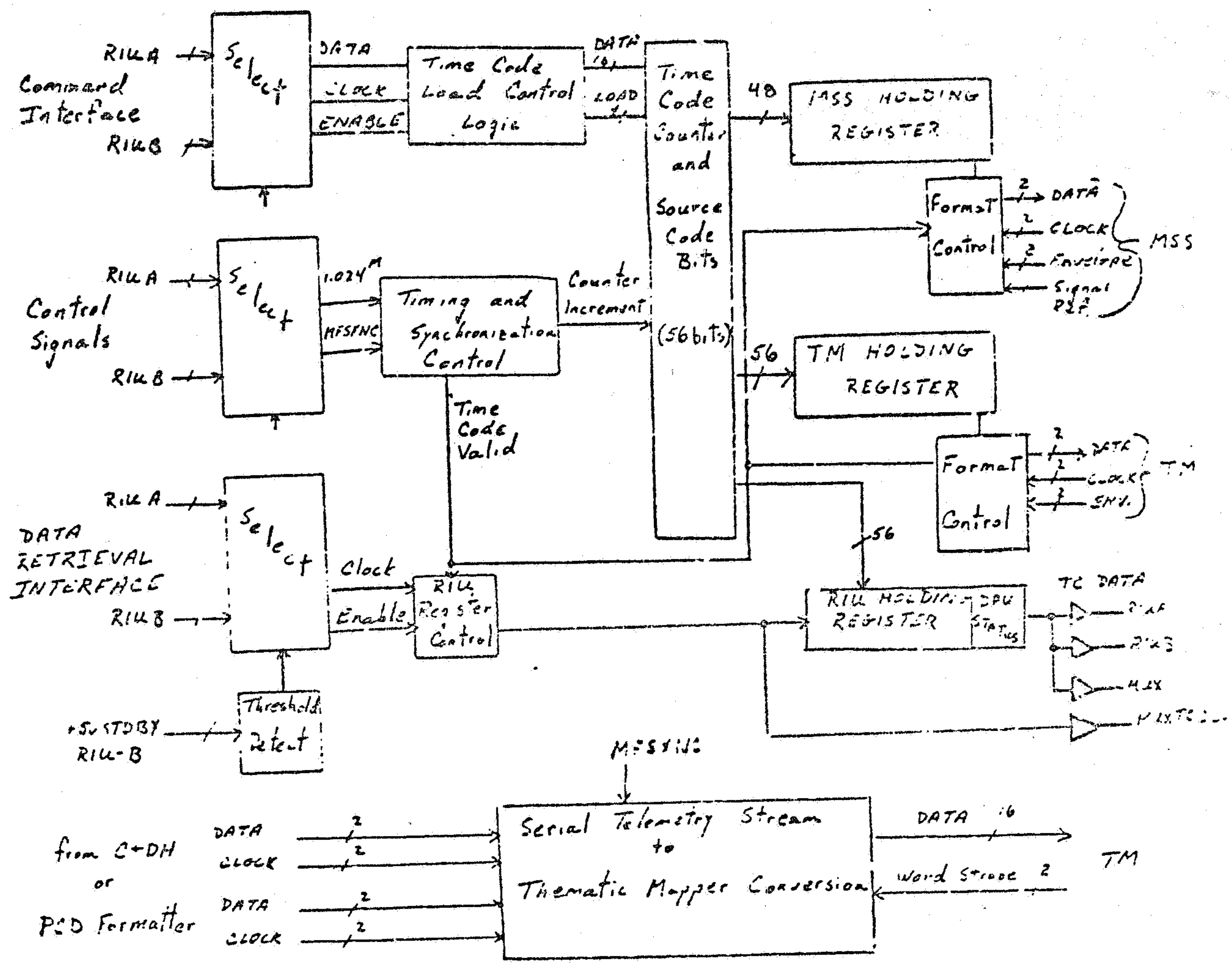

Figure 12.1-1. DPU Block Diagram

The time code will be loaded into the DPU Time Code counter via the RIU using four serial digital commands. The format of these commands is defined in the Data Format Control Book Volume III (Command).

12.1.2 DPU TIME COUNTER

The time code counter becomes valid on the major frame sync after it is loaded. The counter is then incremented every 1/16 of a millisecond. The timing is derived from the 1.024 MHz clock from the RIU and therefore the accuracy of the time code is dependent on the accuracy of this clock. The time code counter is invalid during the loading operation and during the propagation delays after it is incremented. The DPU shall not allow data transfers from the counter to the TM, MSS or RIU holding registers while the counter is invalid. The time code counter does not have to reset after 366 days but may continue to count to 999 days or until loaded with a new time code.

12.1.3 DPU REGISTERS

The DPU contains three holding registers:

RIU Holding Register - 56 bits
TM Holding Register - 56 bits
MSS Holding Register - 48 bits

The registers will be updated on every 1.024 MHz clock providing:

1. The time code counter is valid, and

2. The holding register is not transferring a previous time code

The MSS register is only 48 bits long and the time code in this register will be truncated so the last four LSB's will be hundredths of seconds.

12.1.4 PCD FORMATTER CONVERTER

The DPU will accept data and clock from the PCD formatter and convert it to data acceptable to the Thematic Mapper. This conversion will be from serial telemetry data to 8 bit parallel data that is transferred to the TM. The most recent bit from the serial data will be considered the LSB and be applied to the TM bit 8 buffer. Configuration of the DPU for PCD Formatter is accomplished by internal wiring.

12.1.5 DPU/TM

The TM will interogate the DPU TM holding register by sending a differential envelope and clock signals to the DPU. The DPU outputs formatted time code from the TM holding register upon receipt of the interrogation signals. The TM time code is the last valid time code before the envelope from the TM. The output format is defined in the Data Format Control Book, Volume V (Payload).

12.1.6 DPU/MSS

Upon receipt of an envelope and clock signal from the MSS, the DPU will output formatted time code from the MSS holding register to the MSS. This time code is 4 bits of source code and 44 bits of time information. The time code sent to the MSS is the last valid time code before odd number envelopes from the MSS. The format is defined in the Data Format Control Book, Volume V (Payload).

12.1.7 DPU/RIU

The DPU will output time code to the active RIU upon receipt of the proper serial digital telemetry enable and clock signals. The time code transfer will require eight transfers. The first transfer contains spacecraft code and hundreds of days. The subsequent 6 transfers are time code and the eighth is a telemetry word showing DPU status. The time code sent is the last valid time code before the Major Frame Sync. This format is defined in the Data Format Control Book, Volume V (Payload).

12.2 <u>DPU PERFORMANCE CAPABILITIES</u>

1. Distributes time code to RIU, TM, MSS and PCD formatter.

2. Reformates PCD to TM 8 bit parallel transfer.

12.3 <u>DPU MODES OF OPERATION</u>

12.3.1 DPU STANDBY MODE

Communicates with RIU and sends data to PCD formatter during standby mode.

12.3.2 DPU FULL ON MODE

During DPU Full On Mode, sends time code to RIU, TM, MSS and PCD formatter. Reformates PCD to TM 8 bit parallel transfer.

12.4 <u>DPU CONSTRAINTS</u>

12.4.1 DPU INITIALIZATION CONSTRAINTS

For initialization, the time code must be loaded into DPU.

12.4.2 DPU TELEMETRY CONSTRAINTS

A major frame synch pulse from the RIU is required prior to initiation of the telemetry sequence.

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12.4.3 DPU COMMAND CONSTRAINTS

The loading process of the DPU takes four commands given in proper sequence, followed by a major frame synch pulse.

12.4.4 DPU TEMPERATURE CONSTRAINTS

If the DPU temperature upper limit of TBD degrees centigrade is exceeded, the DPU should be commanded from the FULL ON to STANDBY MODE.

12.4.5 DPU OPERATING MODE CONSTRAINTS

1. DPU Spacecraft time will be updated using the 1.024 MHz clock from the RIU as the timing reference.

2. If switching from PDU A to B (or reverse), the DPU time code output (for telemetry, TM, MSS and PDU MUX) will be lost during the reconfiguration period. This is because PDU A is tied to DPU A. The same is true for the B side.

3. When updating DPU time, the MSS and TM time code will not be updated during the time of receipt of the four serial magnitude commands from the OBC.

12.4.6 DPU SAFE HOLD CONSTRAINTS

1. Once Safehold mode has been entered, the second time code bus for MSS and TM should be disabled. Once recovery has been completed, the DPU can be ground commanded to FULL ON.

12.5 REDUNDANCY AND CROSS-STRAPPING

The DPU is block redundant having an A and a B unit. Both DPU A and DPU B obtain input from RIU A or RIU B. They are cross-strapped and obtain signals from the active RIU. The active RIU is determined by the status of the +5V signal from RIU B. PCD is not cross-strapped; PCD A interfaces only with DPU A and PCD B interfaces with DPU B. The DPU A and DPU B outputs to the TM and MSS are tied together in the TM or MSS respectfully. The DPU is powered by the PDU power supplies. PDU A supplies DPU A with 5 VDC and PDU B supplies DPU B with 5 VDC with no cross-strapping available. DPU redundancy and cross-strapping is shown in Figure 12.5-1.

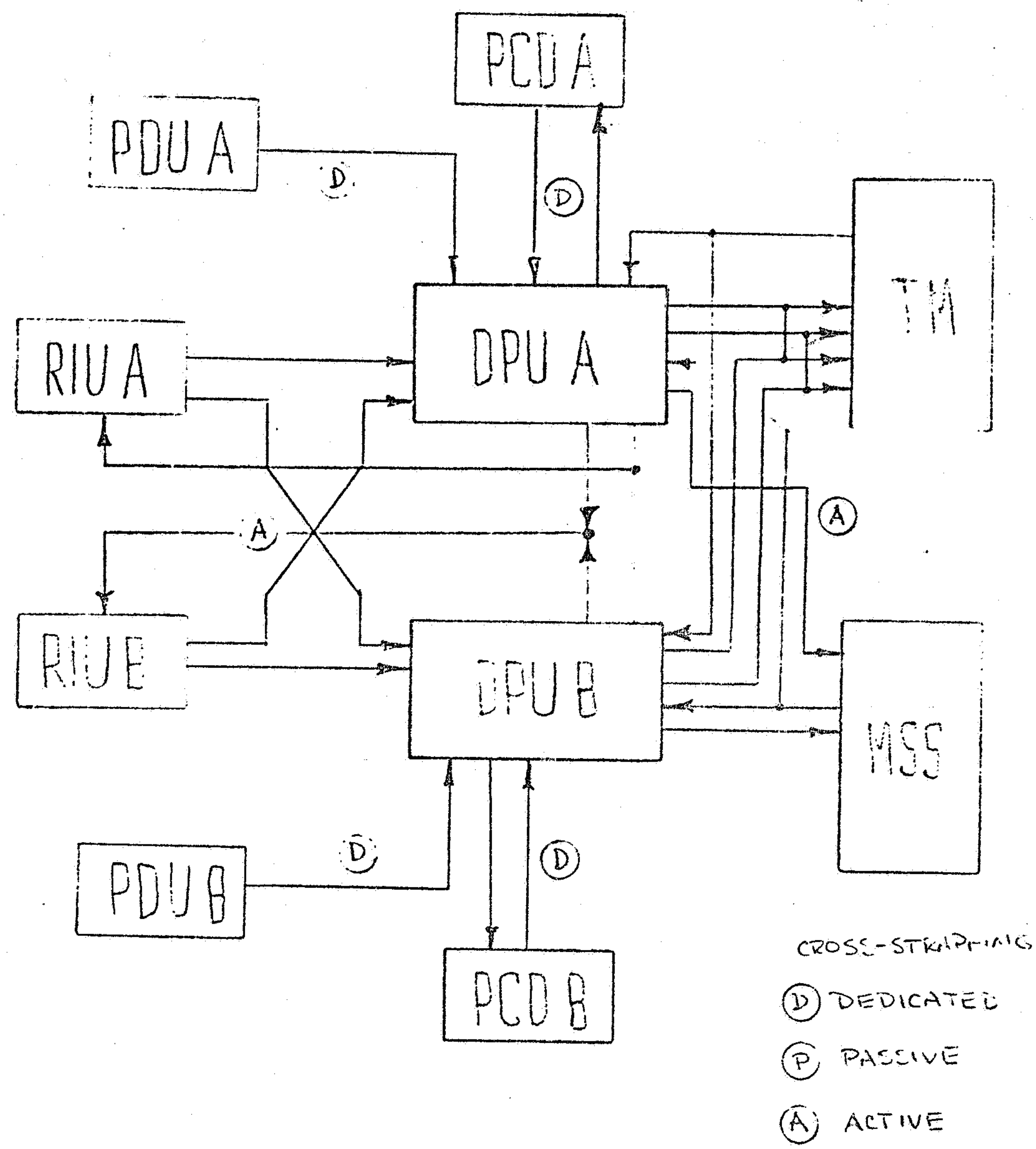

Figure 12.5-1. DPU Redundancy and Cross-Strapping

12.6 DPU COMMANDS

Operation of the DPU is controlled using 4 discrete commands and 1 serial magnitude command. The discrete commands are executed by relays in the Power Distribution Unit (PDU) and the serial magnitude command is executed by logic circuits in the DPU.

Discrete commands affecting DPU operation are listed in Table 12.6-1, which contains the command address (RIU and channel) and the unique acronym assigned to each command function. In the ground test data base and software, these commands are of the form PDU/ACRONYM and are verified as indicated in Table 12.6-2.

Table 12.6-3 presents the bit structure for serial magnitude data in DPU serial command messages. Command descriptions are provided in Section 12.6.1, command sequences in Section 12.6.2, and command restraints in Section 12.6.3.

All DPU commands are addressed to RIU 6, and all commands may be executed by either the A or B RIU. There are no commands dedicated to RIU A only or RIU B only.

Table 12.6-1. Discrete Commands

RIU	CH	Acronym	Command Name
6	14	/PDU,ELECTA	SELECT ELECTRONICS A (PDU & DPU)
6	43	/PDU,ELECTB	SELECT ELECTRONICS B (PDU & DPU)
6	47	/PDU,DPUSBY	DPU STANDBY
6	18	/PDU,DPUON	DPU FULL ON

Table 12.6-2. Discrete Command Verification

Command	Reference Paragraph	Prerequisite	Complement	TLM Verification	Remarks
ELECTA	12.6.1.1		ELECTB	YPDUELE=1 DPUSEL=1	PDU A DPU A
ELECTB	12.6.1.1		ELECTA	YPDUELE=0 DPUSEL=0	PDU B DPU B
DPUSBY	12.6.1.2		DPUON	YDPUPWR=0	
DPUON	12.6.1.2		DPUSBY	YDPUPWR=1	

TABLE 12.6-3. SERIAL COMMAND STRUCTURE

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
6-70	LOAD TIME CODE	TRANSFER 1:																
	(REQUIRES FOUR COMMAND TRANSFERS TO COMPLETE LOAD)	SYNC (SPACECRAFT ID) 1110 = LSD 1101 = LSD PRIME																
		DAYS HUNDREDS								LSB								
		DAYS TENS												LSB				
		DAYS UNITS																LSB
		TRANSFER 2:																
		FILLER BITS	0	0	0	0												
		HOURS TENS								LSB								
		HOURS UNITS												LSB				
		MINUTES TENS																LSB

TABLE 12.6-3. SERIAL COMMAND STRUCTURE

COMMAND RIU-CH	COMMAND TITLE	COMMAND FUNCTION	MAGNITUDE DATA (C10 THROUGH C25) 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
6-70	LOAD TIME CODE (CONTINUED)	TRANSFER 3:																
		FILLER BITS	0	0	0	0												
		MINUTES UNITS					□	□	□	□ LSB								
		SECONDS TENS									□	□	□	□ LSB				
		SECONDS UNITS													□	□	□	□ LSB
		TRANSFER 4:																
		FILLER BITS	0	0	0	0												
		MILLISEC HUNDREDS					□	□	□	□ LSB								
		MILLISEC TENS									□	□	□	□ LSB				
		MILLISEC UNITS													□	□	□	□ LSB

12.6.1 COMMAND DESCRIPTIONS

The following paragraphs describe commands which affect operation of the DPU.

12.6.1.1 Power Control Commands

One of the power converters in the PDU is always powered whenever the spacecraft is powered. The power converter which is on is determined by one of the two mutually exclusive commands /PDU,ELECTA and /PDU,ELECTB. DPU A is dedicated to PDU power converter A, and DPU B to PDU B. There are no PDU or DPU off commands. Either PDU power converter A and DPU A are on, or PDU power converter B and DPU B are on. Thus, ELECTA turns DPU A on and DPU B off. Conversely, ELECTB turns DPU B on and DPU A off.

12.6.1.2 Mode Control Commands

The DPU has two operating modes, Standby and Full On, which are mutually exclusive. The command /PDU,DPUSBY places the DPU which is on from the commands in 12.6.1.1 into the Standby mode. In this mode, the selected DPU will accept Time Code Load commands and provide telemetry outputs to either RIU. The command /PDU,DPUON places the selected DPU into the Full On mode. In this mode the DPU will, in addition to the Standby mode functions, provide time code data to the MSS and TM when strobed by these instruments, and it will accept and process payload correction data for transfer to the TM.

The DPU will retain the mode last commanded. Thus, if DPU A is on in either mode and the commands of 12.6.1.1 are used to switch to DPU B, DPU B will assume the mode in which DPU A had been operating.

12.6.1.3 Time Code Load Commands

Four 16 bit serial magnitude commands to address 670 (RIU 6, serial command enable line 0) are required to complete a time code load, as indicated in Table 12.6-3. The active DPU will, in either the Standby or Full On mode, accept time code load commands from either RIU 6A or 6B. Time code outputs from the DPU will be erroneous during the load period and will not become valid until a major frame sync pulse is received by the DPU after the fourth time code load command has been received. The major frame pulse causes the DPU time code circuits to update to the loaded value and start increasing in sixteenth millisecond increments.

Switching from one DPU to the other causes loss of valid time code data, because the DPU which had been off had no time code retention capability in the unpowered state. It is necessary, therefore, to reload time code whenever a change from one DPU to the other is commanded.

12.6.2 COMMAND SEQUENCES

There are no special command secuences required for DPU operation. Commands may be sent in any order without causing harm to the subsystem or the spacecraft.

12.6.3 COMMAND RESTRAINTS

A time code load must be accomplished after switching from one DPU to the other. If the load is not performed, time code outputs from the DPU will not be valid.

12.7 DPU TELEMETRY

Operation of the DPU is monitored via 6 telemetry channels. Two bilevel digital channels providing RIU status, one passive analog channel providing temperature information, and one serial digital channel providing time code and DPU status, receive inputs directly from the DPU. Two bilevel digital channels providing DPU power and mode status receive inputs from command relays in the PDU.

The telemetry monitors are listed in Table 12.7-1 by function name and acronym. In the table, signal types are designated PASS for passive analog, S for serial digital, and B for bilevel digital functions. The numbers associated with the S and B notations indicate bit numbers of the 8-bit digital word in the telemetry data stream, where bit 0 is the MSB. SMPL RATE defines the number of times a function is sampled in a telemetry major frame.

12.7.1 TELEMETRY DESCRIPTIONS

The DPU telemetry monitors provide command verification, subsystem status, and diagnostic information. This section presents telemetry descriptions using the acronyms in Table 12.7-1. Where possible, monitors are collected into functional groups for ease in understanding.

12.7.1.1 DPU Temperature (DPUTEMP)

This monitor indicates the temperature derived from a thermistor located inside the DPU module. For information regarding calibration curve coefficients for this telemetered function, see Appendix A.12.

Table 12.7-1. DPU Telemetry List

USER ID	FUNCTION NAME	ACRONYM	SIG. TYPE	MTX LOC COL,ROW	SMPL RATE	RIU-CH	REFERENCE PARAGRAPH
DPU-01	TIME CODE DATA: (BCD EXCEPT SPACECRAFT)					06-00	12.7.1.5
	SPACECRAFT (1110=LSD, 1101=LSD PRIME)	DTCSRC	S0-3	32,00	1		
	DAYS HUNDREDS	DTCDAYH	S4-7	32,00	1		
	DAYS TENS	DTCDAYT	S0-3	32,01	1		
	DAYS UNITS	DTCDAYU	S4-7	32,01	1		
	HOURS TENS	DTCHRT	S0-3	32,02	1		
	HOURS UNITS	DTCHRU	S4-7	32,02	1		
	MINUTES TENS	DTCMINT	S0-3	32,03	1		
	MINUTES UNITS	DTCMINU	S4-7	32,03	1		
	SECONDS TENS	DTCSECT	S0-3	32,04	1		
	SECONDS UNITS	DTCSECU	S4-7	32,04	1		
	MILLISECONDS HUNDREDS	DTCMSECH	S0-3	32,05	1		
	MILLISECONDS TENS	DTCMSECT	S4-7	32,05	1		
	MILLISECONDS UNITS	DTCMSECU	S0-3	32,06	1		
	MILLISECONDS FRACTIONS (LSB-1/16 MS)	---	S4-7	32,06	1		
DPU-02	DPU STATUS:					06-00	
	RIU A/B SELECTED	DRIUSEL	S--0	32,07	1		12.7.1.3
	MSS TIME CODE REQUEST YES/NO	DMSSTCR	S--1	32,07	1		12.7.1.6
	TM TIME CODE REQUEST YES/NO	DTMTCR	S--2	32,07	1		12.7.1.6
	PCD-TM DATA TRANSFER YES/NO	DCDHTMT	S--3	32,07	1		12.7.1.6
	DPU LOADING TIME CODE YES/NO	DLDGTC	S--4	32,07	1		12.7.1.4
	TIME CODE REGISTER UPDATE YES/NO	DTCRGUP	S--5	32,07	1		12.7.1.4
	NOT USED	---	S--6	32,07	1		---
	DPU A/B SELECTED	DPUSEL	S--7	32,07	1		12.7.1.2
DPU-03	DPU TEMP	DPUTEMP	PASS	32,76	1	08-24	12.7.1.1
PDU-04	PDU ELECTRONICS A/B SELECTED	YPDUELE	B--0	78	128	06-40	12.7.1.2
	DPU FULL ON/STANDBY	YDPUPWR	B--3	78	128	06-42	12.7.1.2
PDU-05	DPU A RIU A ON/OFF	DARIU	B--6	33,88	1	06-54	12.7.1.3
	DPU B RIU A ON/OFF	DBRIU	B--7	33,88	1	06-55	12.7.1.3

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12.7.1.2 Power and Operating Mode Status Monitors

YPDUELE - PDU electronics A/B selected
YDPUPWR - DPU full on/standby
DPUSEL - DPU A/B selected

These monitors provide telemetry verification for the commands described in Paragraphs 12.6.1.1 and 12.6.1.2. Since DPU A is dedicated to PDU A and DPU B to PDU B, the monitors YPDUELE and DPUSEL will always indicate PDU A and DPU A at the same time, or PDU B and DPU B at the same time. Decoding of the monitors is shown below.

YPDUELE	0 = PDU electronics B selected
	1 = PDU electronics A selected
DPUSEL	0 = DPU B on, A off
	1 = DPU A on, B off
YDPUPWR	0 = Selected DPU in Standby mode
	1 = Selected DPU in Full On mode

12.7.1.3 RIU Status Monitors

DARIU - DPU A RIU A on/off
DBRIU - DPU B RIU B on/off
DRIUSEL - RIU A/B selected

These monitors provide an indication of whether RIU 6A or RIU 6B is providing inputs and accepting outputs from the DPU. DARIU is valid only when DPU A is on (DPUSEL=1), and DBRIU is valid only when DPU B is on (DPUSEL=0). DRIUSEL is valid whichever DPU is on. The monitors are decoded as shown below.

DARIU	0 = DPU A RIU 6A off
	1 = DPU A RIU 6A on
DBRIU	0 = DPU B RIU 6A off
	1 = DPU B RIU 6A on
DRIUSEL	0 = RIU 6B selected
	1 = RIU 6A selected

12.7.1.4 Time Code Load Command Verification

As described in Paragraph 12.6.1.3, four consecutive serial magnitude commands are required to load a new time code in the DPU. The telemetry monitors shown below provide verification of the load commands.

DLDGTC - DPU loading time code yes/no
DTCRGUP - Time code register update yes/no

DLDGTC transitions to a logic "1" state when the DPU receives the first of the four time code load commands and remains in that state until the fourth command is received, at which time it transitions to a logic "0" state. Because of the low sample rate for this monitor (once every telemetry major frame) the transition will not be seen unless the command transmissions happen to coincide with the sample period for DLDGTC. The monitor is decoded as shown below.

DLDGTC 0 = DPU not loading time code
1 = DPU loading time code

The first telemetry major frame sync pulse received by the DPU after reception of the fourth time code load command causes the time code circuits in the DPU to update to the loaded value. At the same time, the monitor DTCRGUP transitions to a logic "1" state and remains in that state until the following major frame pulse is received, which causes it to transition to a logic "0" state. The indication is present, therefore, only during the telemetry major frame in which the updated time code appears. The monitor is decoded as shown below.

DTCRGUP 0 = Time code register update - NO
1 = Time code register update - YES

12.7.1.5 Time Code Data (DPU-01)

Time code data from the DPU appears once per major frame in the telemetry data stream. The data consists of seven 8-bit serial digital telemetry words located in the first seven telemetry minor frames as shown in Table 12.7-1 and below.

Minor Frame	Bits 0-3	Bits 4-7
0	DTCSRC	DTCDAYH
1	DTCDAYT	DTCDAYU
2	DTCHRT	DTCHRU
3	DTCMINT	DTCMINU
4	DTCSECT	DTCSECU
5	DTCMSECH	DTCMSECT
6	DTCMSECU	MS fractions

The time contained in the seven words is the time which was stored in the time code register at the beginning of the telemetry major frame in which the time code data appears. As discussed in Paragraph 12.6.1.3, time code data becomes erroneous while time code load commands are being executed, and also when switching from one DPU to the other.

12.7.1.6 Data Output Monitors

The DPU provides, upon request, time code to the MSS and TM instruments, and payload correction data (PCD) to the TM. The DPU must be in the Full On mode to accomplish the data transfers. Three telemetry monitors are provided to indicate whether time code requests were received or PCD was transferred by the DPU. The monitors indicate status for the telemetry major frame preceding the major frame in which they occur. Thus, if a data request or data transfer occurred at any time during major frame N, the telemetry indication of the occurrence will occur in major frame N+1. Decoding of the monitors is shown below.

DMSSTCR	0 = MSS time code not requested
	1 = MSS time code requested
DTMTCR	0 = TM time code not requested
	1 = TM time code request
DCDHTMT	0 = PCD not transferred to TM
	1 = PCD transferred to TM

13.0 WIDEBAND COMMUNICATION SUBSYSTEM

SECTION 13.0

WIDEBAND COMMUNICATIONS SUBSYSTEM

13.1 FUNCTIONAL DESCRIPTION

The Wideband Communications Subsystem (WBCS) receives digital data signals from the Thematic Mapper (TM) and the Multiplexer Scanner (MSS) sensors and transmits the data to the Tracking and Data Relay Satellite (TDRS) System at Ku-band and/or to selected ground stations at X-band. The subsystem also includes the S-Band High Gain Antenna for communication with the TDRS.

The WBCS consists of a wideband module (WBM), RF compartment (RFC) and the gimbal drive assembly.

The wideband module contains the X-band transmission link equipment Traveling Wave Tube Amplifiers (TWTA), signal and power control, gimbal drive electronics, the modulator portion of the Ku-band transmission link equipment, and the autotrack receiver.

The RF compartment contains the Ku/S-band antenna, the Ku-band switching, diplexing, up conversion components, Ku-band TWTA's, and down converters for the Autotrack System. The RF compartment and Ku/S-band antenna are attached to the top of the antenna mast by means of the gimbal drive assembly, a two-axis rotary mechanism consisting of an elevation-over-azimuth mount.

See Figure 13.1-1 for block diagram of Wideband Communication Subsystem.

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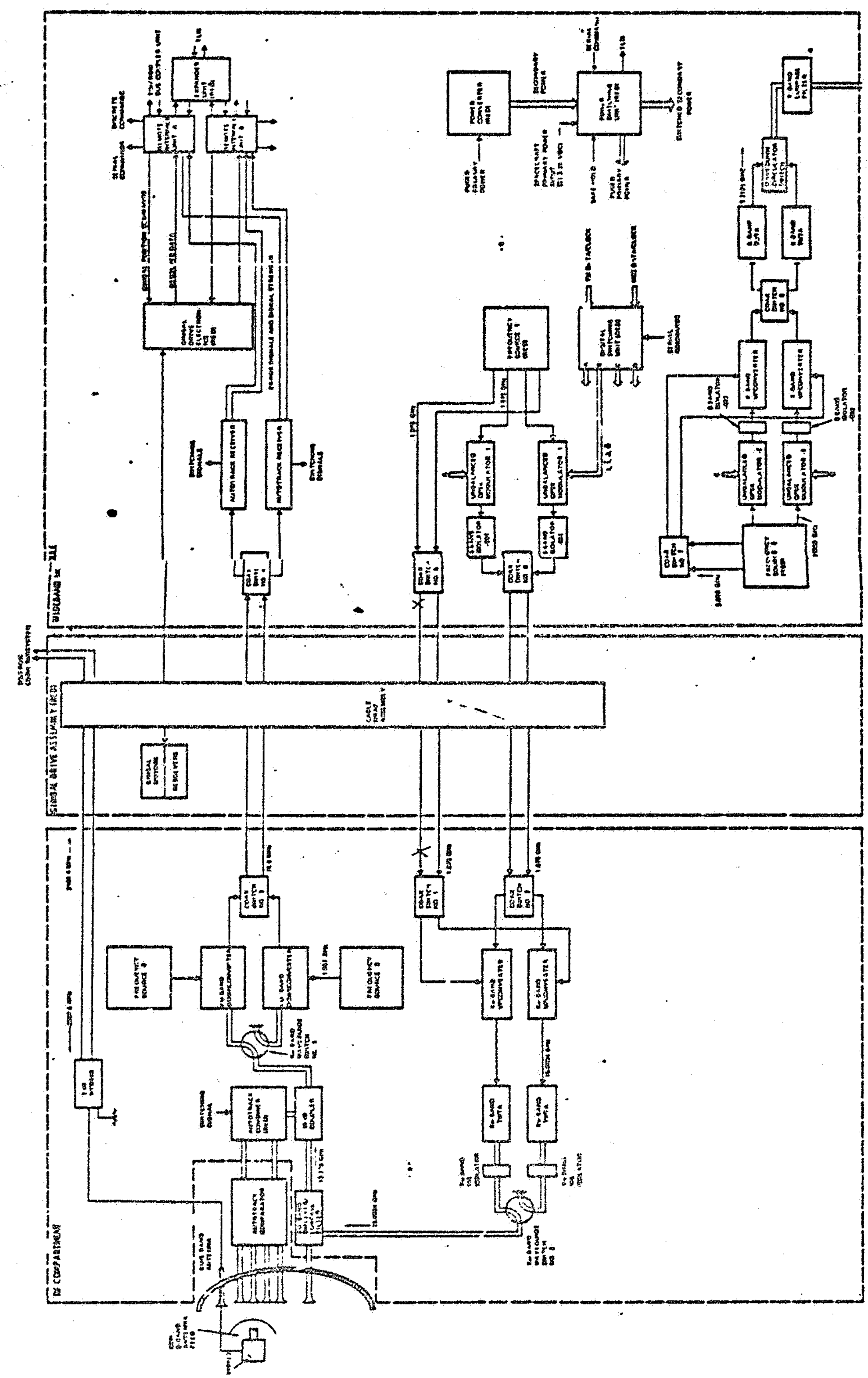

Figure 13.1-1 Block Diagram, Wideband Communication Subsystem

13.1.1 KU-BAND FORWARD LINK

The Ku-band forward link signal (3 mega chips/sec PN spread spectrum) from the TDRSS is received by the five-horn feed assembly of the 1.8 meter Ku/S-band steerable antenna. Four small monopulse feed horns, which surround the sum channel feed horn, and the autotrack comparator, synthesize the azimuth and the elevation difference signals. These signals are proportional to the angular error between the antenna boresight and the received TDRSS signal line of sight. They are biphase modulated, time multiplexed, and added in-phase to the reference sum channel received signal by means of a 10-dB coupler to generate the amplitude-modulated (AM) autotrack signal. As shown in the block diagram, Figure 13-2, the sum channel signal is routed to the downconverter via the diplexer/filter which provides receive-band selection in addition to attenuation of the receiver image band and Ku-band TWTA broadband noise.

The composite single channel AM autotrack signal is downconverted and routed through the cable wrap assembly and down the boom to the autotrack receivers (ATR) located in the wideband module. Coax switches provide cross-strap redundancy between the downconverters and the autotrack receivers. The signal is amplified by an automatic gain-controlled IF amplifier prior to square-law detection to remove the amplitude modulation representing the normalized azimuth and elevation error signals. Separation of the azimuth and elevation error signals is accomplished by a demultiplexer contained within the autotrack receiver. The demultiplexing waveform which separates both these signals is identical to, and synchronized with, the multiplexing waveform. A low frequency filtered dc signal derived from the AGC circuit provides signautomatic gain control al strength indication. The two pointing error signals, together with the signal strength signal, are digitized by the standard NASA Remote Interface Units (RIUs) and provided to the onboard computer (OBC) via the Flight Segment (FS) multiplex data bus. The signal strength signal is processed by the onboard computer (OBC) to activate the autotrack mode and is also telemetered to the TDRSS ground station via the Communications and Data Handling (C&DH) subsystem to verify that the TDRSS-to-Landsat FS link has been established.

The autotrack receiver, antenna, gimbal drive assembly and OBC form a closed loop monopulse tracking system. The azimuth and elevation error signals are processed by the OBC to generate appropriate command signals which are, in turn, fed back through the RIUs to the gimbal drive assembly. In response to these signals, the gimbal motors position the antenna in a direction which minimizes the angular error between the antenna boresight and the TDRSS signal line of sight.

In addition to the autotrack mode of operation, the steerable high gain antenna also operates in a program track mode. Position feedback to the onboard computer via the RIUs is provided by azimuth and elevation gimbal resolvers.

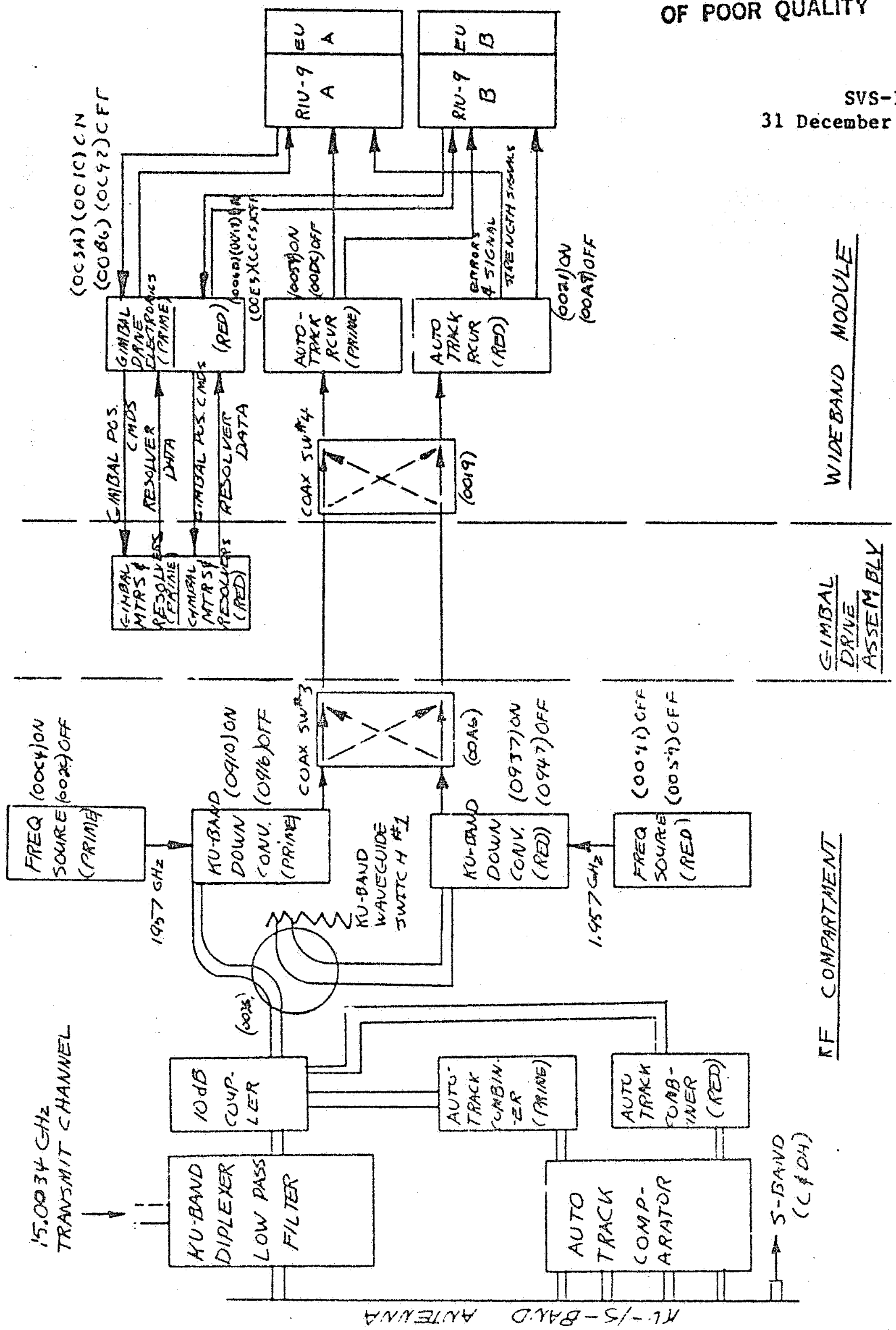

Figure 13.1-2. Ku-Band Forward Channel

13.1.2 SENSOR DATA MODULATION AND MODS

TM and MSS data are first routed to the digital switching unit (DSU) in the wideband module where they are reclocked by means of associated clock signals, prior to mode selection. Independent mode selection is provided for both X-band and Ku-band operation activating one of fifteen data output combinations for the two links. The outputs from the DSU, consisting of differently encoded TM and MSS data on separate in-phase (I) and quadrature phase (Q) lines, are provided as inputs to unbalanced quadrature phase-shift keyed (QPSK) modulators. The QPSK modulators modulate the selected TM and MSS data onto S-band RF carrier references.

13.1.3 KU-BAND TRANSMISSION LINK

For the Ku-band transmission link via TDRSS, the UQPSK modulated S-band signal is routed to redundant Ku-band upconverters in the RF compartment. The upconverters, driven by frequency sources in the wideband module, translate the modulated S-band signal to the Ku-band. The upconverter output is amplified by one of two redundant 22-watt TWTAs prior to being transmitted via the diplexer/filter and Ku/S-band antenna as in Figure 13.1-3.

The output from the diplexer/filter drives the 1.8 meter high-gain antenna. The antenna also contains an S-band feed which provides a high-gain antenna receive/transmission capability for C&DH module S-band command reception and telemetry data transmission. The narrow-band communications discussion (Section 20) for physical description and operational procedures of the high-gain antenna.

13.1.4 X-BAND TRANSMISSION LINK

For X-band direct readout transmission, redundant modulated S-band signals from the dedicated UQPSK modulators in the wideband module are provided as an input to X-band upconverters. The upconverters, driven from frquency sources located within the module, upconvert the modulated S-band signal to X-band. The output from the upconverter is amplified by means of a 44-watt TWTA prior to being filtered by a transmit lowpass filter as depicted in Figure 13.1-4.

The output from the lowpass filter drives an X-band shaped-beam antenna which provides essentially constant Effective Isotropic Radiated Power EIRP over the illuminated surface of the earth.

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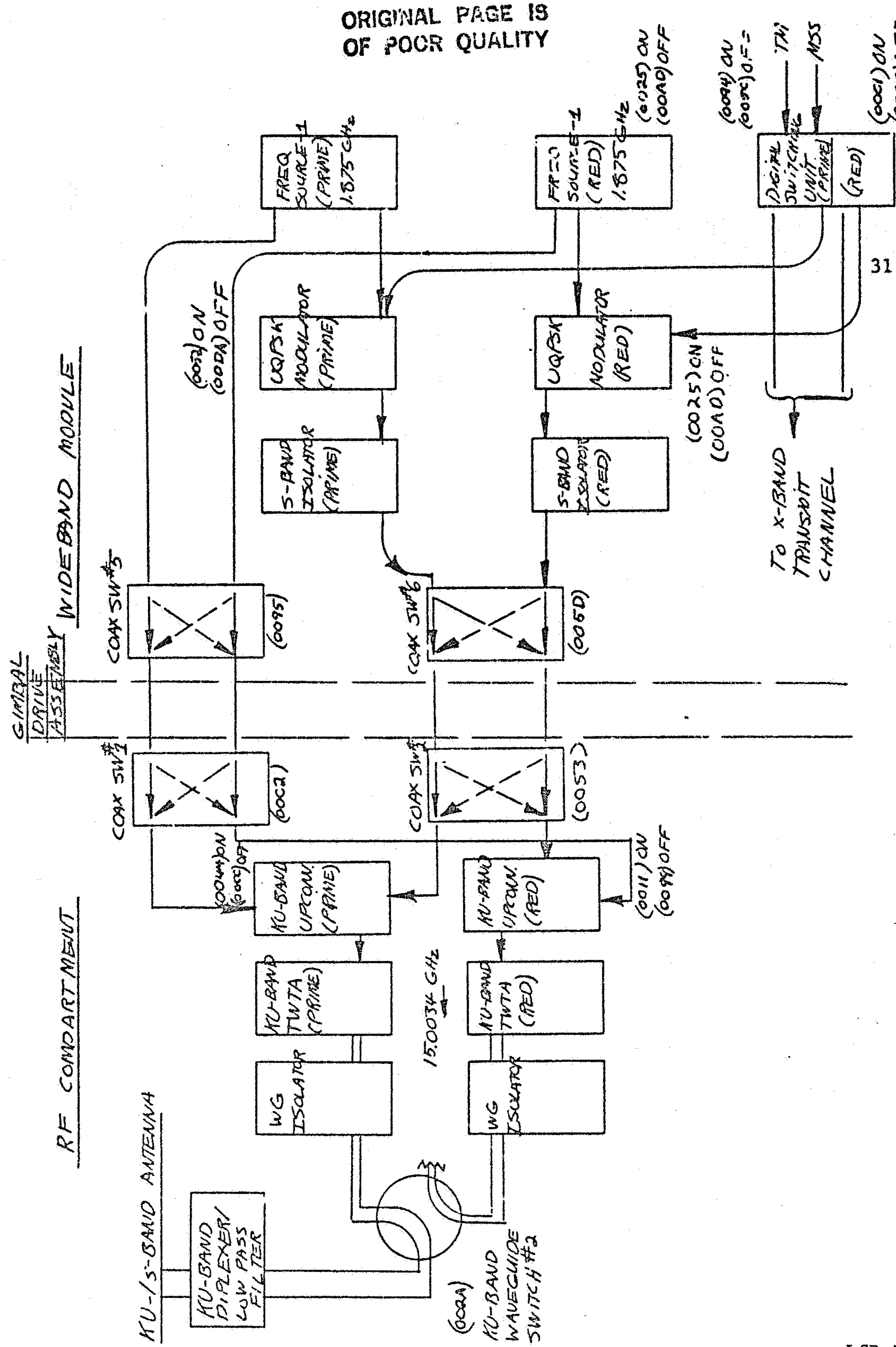

Figure 13.1-3. Ku-Band Transmit Channel

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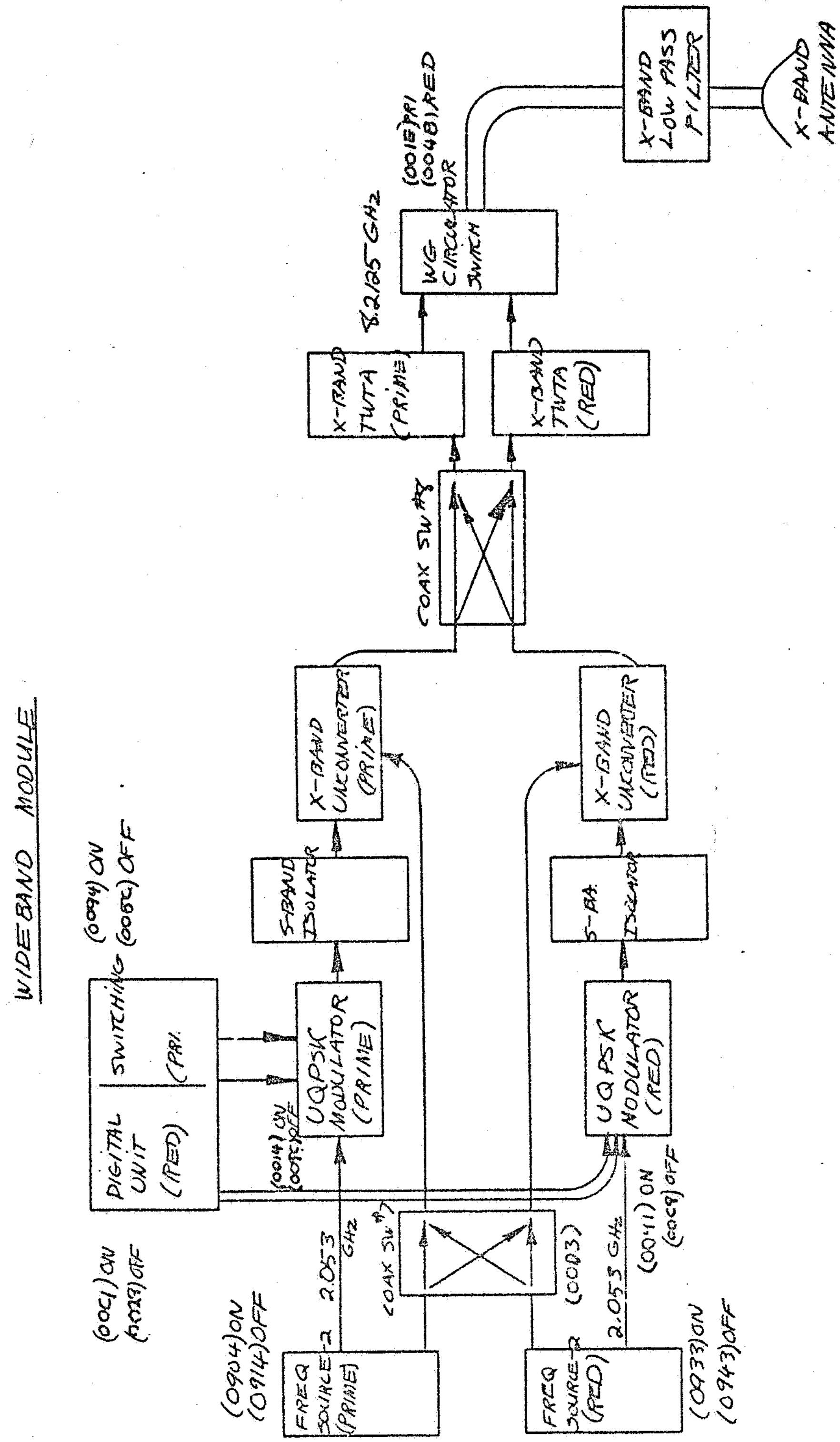

Figure 13.1-4. X-Band Transmit Channel

13.2 PERFORMANCE CAPABILITIES (WBCS)

The Wideband Communications Subsystem capabilities are summarized in Table 13.2-1.

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Table 13-1. WBCS Performance Capabilities

Function	Landsat D FS Characteristics
Ku-band return-link modes	• Ku-band Single Access (KSA), X and S-band links operate independently and simultaneously for limited periods • Switching provided to allow independent selection of transmission mode • No data interruptions as a result of data mode switching
Ku-band return-link margin at beginning of life	• 4.7 dB in the autotrack mode • $\geq$3.7 dB in the program mode
TM & MSS data conditioning prior to KU and X band modulation	• Differentially encoded (e.g., NRZ-M Pulse Code Modulation) • Automatically resolves channel and polarity. ambiguity NRZ-L output from ground stations
Ku-band antenna	• Polarization: Right-hand circular • Frequency: 13,775 ++ 0.7 MHz (Forward link); 15,003.4 $\pm$ 0.76 MHZ (Return Link) • Pointing error (3 sigma CEP): Program track 0.255° Autotrack 0.1° • Power handling: >1 dB over the maximum power at the antenna

LSD-WPC-263

Table 13-1. WBCS Performance Capabilities

	• Gain: Consistent with EIRP and Power Flux Density (PFD) requirements • Axial Ratio: <1.5 dB over 3 dB Beamwidth
Input power (max)/operating mode	Mode # 1) Standby 170 watts 2) Ku-band Transmission (X Standby)* 264 Watts 3) X-band Transmission (KU Standby) 282 Watts** 4) Ku and X-band Transmission**: 350 Watts 5) Safehold: 157 Watts
X-band downlink margin at beginning of life	• 3 dB based on a bit error rate rate of 10^{-6}
X-band Antenna	• Polarization: Right-hand circular • Frequency: 8,213.5 $\pm$ 0.4 MHZ • Power Handling: >1 dB over the maximum power at the antenna • Coverage: Provides an approximate constant PFD on earth for a subtended angle of $\pm$63.8 degrees

* Gimbal Assembly auto-tracking TDRSS at average rate.
**Gimbal Assembly program tracking TDRSS at average rate.

Table 13-1. WBCS Performance Capabilities

S-band high gain antenna	• VSWR (receive and transmit) ≤1.5:1 • Power handling (Transmit) 6 Watts
Ku-Band Forward Link	• KU-Band autotrack receiver input signal characteristics: Center Freq. 13.775 GHz ± 0.7 MHz Signal bandwidth: 6 MHz Dynamic Range & rracking: -162 to -153 dBwi Polarization: RCP Modulation UQPSK: (10:1 power split) with two 3 Mps PN codes bi-phase modulating the carriers
Ku-Band Gimbal Assembly Performance	• Rotation: Bidirectional • Elevation: 130 degrees • Azimuth: 400 degrees • Nominal step-size at output: 0.018 degrees • Nominal tracking speed: 0.06 deg/sec • Slew speed (max): 2.81 deg/sec • Gimbal Acceleration: 0.5 deg/sec^2 (max) • Mechanical Hardstop: azimuth ±200 degrees referenced to FS ∓X axis elevation +125, -5 degrees referenced to spacecraft -Z axis. • Input gimbal step cmd (max): 80 steps/512 millisecs (2.8125 deg/sec) • Input gimbal step cmd (min): 0 step/512 millsec • Input gimbal step cmd (data format) Serial from RIU (one 16-bit word each used

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Table 13-1. WBCS Performance Capabilities

	at AZ and EL) • Input gimbal step cmd (Max) Word Rate: 1 word/512 millsecs • Output Resolver Data: 0 to 360 to a resolution of 0.022 • Word size: Two 8 bit serial data words/axis via RIU [+14 bit (1 make bit + a spare bit] (Azimuth only) • Convert pulse: Discrete command from RIU every 256 millisec
WBCS Life Performance	• Minimum of 3 years with TWTA's and CDA cycled as follows:

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Traveling Wave Tube Amplifier Operation

	Performance	X-Band	Ku-Band
	Cycles (Operation & Test)	25,000	25,000
	Nominal Duty Cycle	10 Min/100 Min	15 Min/100 Min
Maximum Duty	30 Min/100 Min	30 Min/100 Min	30 Min/100 Min
Cycle Test Hours (GE)	200 Hours	200 Hours	200 Hours

Antenna Gimbal Assembly Operation

Full Cycles (Operation & Test)	20,000
Test Cycles (GE)	1,000

13.3 MODES OF OPERATION (WBCS)

The RF compartment, gimbal drive assembly and the wideband module are configured to operate in one of five modes. These WBCS configurations are shown in Figure 14.3-1 along with the WBCS equipment ON/OFF status by modes. Figure 13.3-2 provides the data mode combinations for each transmission link.

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	EQUIPMENT	MODE 1 BOTH STBY	MODE 2 KU OPER	MODE 3 X OPER	MODE 4 BOTH OPER	MODE 5 SAFEHOLD
	<u>RFC</u>					
	KU UPCV	X	X	X	X	
	KU TWTA	STBY	X	STBY	X	
	FS-3		X		X	
	AT DNCV		X		X	
	ATC		X		X	
	<u>GDA</u>					
	EL GDA	X	X	X	X	
	AX GDA	X	X	X	X	
	<u>WBM</u>					
	X TWTA	STBY	STBY	X	X	
	UQPSK-2(X)			X	X	
	X FS ELEC		X	X	X	
	X FS OVEN	X	X	X	X	X
	KU FS ELEC		X	X	X	
	KU FS OVEN	X	X	X	X	X
	UQPSK-1(KU)		X		X	
	DSU		X	X	X	
	ATR		X		X	
	GDE	X	X	X	X	
	RIU	X	X	X	X	X
3-10	EU	X	X	X	X	X
	PSU	X	X	X	X	X
	PC	X	X	X	X	X

Figure 13.3-1. WCS Equipment ON/OFF Status by Modes

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DATA MODE	X-BAND I CHAN	X-BAND Q CHAN	KU-BAND I CHAN	KU-BAND Q CHAN
1	-	-	-	-
2	*	MSS	-	-
3	-	-	*	MSS
4	TM	TM	-	-
5	-	-	TM	TM
6	TM	MSS	-	-
7	-	-	TM	MSS
2&3	*	MSS	*	MSS
2&5	*	MSS	TM	TM
2&7	*	MSS	TM	MSS
4&3	TM	TM	*	MSS
4&5	TM	TM	TM	TM
4&7	TM	TM	TM	MSS
6&3	TM	MSS	*	MSS
6&5	TM	MSS	TM	TM
6&7	TM	MSS	TM	MSS

*PN 84.903 Mbps ± 0.2%.

Figure 13.3-2. Data Mode Combinations

13.3.1 MODE 1 - STANDBY

This mode is set to cycle the TWTA's for both KU-band and X-band from an operate mode to standby when they are utilized in succeeding passes. This allows the TWTA's to remain in a power ON, heater power ON, and beam current OFF state.

13.3.2 MODE 2 - KU-BAND ON (X-BAND OFF)

The KU-band forward and return channels are configured for TDRSS tracking and data transmission. The KU-band TWTA will be in operate mode with its beam current ON. The X-band TWTA remains in STANDBY or OFF depending on the scheduled mission operation.

13.3.3 MODE 3 - X-BAND ON (KU-BAND OFF)

The X-band transmit channel is configured for data transmission with the X-band TWTA in operate mode, beam current ON. The KU-band TWTA remains in STANDBY or OFF depending on the scheduled mission operation.

13.3.4 MODE 4 - BOTH KU-BAND AND X-BAND ON

Both links are in operation with data transmission configured in accordance with scheduled mission operation.

13.3.5 MODE 5 - SAFEHOLD

This mode is a result of an abnormal condition sensed by the flight segment safe-hold monitor. Safe-hold signals from the Power Distribution Unit of the FS will be provided to the WBCS to terminate all wide band transmission and to stop the TDRSS Antenna gimbal motion. If this condition should occur, the WBCS oven heaters for both the KU-band and X-band frequency source components are the only equipment that remain energized.

If it is determined safe to re-energize the KU-band and/or the X-band links, the return to normal operation can occur with transmission of commands regardless of the state of the redundant safe-hold relays.

13.4 CONSTRAINTS

13.4.1 When both KU-band and X-band links are operated daily, the TWTA's are to remain ON and cycled to operate mode (beam current ON) or standby mode (beam current OFF, heater power ON). If the TWTA's are not operated daily, the TWTA's will be de-energized (power OFF).

13.4.2 The TWTA's both KU-band and X-band, will be switched from the operate mode to standby mode when the TWTA collector temperature is $\geq$ +165°F (74°C). The OBC continuously monitors the following telemetry points and issues the TWTA standby command when the last three consecutive samples of the telemetry point chicks out-of-limit. The telemetry sampled and the commands issued by the OBC are as follows:

Telemetry	Standby Command
RFC-Y PANEL (KU-TWTA-A) TEMP	KU TWTA PRI TO STANDBY
RFC-Y PANEL (KU-TWTA-B) TEMP	KU TWTA RED TO STANDBY
WBM-Y PANEL (X-TWTA-A) TEMP	X-BAND TWTA PRI TO STANDBY
WBM-Y PANEL (X-TWTA-B) TEMP	X-BAND TWTA RED TO STANDBY

13.4.3 The TWTA's will not be operated without drive and without a modulated carrier. The I and Q channels must have either PN or sensor data modulation. The command sequences to satisfy this constraint are as follows:

TWTA Turn-On Command Sequences

KU-BAND TWTA	X-BAND TWTA
FUNCTION	FUNCTION
1) Set Coax Switch Configuration 2) Digital SW Unit ON 3) Set Digital SW Unit Data Path 4) KU-Band UQPSK ON 5) KU-Band Freq Source 1-ON 6) KU-BAND Up-Conv. ON 7) KU-TWTA ON (Standby) 8) At Receiver ON 9) Sensor Data ON 10) Calibrate Auto Track Receiver 11) TWTA To Operate 12) OBC Sets Autotrack Mode	1) Set Coax Switch Configuration 2) Digital SW Unit ON 3) Set Digital SW Unit Data Path 4) X-Band UQPSK ON 5) X-Band Freq Source 2-ON 6) X-Band Up-Conv. ON 7) X-Band TWTA ON (Standby) 8) Sensor Data ON 9) TWTA To Operate

NOTE: The KU-band command sequence assumes that the command and telemetry link via TDRSS-SSA is established.

13.4.4 Both Ku-band TWTA's will not be operated simultaneously. One Ku-band TWTA must be OFF to avoid excessive TWTA collector temperature increase.

13.4.5 Both X-band TWTA's will not be operated simultaneously. One X-band TWTA must be OFF to avoid excessive TWTA collector temperature increase.

13.4.6 The Ku-band waveguide switch and the X-band waveguide circulator switch will not be repositioned when RF power is ON.

13.4.7 The maximum duty cycle for either KU or X-band TWTA will not exceed 30 minutes in a 100 minute period.

13.4.8 If both the MSS and TM instruments are ON and data is being received by the TDRSS G/S, de-energizing the MSS can cause the TDRSS G/S to drop-out and reconfigure. Therefore, the MSS is not to be de-energized if the TM is on.

13.5 REDUNDANCY/CROSS STRAPPING

The implementation of the WBCS of the wideband communication subsystem (WBCS) is highly redundant with the exception of those elements identified in Table 13.5-1 as single point failure items. Table 13.5-2 provides a list of the meaning of the various single point failure classifications.

Most of the redundancy in the WBCS is provided as separate primary and separate redundant component assemblies except for the gimbal drive electronics (GDE), the DSU, and the power switching unit (PSU). Each of these functions are single component assemblies with each device containing both the primary and redundant functions.

Cross strapping is provided by coaxial and KU-band waveguide transfer switches. The coaxial latching transfer switch is a four-part, two-position RF transfer switch actuated by a command pulse. The waveguide transfer switch is also a four part two position switch actuated by a command pulse.

The X-band waveguide circulator switch contains no moving parts. It contains three ports; one output port and two input ports for the redundant X-band TWTA. It converts the RF output of the active TWTA to the X-band lowpass filter while disconnecting the inactive TWTA.

Figure 13.5-1, 13.5-2 and 13.5-3 illustrate the redundancies for the Ku-Band and X-Band downlinks, the autotrack, and power supply respectively. It should be pointed out that in the context of Figures 13.1-7, 13.1-8 and 13.1-9, "passive" redundancy implies a switch exists in the circuit, while "active" implies that there is no switch in the circuit, and "dedicated" implies that there is no cross strapping.

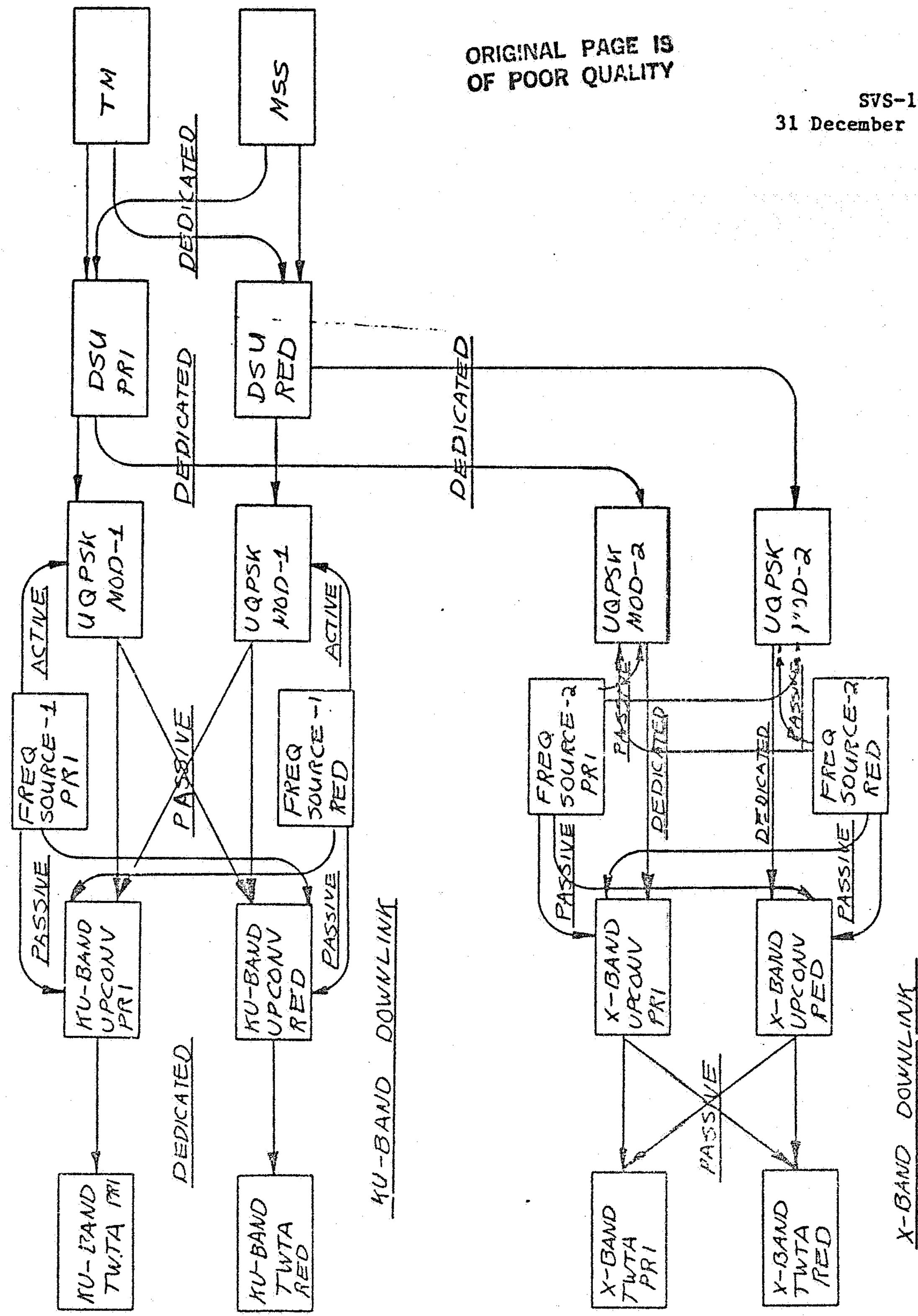

Figure 13.5-1. Ku-Band and X-Band Downlink Redundancies

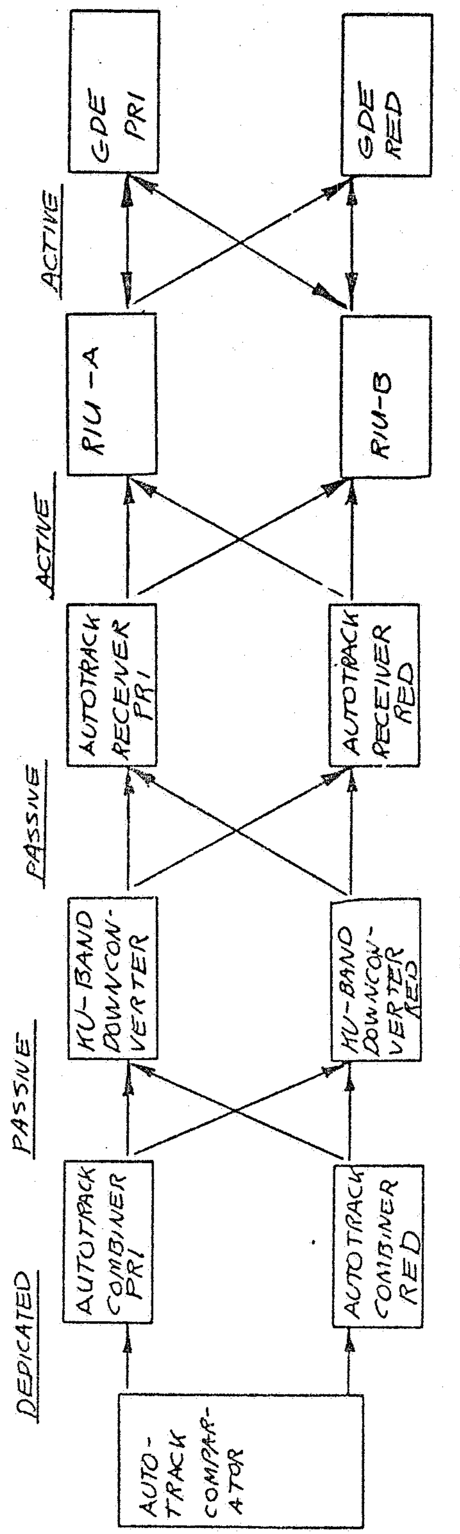

Figure 13.6-2. Autotrack Redundancy

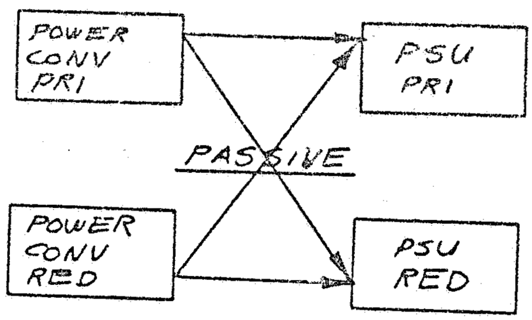

Figure 13.5-3. Power Redundancy

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Table 13.5-1. Meaning of Single Point Failure Classification

Classification Category and Level	Meaning	Subsystem Condition
Catastrophic	Will cause loss of total wideband communication subsystem Ku and X-Band transmissions	Subsystem electrical power failure
Critical	Will cause significant loss of either transmit or backup capabilities.	Ku-Band or X-Band transmit function fails, but not both.
	Loss of either TM or MSS data, but not both.	Simultaneous loss of backup redundancy in Ku-Band and X-band transmit designs
Major	Will cause loss/ degradation of subsystem functional capabilities	Loss of autotrack system capability
		Loss of capability to turn off component which consumes significant power (e.g., inability to turn off TWTA would negate use of standby mode).
		Significant degradation in critical link performance parameter (e.g., EIRP).

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Table 13.5-2. Single Point Failure Items

Subsystem Function	Item Description	Quantity	Classification
Ku and X-Band Transmit	None	0	Catastrophic
TM Data	None	0	Catastrophic
MSS Data	None	0	Catastrophic
Ku-Band Transmit	- Ku-Band WG Switch (Rotor-Port)*	1	Critical
	- Diplexer/LP Filter	1	Critical
	- Ku-S-Band Antenna	1	Critical
X-Band Operation	- WG Circulator Switch (Ferrite Switch)	1	Critical
	- LP Filter	1	Critical
	- X-Band Antenna	1	Critical
Ku-Band Autotrack	- Ku S-Band Antenna	-	Major
	- Hybrid Coupler	2	Major
	- Magic Tee Coupler	2	Major
	- Phase Shifter	2	Major
	- Diplexer	-	Major
	- 10 dB Coupler	1	Major
	- WG Transfer Switch	-	Major
	- Cable Wrap Assembly (Bond Strap)	-	Major

*These elements support both autotrack and Ku-Band transmit functions.

13.6 COMMAND (WBCS)

The wideband communication subsystem uses both discrete and serial digital commands.

13.6.1 PSU DISCRETE COMMANDS

The discrete commands are transmitted directly from the RIU-9 to the power switching unit (PSU). The PSU performs control functions or causes switching of secondary power to the using units. All even numbered commands are assigned to primary function and odd numbered commands to redundant functions. Table 13.6-1 provides a listing of the WBCS discrete commands, and Table 13.6-2 is a listing of PSU (only) discrete commands.

Table 13.6-1. Wideband Communication Subsystem Discrete Commands

RIU CMD CH NO.	COMMAND NAME	LOCATION	COMMAND COMPLEMENT	PREREQ	FUNCTION PERFORMED	USER ID		MATRIX LOCATION COL	ROW	BIT	BIT STATE
0900	SELF RIU ENABLE (STANDBY 1)										
0901	FREQ SOURCE-1 REDUNDANT ON		0911		SWITCHES +15VDC & +28VDC SEC PWR ON	WB	09	99	61	2	1
0902	KU TWTA PRIMARY ON		0908		SWITCHES KU TWTA PRI ON	WB	05	99	05	1	1
0904	FREQ SOURCE-2 PRIMARY ON		0914		SWITCHES -15VDC & +28VDC SEC PWR ON	WB	08	99	43	4	1
0905	AT COMBINER REDUNDANT ON		0915		SWITCHES +15VDC SEC PWR ON	WB	09	99	61	4	1
0906	X-BAND TWTA PRIMARY ON		0912		SWITCHES X-BAND TWTA PRI ON	WB	06	99	12	1	1
0907	PSU CMD PROC REDUNDANT ON		0929		SWITCHES +5.2VDC & +28VDC SEC PWR ON	WB	11	99	80	2	1
0908	KU TWTA PRIMARY OFF		0902		SWITCHES KU TWTA PRI OFF	WB	05	99	05	1	0
0909	X-BAND WG SWITCH REDUND ENABLE		0919		SWITCHES +15VDC SEC PWR ON	WB	11	99	80	7	1
0910	KU DOWN CONV PRIMARY ON		0916		SWITCHES +15VDC & -15VDC SEC PWR ON	WB	05	99	05	3	1
0911	FREQ SOURCE-1 REDUNDANT OFF		0901		SWITCHES -15VDC & +28VDC SEC PWR OFF	WB	58	99	49	2	0
0912	X-BAND TWTA PRIMARY OFF		0906		SWITCHES X-BAND TWTA PRI OFF	WB	06	99	12	1	0
0913	REDUND SAFEHOLD MODE ENABLE		0923		SWITCHES 5.2VDC & 28VDC SEC PWR ON	WB	11	99	80	3	1
0914	FREQ SOURCE-2 PRIMARY OFF		0904		SWITCHES -15VDC & +28VDC SEC PWR OFF	WB	08	99	43	4	0
0915	AT COMBINER REDUNDANT OFF		0905		SWITCHES +15VDC SEC PWR OFF	WB	09	99	61	4	0
0916	KU DOWN CONV PRIMARY OFF		0910		SWITCHES +15VDC & -15VDC SEC PWR OFF	WB	05	99	05	3	0
0917	PWR CONVERTER REDUNDANT ON		0927		SWITCHES CONV B ON	WB	43	99	79	A	
0918	KU TWTA PRI TO OPERATE		0924	0902, 0912, 0936	SWITCHES KU TWTA PRI TO OPERATE	WB	46	99	07	A	
0919	X-BAND WG SWITCH REDUND DISABLE		0909		SWITCHES +15VDC SEC PWR OFF	WB	11	99	80	7	0
0921	PSU CMD PROC REDUND TO CONV A		0925		SWITCHES +5.2VDC & +28VDC SEC PWR						
0922	X-BAND TWTA PRI TO OPERATE		0928	0906, 150, 0906	SWITCHES X-BAND TWTA PRI TO OPERATE	WB	48	99	73	A	
0923	REDUND SAFEHOLD MODE DISABLE		0913		SWITCHES 5.2VDC & 28VDC SEC PWR OFF	WB	11	99	80	3	0
0924	KU TWTA PRI TO STANDBY		0918/0902		SWITCHES TWTA PRI TO STAND BY	WB	46	99	07	A	
0925	PSU CMD PROC REDUND TO CONV B		0921		SWITCHES +5.2VDC & +28VDC SEC PWR	V					
0927	PWR CONVERTER REDUND OFF		0917		SWITCHES CONV B OFF	WB	43	99	79	A	
0928	X-BAND TWTA PRI TO STANDBY		0922/0906		SWITCHES X-BAND TWTA PRI TO STANDBY	WB	48	99	73	A	
0929	PSU CMD PROC REDUND OFF		0907		SWITCHES +5.2VDC & 28VDC SEC PWR OFF	WB	11	99	80	2	0
0930	GDE PRIME DATA CONVERT				UPDATE REGISTER DATA						
0932	AT COMBINER PRIMARY ON		0942		SWITCHES +15VDC SEC PWR ON	WB	05	99	05	4	1
0933	FREQ SOURCE-2 REDUND ON		0943		SWITCHES -15VDC & +28VDC SEC PWR ON	WB	58	99	49	4	1
0934	PSU CMD PROC PRIMARY ON		0956		SWITCHES +5.2VDC & +28VDC SEC PWR ON	WB	07	99	29	2	1
0935	X-BAND TWTA REDUND ON		0941		SWITCHES X-BAND TWTA RED ON	WB	10	99	75	1	1
0936	FREQ SOURCE-1 PRIMARY ON		0946		SWITCHES -15VDC & +28VDC SEC PWR ON	WB	08	99	43	2	1
0937	KU DOWN CONV REDUND ON		0947		SWITCHES +15VDC & -15VDC SEC PWR ON	WB	09	99	61	3	1
0939	KU TWTA REDUNDANT ON		0945		SWITCHES KU TWTA REDUNDANT ON	WB	09	99	61	1	1
0940	PRI SAFEHOLD MODE ENABLE		0950		SWITCHES +5.2VDC & +28VDC SEC PWR ON	WB	07	99	29	3	1
0941	X-BAND TWTA REDUND OFF		0935		SWITCHES X-BAND TWTA REDUND OFF	WB	10	99	27	1	0

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Table 13.6-1. Widebend Communication Subsystem Discrete Commands (Cont'd)

RIU CMD CH NO	COMMAND NAME	LOCATION	COMMAND COMPLEMENT	FORBID	FUNCTION PERFORMED	USER ID	MATRIX COL	LOCATION ROW	BIT	BIT STATE
0942	AT COMBINER PRIMARY OFF		0932		SWITCHES +15VDC SEC PWR OFF	WB 05	99	05	4	0
0943	FREQ SOURCE-B REDUND OFF		0933		SWITCHES 15VDC & +28VDC SEC PWR OFF	WB 58	99	49	4	0
0944	X-BAND WG SWITCH PRI ENABLE		0934		SWITCHES +15VDC SEC PWR ON	WB 07	99	29	7	1
0945	KU TWTA REDUNDANT OFF		0939		SWITCHES KU TWTA RED OFF	WB 09	99	61	1	0
0946	FREQ SOURCE-A PRIMARY OFF		0936		SWITCHES -15VDC & +28VDC SEC PWR ON	WB 08	99	43	2	1
0947	KU DOWN CONV REDUND OFF		0937		SWITCHES +15VDC & -15VDC SEC PWR OFF	WB 09	99	61	3	0
0948	PSU CMD PROC PRI TO CONV A		0940		SWITCHES +5.2VDC & +28VDC SEC. PWR					
0950	PRI SAFEHOLD MODE DISABLE		0940		SWITCHES 5.2VDC & 28VDC SEC. PWR OFF	WB 07	99	29	3	0
0951	X-BAND TWTA REDUND TO OPERATE		0957	0935, [illegible]	SWITCHES X-BAND TWTA RED TO OPERATE	WB 49	99	74	A	
0952	PWR CONVERTER PRIMARY ON		0962		SWITCHES CONV A ON	WB 42	99	15	A	
0954	X-BAND WG SWITCH PRI DISABLE		0944		SWITCHES +15VDC SEC PWR OFF	WB 07	99	29	7	0
0955	KU TWTA REDUND TO OPERATE		0961	0939, [illegible] 0961	SWITCHES KU TWTA RED TO OPERATE	WB 45	99	10	A	
0956	PSU CMD PROC PRIMARY OFF		0934		SWITCHES +5.2VDC & 28VDC SEC OFF	WB 07	99	29	2	0
0957	X-BAND TWTA REDUND TO STANDBY		0951/0935		SWITCHES X-BAND TWTA RED TO STANDBY	WB 49	99	74	A	
0959	CMD REDUND DATA CONVERT				UPDATE REGISTER DATA					
0960	PSU CMD PROC PRI TO CONVERT B		0948		SWITCHES +5.2VDC & 28VDC SEC PWR					
0961	KU TWTA REDUND TO STANDBY		0955/0939		SWITCHES KU TWTA TO STANDBY	WB 45	99	10	A	
0962	PWR CONVERTER PRIMARY OFF		0952		SWITCHES CONV A OFF	WB 42	99	15	A	
0963	SELF RIU STANDBY 2 (WATE RIU DISABLE)									

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Table 13.6-2. PSU Discrete Commands

RIU CMD CH NO.	Command Name
0907	PSU CMD PROC REDUNDANT ON
0929	PSU CMD PROC REDUNDANT OFF
0921	PSU CMD PROC REDUND TO CONV A
0925	PSU CMD PROC REDUND TO CONV B
0934	PSU CMD PROC PRIMARY ON
0956	PSU CMD PROC PRIMARY OFF
0948	PSU CMD PROC PRIMARY TO CONV A
0960	PSU CMD PROC PRIMARY TO CONV B

13.6.2 PSU SERIAL DIGITAL COMMANDS

The PSU also receives from RIU 9 a primary and a redundant serial digital command. The PSU decodes the serial digital commands and execute switching of regulated power to the users, transmits coaxial and waveguide switch commands and enables heater circuits of other WBCS. Figure 13.6-1 provides the serial digital command to discrete command conversion format. Table 13.6-3 provides a listing of the decoded serial digital command function. These command numbers are shown in octal.

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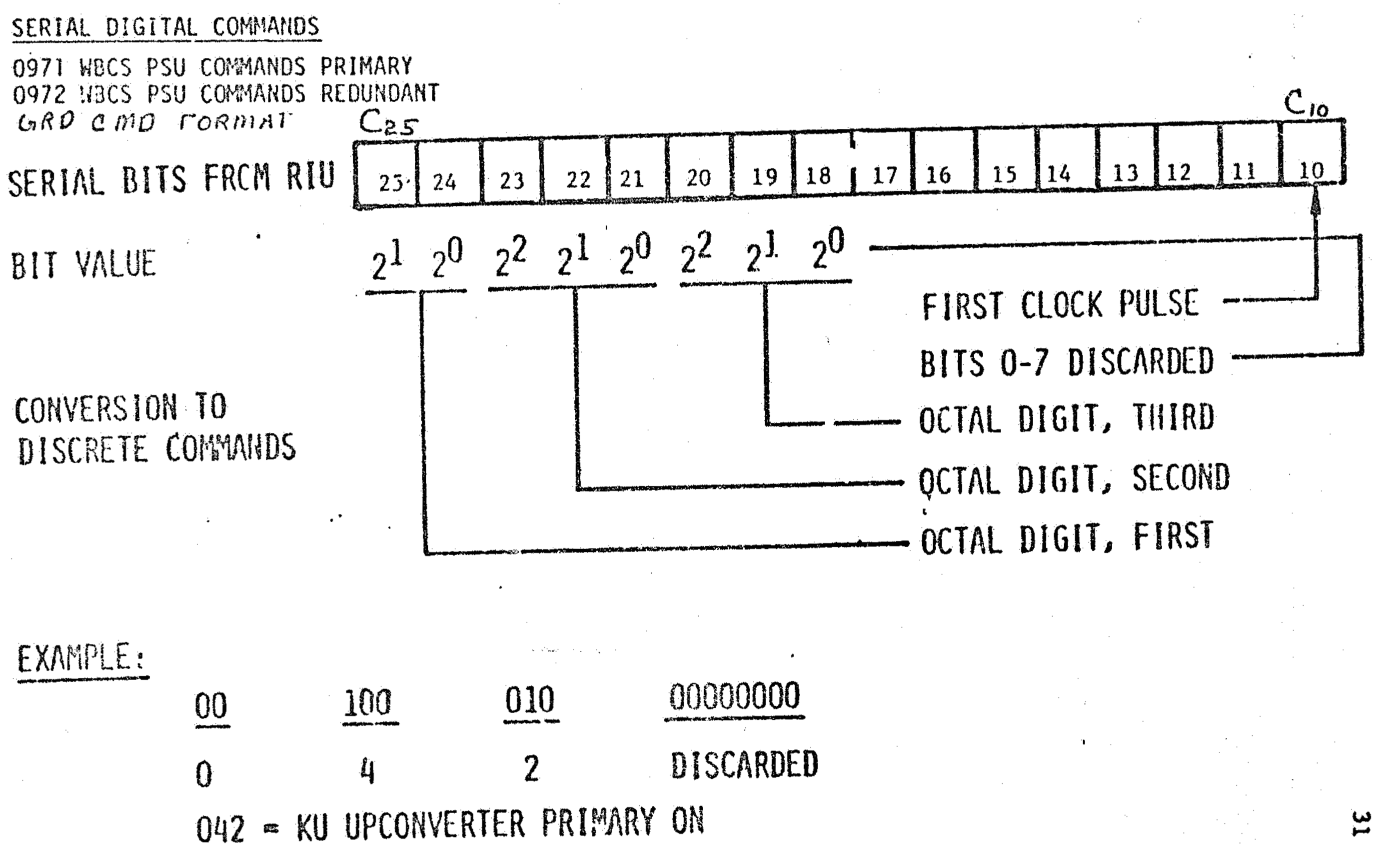

Figure 13.6-1. PSU command Matrix - Serial Digital Commands to Discrete Command Conversion

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Table 13.6-3. WBCS Power Switching Unit (PSU) Serial Digital Commands

RIU TO PSU SERIAL DIGITAL COMMANDS
0971 WBCS PSU COMMANDS PRIMARY
0972 WBCS PSU COMMANDS REDUNDANT
PSU DECODED COMMANDS

	MAGNITUDE COMMAND	COMMAND NAME	COMMAND LOCATION	COMMAND COMPLEMENT	PREREQ	FUNCTION PERFORMED	USER ID	MATRIX LOCATION COL	MATRIX LOCATION ROW	MATRIX LOCATION BIT	BIT STATE
042	0044	KU UPCONVERTER PRIMARY ON		00CC			WB05	99	05	0	1
043	00C4	FREQUENCY SOURCE -3 PRIMARY ON		002C			WB05	99	05	2	1
044	0024	PRIMARY RFC/GDA HEATERS ENABLE		00AC			WB05	99	05	5	1
	00A4	SPARE									
	0064	SPARE									
	00E4	SPARE									
050	0014	UQPSK MOD -2 PRIMARY ON		009C			WB06	99	12	2	1
051	0094	DIGITAL SWITCHING UNIT PRIMARY ON		005C			WB06	99	12	6	1
052	0054	AUTOTRACK RECEIVER IF/DEMUX PRIMARY ON		00DC			WB56	99	25	A	
053	0004	CDE/MDE PRIMARY ON		003C			WB07	99	24	0	1
054	0034	FREQUENCY SOURCE -1 AMPLIFIER PRIMARY ON		00BC							
	0084	SPARE									
062	004C	COAX/WAVEGUIDE SWITCH SELECT POSITION AA/BB		008B			WB08	99	43	3	1
063	00CC	KU UPCONVERTER PRIMARY OFF		0044			WB05	99	05	0	0
064	002C	FREQUENCY SOURCE -3 PRIMARY OFF		00C4			WB05	99	05	2	0
065	00AC	PRIMARY RFC/GDA HEATERS DISABLE		0024			WB05	99	05	5	0
	006C	SPARE									
	00EC	SPARE									
070	001C	PRIMARY CDE/MDE PRIMARY POWER ON		0072							
071	009C	UQPSK MOD -2 PRIMARY OFF		0014			WB06	99	12	2	0
072	005C	DIGITAL SWITCHING UNIT PRIMARY OFF		0094			WB06	99	12	6	0
073	00DC	AUTOTRACK RECEIVER IF/DEMUX PRIMARY OFF		0054			WB56	99	25	A	
074	003C	CDE/MDE PRIMARY OFF		0004			WB07	99	27	0	0
075	008C	FREQUENCY SOURCE -1 AMPLIFIER PRIMARY OFF		0034							
	0042	SPARE									
103	00C2	POSITION COAX SWITCH NO. 1		—			WB11	99	80	5	1
	0022	SPARE									
	00A2	SPARE									
	0062	SPARE									
	00E2	SPARE									
110	0012	PRIMARY X-BAND TWTA HEATERS ENABLE		009A			WB05	99	05	6	1
74	0092	PRIMARY CDE/MDE PRIMARY POWER OFF		001C							
112	0052	UQPSK MOD -1 PRIMARY ON		00DA			WB06	99	72	5	1
	00D2	SPARE									
	0032	SPARE									
	00B2	SPARE									
	004A	SPARE									
	00CA	SPARE									
124	002A	POSITION COAX SWITCH NO. 2		—			WB07	99	69	6	1
	00AA	SPARE									
	006A	SPARE									
	00EA	SPARE									
	001A	SPARE									
131	009A	PRIMARY X-BAND TWTA HEATERS DISABLE		0012			WB05	99	05	6	0
	005A	SPARE									
133	00DA	UQPSK MOD -1 PRIMARY OFF		0052			WB06	99	72	5	0

Table 13.6-3. WBCS Power Switching Unit (PSU) Serial Digital Commands

MAGNITUDE COMMAND	COMMAND NAME	LOCATION	COMMAND COMPLEMENT	PREREQ	FUNCTION PERFORMED	USER ID	MATRIX LOCATION COL	MATRIX LOCATION ROW	MATRIX LOCATION BIT	BIT STATE
003A	GDE/RPE PRIMARY ON		00B6							
008A	SPARE									
0046	SPARE									
00C6	SPARE									
0026	POSITION WAVEGUIDE SWITCH NO. 1		—			WB58	99	47	0	1
00A6	POSITION COAX SWITCH NO. 3		—			WB07	99	29	4	1
0066	SPARE									
00E6	SPARE									
0016	SPARE									
0096	SPARE									
0056	PRIMARY WIDEBAND MODULE HEATERS ENABLE		00D2			WB05	99	05	7	1
00D6	FREQUENCY SOURCE -2 AMPLIFIER PRIMARY ON		003E							
0036	PSU PRIMARY LOADS TO CONVERTER A		00BE			WB06	99	12	0	1
0086	GDE/RPE PRIMARY OFF		003A							
004E	SPARE									
00CE	SPARE									
002E	SPARE									
00AE	SPARE									
006E	POSITION COAX SWITCH NO. 8		—			WB58	99	49	5	1
00EE	SPARE									
001E	X-BAND WAVEGUIDE PRIMARY POSITION		004B							
009E	SPARE									
005E	SPARE									
00DE	PRIMARY WIDEBAND MODULE HEATERS DISABLE		0056			WB05	99	05	7	0
003E	FREQUENCY SOURCE -2 AMPLIFIER PRIMARY OFF		00D6							
00BE	PSU PRIMARY LOADS TO CONVERTER B		0036			WB06	99	12	0	0
0041	UQPSK MOD -2 REDUNDANT ON		00C9			WB10	99	75	2	1
00C1	DIGITAL SWITCHING UNIT REDUNDANT ON		0029			WB10	99	75	6	1
0021	AUTOTRACK RECEIVER IF/DEMUX REDUNDANT ON		00A9			WB53	99	28	A	
00A1	GDE/MDE REDUNDANT ON		0069							
0061	FREQUENCY SOURCE -1 AMPLIFIER REDUNDANT ON		00E9			WB58	99	49	6	1
00E1	SPARE									
0011	KU UPCONVERTER REDUNDANT ON		0099			WB09	99	61	0	1
0091	FREQUENCY SOURCE -3 REDUNDANT ON		0059			WB09	96	61	2	1
0051	REDUNDANT RFC/GUA HEATERS ENABLE		00D9			WB09	96	61	5	1
00D1	SPARE									
0031	SPARE									
00B1	SPARE									
0049	REDUNDANT CDM/MDE PRIMARY POWER ON		00C6			WB11	99	80	1	1
00C9	UQPSK MOD -2 REDUNDANT OFF		0041			WB10	99	75	2	0
0029	DIGITAL SWITCHING UNIT REDUNDANT OFF		00C1			WB10	99	75	6	0
00A9	AUTOTRACK RECEIVER IF/DEMUX REDUNDANT OFF		0021			WB53	99	28	A	
0069	GDE/MDE REDUNDANT OFF		00A1							
00E9	FREQUENCY SOURCE -1 AMPLIFIER REDUNDANT OFF		0061			WB58	99	49	6	0
0019	POSITION COAX SWITCH NO. 4		—			WB09	99	61	0	0
0099	KU UPCONVERTER REDUNDANT OFF		0011			WB09	99	61	0	0

Table 13.6-3. WBCS Power Switching Unit (PSU) Serial Digital Commands

	Magnitude Command	Command Name	Command Location	Command Complement	Freq	Function Performed	User ID	Matrix Location Col	Matrix Location Row	Matrix Location Bit	Bit State
32	0059	FREQUENCY SOURCE -3 REDUNDANT OFF		0091			WB09	96	61	2	0
33	00D9	REDUNDANT RFC/CDA HEATERS DISABLE		0051			WB09	96	61	5	0
	0039	SPARE									
	00B9	SPARE									
42	0045	REDUNDANT X-BAND TWTA HEATERS ENABLE		00C0			WB09	99	81	6	1
43	00C5	REDUNDANT CDE/MDE PRIMARY POWER OFF		0044			WB11	99	80	1	0
44	0025	UQQPSK MOD -I REDUNDANT ON		00AD			WB10	99	75	5	1
	00A5	SPARE									
	0065	SPARE									
	00E5	SPARE									
	0015	SPARE									
51	0095	POSITION COAX SWITCH NO. 5		—			WB07	99	29	3	1
	0055	SPARE									
	00D5	SPARE									
	0035	SPARE									
	00B5	SPARE									
	004D	SPARE									
53	00CD	REDUNDANT X-BAND TWTA HEATERS DISABLE		0045			WB09	99	61	6	0
	002D	SPARE									
65	00AD	UQPSK MOD -I REDUNDANT OFF		0035			WB10	99	75	5	0
66	006D	CDE/RFE REDUNDANT ON		00E3							
	00ED	SPARE									
	001D	SPARE									
	009D	SPARE									
72	005D	POSITION COAX SWITCH NO. 6		—			WB10	99	29	6	1
	00DD	SPARE									
	003D	SPARE									
	00BD	SPARE									
	0043	SPARE									
	00C3	SPARE									
304	0023	REDUNDANT WIDEBAND MODULE HEATERS ENABLE		00AB			WB09	99	81	7	1
305	00A3	FREQUENCY SOURCE -2 AMPLIFIER REDUNDANT ON		006B							
306	0063	FSU REDUNDANT LOADS TO CONVERTER A		00EB			WB11	99	75	0	1
307	00E3	CDE/RFE REDUNDANT OFF		006D							
	0013	SPARE									
	0093	SPARE									
312	0053	POSITION WAVEGUIDE SWITCH NO. 2		—			WB08	99	43	0	1
313	00D3	POSITION COAX SWITCH NO. 7		—			WB08	99	43	5	1
	0033	SPARE									
	00B3	SPARE									
322	004B	X-BAND WAVEGUIDE REDUNDANT POSITION		001E							
	00CB	SPARE									
	002B	SPARE									
325	00AB	REDUNDANT WIDEBAND MODULE HEATERS DISABLE		0023			WB09	99	81	7	0
326	006B	FREQUENCY SOURCE -2 AMPLIFIER REDUNDANT OFF		00A3							
327	00EB	FSU REDUNDANT LOADS TO CONVERTER B		0063			WB11	99	75	0	0
	001B	SPARE									
	009B	SPARE									
	005B	SPARE									
	00DB	SPARE									
14	003B	COAX/WAVEGUIDE SWITCH SELECT POSITION AB/BA		004C			WB08	99	43	3	0
	00BB	SPARE									

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13.6.3 GDE DISCRETE COMMANDS

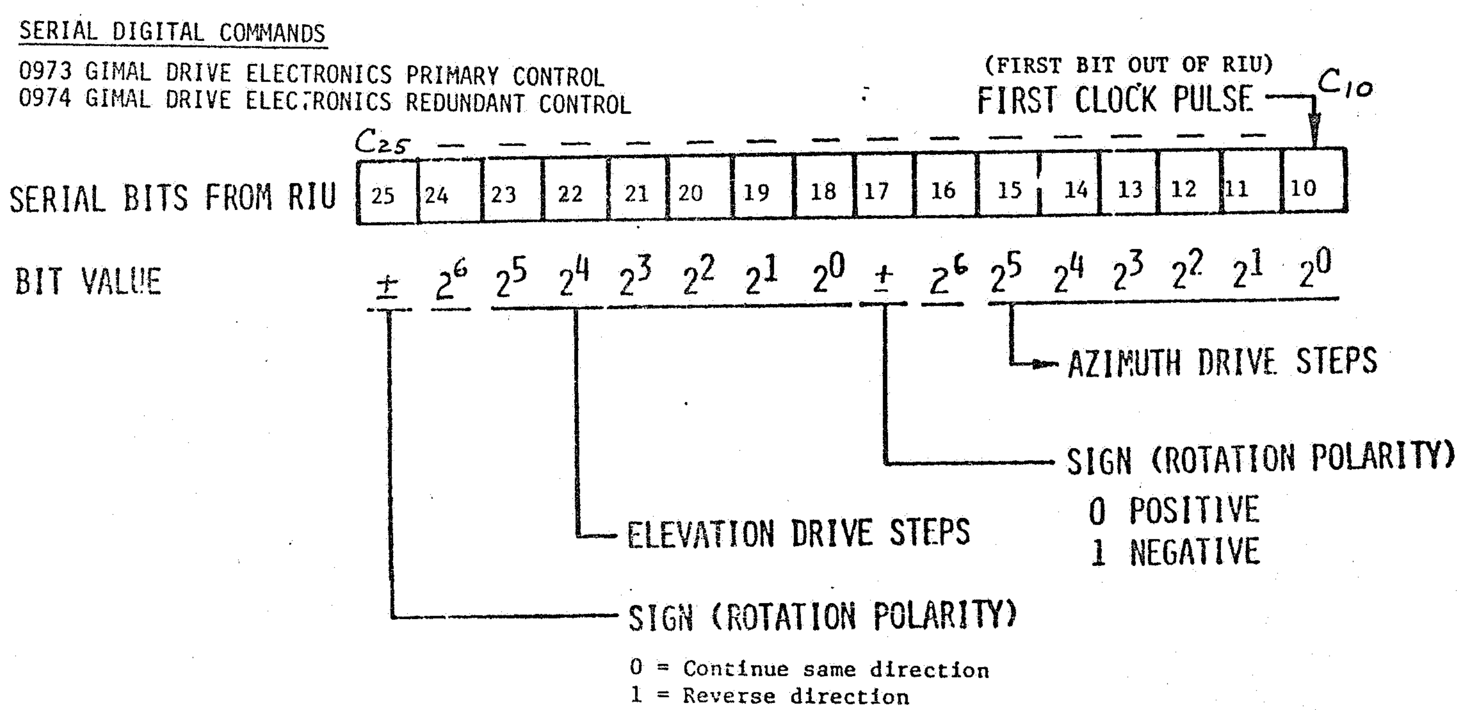
GDE discrete commands are shown in Table 13.6-4.

Table 13.6-4. GDE Discrete Commands

RIU CMD CH. NO.	Command Name
0930	GDE PRIME DATA CONVERT
0959	GDE REDUND DATA CONVERT

13.6.4 GDE SERIAL DIGITAL COMMANDS

The motor drive electronics of the gimbal drive electronics (GDE) receives from RIU 9 a primary and redundant serial digital command. These commands are used to control the gimbal drive motors. Figure 13.6-2 describes the decoding of the serial digital commands into the incremental drive pulses. RIU 9A/9B are directly connected with each GDE which is internally cross-strapped. Table 13.6-5 is a listing of GDE serial digital commands.



EXAMPLE:

1 0 001010 0 0 000101 (FIRST IN TIME ⟶)

MOVE AZIMUTH MOTOR 5 STEPS IN POSITIVE DIRECTION

MOVE ELEVATION MOTOR 10 STEPS IN NEGATIVE DIRECTION

Figure 13.6-2. Conversion of GDE/Serial Digital Command Discrete Motor Drive Commands

Table 13.6-5. GDE Serial Digital Commands

Magnitude Command	Command
00D4	GDE/MDE PRI ON
003C	GDE/MDE PRI OFF
001C	PRI GDE/MDE PRI POWER ON
0092	PRI GDE/MDE PRI POWER OFF
003A	GDE/RPE PRI ON
00B6	GDE/RPE PRI OFF
00A1	GDE/MDE REDUND ON
0069	GDE/MDE REDUND OFF
0049	REDUND GDE/MDE PRI POWER ON
00C5	REDUND GDE/MDE PRI POWER OFF
006D	GDE/RPE REDUND ON
00E3	GDE/RPE REDUND OFF

13.6.5 DSU SERIAL COMMANDS

The digital switching unit (DSU) receives a primary and redundant serial digital command. The DSU decodes and converts the serial digital commands into 15 equivalent discrete commands to execute switching of TM and MSS data to the Ku-band system, or the X-band system, or both. Each RIU is connected to each DSU which is internally cross-strapped. Table 13.6-6 is a listing of DSU serial digital commands.

Table 13.6-6. DSU Serial Digital Commands

Magnitude Command	Command
0094	DSU PRI ON
005C	DSU PRI OFF
00C1	DSU REDUND ON
0029	DSU REDUND OFF

Figure 13.6-3 provides the DSU command and telemetry format.

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SVS-10266
31 December 1981

SERIAL DIGITAL COMMANDS

0975 WBCS DSU PRIMARY CONTROL
0976 WBCS DSU REDUNDANT CONTROL

COMMAND (16 BITS) 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0	X-BAND		KU-BAND	
	I-CHANNEL	Q-CHANNEL	I-CHANNEL	Q-CHANNEL
11 100 100 XXXXXXXX	84 PN	MSS		
11 001 010 XXXXXXXX			84 PN	MSS
11 010 100 XXXXXXXX	TM	TM		
11 001 001 XXXXXXXX			TM	TM
11 000 100 XXXXXXXX	TM	MSS		
11 001 000 XXXXXXXX			TM	MSS
11 100 010 XXXXXXXX	84 PN	MSS	84 PN	MSS
11 100 001 XXXXXXXX	84 PN	MSS	TM	TM
11 100 000 XXXXXXXX	84 PN	MSS	TM	MSS
11 010 010 XXXXXXXX	TM	TM	84 PN	MSS
11 010 001 XXXXXXXX	TM	TM	TM	TM
11 010 000 XXXXXXXX	TM	TM	TM	MSS
11 000 010 XXXXXXXX	TM	MSS	84 PN	MSS
11 000 001 XXXXXXXX	TM	MSS	TM	TM
11 000 000 XXXXXXXX	TM	MSS	TM	MSS

FIRST BIT IN TIME, BIT 0

BITS 0-7 DISCARDED

KU-BAND, BITS 10-9-8
- 000 TM AND MSS ON
- 001 TM AND TM ON
- 010 84 PN AND MSS ON
- 1XX KU-BAND OFF

X-BAND, BITS 13-12-11
- XX1 X-BAND OFF
- 000 TM AND MSS ON
- 010 TM AND TM ON
- 100 84 PN AND MSS ON

ENABLE, BITS 15-14
- 11 ENABLE
- 10 DISABLE
- 01 DISABLE
- 00 DISABLE

NOTE: X = DON'T CARE BIT

Figure 13.6-3. Digital Switching Unit (DSU) Command Format

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13.6.6 SYSTEM RESPONSES TO THE LISTED COMMANDS

The following setions depict the system response to the various commands. Schematic diagrams are provided to aid in understanding the response.

The sections are arranged in this order:

1. Power Converter
2. Command Decoder
3. Coaxial Relays and Waveguide Switches
4. UQPSK Modulator
5. DSU Control
6. Ku-Band TWTA Control
7. X-Band TWTA Control
8. X-Band Waveguide Switches
9. Ku-Band Upconverter
10. Autotrack Receiver
11. Heater Control
12. X-Band TWTA Heater Control
13. Autotrack Down Converter
14. Frequency Sources
15. Gimbal Drive Control
16. Autotrack Combiner

13.7 TELEMETRY (WBCS)

Operation of the WBCS is monitored by analog, passive analog, bilevel gates, and serial digital telemetry, which are shown in Table 13.7-1. Note that sample rate refers to samples/major frame.

For information regarding calibration curves for the telemetered functions, see Appendix A.13.

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Table 13.7-1. WBCS Telemetry List

USER ID	TLM FUNCTION DESCRIPTION	SGNL TYPE	MTX LOC COL,ROW	SMPL RATE	M	ADDRESS RIU-CH	RIU CONN	S/S CONN	I/F CONN
WB-01	GDE PRIMARY SERIAL OUTPUT:					09-09			
	WORD 1								
	GDA AZIM POS'N, DEGREED 0.0/0.0	S--0	96,01	4					
	GDA AZIM POS'N, DEGREES 0.0220.0.0	S--1	96,01	4					
	GDA AZIM POS'N, DEGREES 0.0439/0.0	S--2	96,01	4					
	GDA AZIM POS'N, DEGREES 0.0879/0.0	S--3	96,01	4					
	GDA AZIM POS'N, DEGREES 0.1758/0.0	S--4	96,01	4					
	GDA AZIM POS'N, DEGREES 0.3516/0.0	S--5	96,01	4					
	GDA AZIM POS'N, DEGREES 0.7031/0.0	S--6	96,01	4					
	GDA AZIM POS'N, DEGREES 1.4060/0.0	S--7	96,01	4					
	WORD 2								
	GDA AZIM POS'N, DEGREES 2.8130/0.0	S--0	97,01	4					
	GDA AZIM POS'N, DEGREES 5.6250/0.0	S--1	97,01	4					
	GDA AZIM POS'N, DEGREES 11.250/0.0	S--2	97,01	4					
	GDA AZIM POS'N, DEGREES 22.500/0.0	S--3	97,01	4					
	GDA AZIM POS'N, DEGREES 45.000/0.0	S--4	97,01	4					
	GDA AZIM POS'N, DEGREES 90.000/0.0	S--5	97,01	4					
	GDA AZIM POS'N, DEGREES 180.00/0.0	S--6	97,01	4					
	GDA AZIM POS'N, DEGREES GT360/LT360	S--7	97,01	4					
	WORD 3								
	GDA ELEV POS'N, DEGREES 0.0/0.0	S--0	98,01	4					
	GDA ELEV POS'N, DEGREES 0.0/0.0	S--1	98,01	4					
	GDA ELEV POS'N, DEGREES 0.0220/0.0	S--2	98,01	4					
	GDA ELEV POS'N, DEGREES 0.0439/0.0	S--3	98,01	4					
	GDA ELEV POS'N, DEGREES 0.0879/0.0	S--4	98,01	4					
	GDA ELEV POS'N, DEGREES 0.1758/0.0	S--5	98,01	4					
	GDA ELEV POS'N, DEGREES 0.3516/0.0	S--6	98,01	4					
	GDA ELEV POS'N, DEGREES 0.7031/0.0	S--7	98,01	4					
	WORD 4								
	GDA ELEV POS'N, DEGREES 1.4060/0.0	S--0	99,01	4					
	GDA ELEV POS'N, DEGREES 2.8130/0.0	S--1	99,01	4					
	GDA ELEV POS'N, DEGREES 5.6250/0.0	S--2	99,01	4					
	GDA ELEV POS'N, DEGREES 11.250/0.0	S--3	99,01	4					
	GDA ELEV POS'N, DEGREES 22.500/0.0	S--4	99,01	4					
	GDA ELEV POS'N, DEGREES 45.000/0.0	S--5	99,01	4					
	GDA ELEV POS'N, DEGREES 90.000/0.0	S--6	99,01	4					
	GDA ELEV POS'N, DEGREES 180.00/0.0	S--7	99,01	4					
WB-02	GDE REDUND SERIAL OUTPUT (WORD 1)	SO-7	96,03	4		09-73			
	GDE REDUND SERIAL OUTPUT (WORD 2)	SO-7	97,03	4					
	GDE REDUND SERIAL OUTPUT (WORD 3)	SO-7	98,03	4					
	GDE REDUND SERIAL OUTPUT (WORD 4)	SO-7	99,03	4					
WB-03	DSU PRIMARY STATUS:					09-08			
	KU-BAND Q CHANNEL TM/MSS	S--0	98,13	1					
	KU-BAND I CHANNEL 84PN/TM	S--1	98,13	1					

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Table 13.7-1. WBCS Telemetry List

USER ID	TLM FUNCTION DESCRIPTION	SGNL TYPE	MTX LOC COL,ROW	SMPL RATE	M	ADDRESS RIU-CH	RIU CONN	S/S CONN	I/F CONN
	KU-BAND OFF/ON	S--2	98,13	1					
	X-BAND OFF/ON	S--3	98,13	1					
	X-BAND Q CHANNEL TM/MSS	S--4	98,13	1					
	X-BAND I CHANNEL 84PN/TM	S--5	98,13	1					
	COMMAND ENA/DISA STATUS (11=ENABLE)	S6-7	98,13	1					
WB-04	DSU REDUNDANT STATUS:					09-72			
	KU-BAND Q CHANNEL TM/MSS	S--0	99,13	1					
	KU-BAND I CHANNEL 84PN/TM	S--1	99,13	1					
	KU-BAND OFF/ON	S--2	99,13	1					
	X-BAND OFF/ON	S--3	99,13	1					
	X-BAND Q CHANNEL TM/MSS	S--4	99,13	1					
	X-BAND I CHANNEL 84PN/TM	S--5	99,13	1					
	COMMAND ENA/DIS STATUS (11=ENABLE)	S6-7	99,13	1					
WB-05	BILEVEL WORD 01:					09-32			
	KU UP CONV PRIMARY ON/OFF	B--0	99,05	1		09-32			
	KU TWTA PRIMARY ON/OFF	B--1	99,05	1		09-33			
	AUTOTRACK FREQ SOURCE PRIMARY ON/OFF	B--2	99,05	1		09-34			
	KU DOWN CONV PRIMARY ON/OFF	B--3	99,05	1		09-35			
	AUTOTRACK COMBINER PRIMARY ON/OFF	B--4	99,05	1		09-36			
	HEATERS PRIMARY RFC/GDA ON/OFF	B--5	99,05	1		09-37			
	HEATERS PRIMARY X-BAND TWTA ON/OFF	B--6	99,05	1		09-38			
	HEATERS PRIMARY WBM (PSU&GDE) ON/OFF	B--7	99,05	1		09-39			
WB-06	BILEVEL WORD 02:					09-40			
	PSU PRIMARY LOADS TO PWR CONV A/B	B--0	99,12	1		09-40			
	X BAND TWTA PRIMARY ON/OFF	B--1	99,12	1		09-41			
	X-BAND UQPSK MOD PRIMARY ON/OFF	B--2	99,12	1		09-42			
	X-BAND FREQ SOURCE AMP PRI ON/OFF	B--3	99,12	1		09-43			
	KU-BAND FREQ SOURCE AMP PRI ON/OFF	B--4	99,12	1		09-44			
	KU-BAND UQPSK MOD PRIMARY ON/OFF	B--5	99,12	1		09-45			
	DSU PRIMARY ON/OFF	B--6	99,12	1		09-46			
	AUTOTRACK RCVR PRIMARY ON/OFF	B--7	99,12	1		09-47			
W[illegible]-07	BILEVEL WORD 03:					09-48			
	GDE/RP[illegible] [illegible]IMARY ON/OFF	B--0	99,29	1		09-48			
	GDE [illegible] [illegible]RIVE PRIME BUS PWR ON/OFF	B--1	99,29	1		09-49			
	PSU PR[illegible]Y CMD PROC ON/OFF	B--2	99,29	1		09-50			
	PSU PRIMARY SAFEHOLD ENA/DISAB	B--3	99,29	1		09-51			
	CX SW3 KU-DNCNV/ATR CABLE CROSS/NORM	B--4	99,29	1		09-52			
	CX SW5 FS/KU-UPCNV CABLE CROSS/NORM	B--5	99,29	1		09-53			
	CX SW6 UQPSK/KU-UPCN CABLE CROSS/NORM	B--6	99,29	1		09-54			
	X WAVEGUIDE SWITCH PRIMARY ENA/DISAB	B--7	99,29	1		09-55			
WB-08	BILEVEL WORD 04:					09-56			
	WG SWITCH 2 KU-TWTA PRIME/REDUNDANT	B--0	99,43	1		09-56			
	RIU 09 B ON/A ON	B--1	99,43	1		09-57			
	KU FREQ SOURCE OSC/OVEN PRIMARY ON/OFF	B--2	99,43	1		09-58			

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Table 13.7-1. WBCS Telemetry List

USER ID	TLM FUNCTION DESCRIPTION	SGNL TYPE	MTX LOC COL,ROW	SMPL RATE	M	ADDRESS RIU-CH	BIU CONN	S/S COLN	I/F CONN
	COAX/WG SWITCH POSITION NORM/CROSS	B--3	99,43	1		09-59			
	X-FREQ SOURCE OSC/OVEN PRIMARY ON/OFF	B--4	99,43	1		09-60			
	CX SW7 X-FS/X-UPCNV LO CROSS/NORM	B--5	99,43	1		09-61			
	GDE/MDE PRIMARY ON/OFF	B--6	99,43	1		09-62			
WB-09	BILEVEL WORD 05:					09-96			
	KU UP CONV REDUNDANT ON/OFF	B--0	99,61	1		09-96			
	KU TWTA REDUNDANT ON/OFF	B--1	99,61	1		09-97			
	AUTOTRACK FREQ SOURCE REDUNDANT ON/OFF	B--2	99,61	1		09-98			
	KU DOWN CONV REDUNDANT ON/OFF	B--3	99,61	1		09-99			
	AUTOTRACK COMBINER REDUNDANT ON/OFF	B--4	99,61	1		09-100			
	HEATERS REDUNDANT RFC/GDA ON/OFF	B--5	99,61	1		09-101			
	HEATERS REDUNDANT X-BAND TWTA ON/OFF	B--6	99,61	1		09-102			
	HEATERS REDUNDANT UBM (PSU&GDE) ON/OFF	B--7	99,61	1		09-103			
WB-10	BILEVEL WORD 06:					09-104			
	PSU REDUND LOADS TO PWR CONV B/A	B--0	99,75	1		09-104			
	X-BAND TWTA REDUNDANT ON/OFF	B--1	99,75	1		09-105			
	X-BAND UQPSK MOD REDUNDANT ON/OFF	B--2	99,75	1		09-106			
	X-BAND FREQ SOURCE AMP RED ON/OFF	B--3	99,75	1		09-107			
	KU-BAND FREQ SOURCE AMP RED ON/OFF	B--4	99,75	1		09-108			
	KU-BAND UQPSK MOD REDUNDANT ON/OFF	B--5	99,75	1		09-109			
	DSU REDUNDANT ON/OFF	B--6	99,75	1		09-110			
	AUTOTRACK RCVR REDUNDANT ON/OFF	B--7	99,75	1		09-111			
WB-11	BILEVEL WORD 07:					09-112			
	GDE/RPE REDUNDANT ON/OFF	B--0	99,80	1		09-112			
	GDE MOTOR DRIVE RED. BUS PWR ON/OFF	B--1	99,80	1		09-113			
	PSU REDUNDANT CMD PROC ON/OFF	B--2	99,80	1		09-114			
	PSU REDUNDANT SAFEHOLD ENABLE/DISAB	B--3	99,80	1		09-115			
	CX SW4 ATR/KU-DNCNV CABLE CROSS/NORM	B--4	99,80	1		09-116			
	CX SW1 KU-UPCNV/FS CABLE CROSS/NORM	B--5	99,80	1		09-117			
	CX SW2 KU-UPCV/UQPSK CABLE CROSS/NORM	B--6	99,80	1		09-118			
	X WAVEGUIDE SWITCH REDUND ENABLE/DISAB	B--7	99,80	1		09-119			
WB-58	BILEVEL WORD 08:					09-120			
	WG SWITCH 1 KU-DNCNV PRIME/REDUNDANT	B--0	99,49	1		09-120			
	RIU 09 MATE STANDBY 1/OFF	B--1	99,49	1		09-121			
	KU-FREQ SOURCE OSC/OVEN REDUNDANT ON/OFF	B--2	99,49	1		09-122			
	X-FREQ SOURCE OSC/OVEN REDUNDANT ON/OFF	B--4	99,49	1		09-124			
	CX SW8 X-UPCNV/X-TWTA CROSS/NORM	B--5	99,49	1		09-125			
	GDE/MDE REDUNDANT ON/OFF	B--6	99,49	1		09-126			
WB-12	GDA ELEVATION MOTOR TEMP REDUNDANT	PASS	99,93	1		09-92			
WB-13	GDA AZIMUTH MOTOR TEMP PRIME	PASS	99,64	1		09-17			
WB-14	RFC PANEL(NEAR FEED) TEMP	PASS	99,76	1		09-29			
WB-15	RFC KU DIPLEXER TEMP	PASS	99,68	1		09-30			
WB-[illegible]	RFC SPARE TEMP 1	PASS	99,96	1		09-31			
WB-[illegible]	RFC KU-TWTA BASE.LATE TEMP PRIME	PASS	99,98	1		09-19			

Table 13.7-1. WBCS Telemetry List

USER ID	TLM FUNCTION DESCRIPTION	SGNL TYPE	MTX LOC COL,ROW	SMPL RATE	M	ADDRESS RIU-CH	RIU CONN	S/S CONN	I/F CONN
WB-18	RFC AUTOTRACK FREQ SOURCE TEMP	PASS	99,100	1		09-20			
WB-19	RFC PANEL (GDA MOUNT) TEMP	PASS	99,107	1		09-21			
WB-20	RFC KU UPCONVERTER TEMP	PASS	99,66	1		09-93			
WB-21	RFC KU AUTOTRACK FEED ASSY TEMP	PASS	99,69	1		09-94			
WB-22	RFC SPARE TEMP 2	PASS	99,109	1		09-95			
WB-23	RFC KU-TWTA BASEPLATE TEMP RED.	PASS	99,125	1		09-83			
WB-24	WBM X-TWTA SIDE TEMP	PASS	99,101	1		09-84			
WB-25	RFC KU DOWNCONVERTER TEMP	PASS	99,108	1		09-85			
WB-26	WBM +X COVER TEMP	PASS	99,111	1		09-22			
WB-27	WBM AUTOTRACK RCVR TEMP	PASS	99,32	1		09-23			
WB-28	WBM PSU TEMP (+Y PANEL)	PASS	99,34	1		09-24			
WB-29	WBM X-TWTA BASEPLATE TEMP PRIME	PASS	99,36	1		09-25			
WB-30	WBM +Z PANEL TEMP	PASS	99,44	1		09-26			
WB-31	WBM KU FREQ SOURCE TEMP	PASS	99,47	1		09-27			
WB-32	WBM X-BAND FREQ SOURCE TEMP	PASS	99,112	1		09-86			
WB-33	WBM PSU TEMP (-X PANEL)	PASS	99,63	1		09-87			
WB-34	WBM GIMBAL DRIVE ELECTRONICS TEMP	PASS	99,77	1		09-88			
WB-35	WBM X-TWTA BASEPLATE TEMP RED.	PASS	99,37	1		09-89			
WB-36	WBM UQPSK MODULATOR TEMP	PASS	99,45	1		09-90			
WB-37	RFC KU-TWTA SIDE TEMP	PASS	99,48	1		09-91			
WB-38	GDA ELEVATION MOTOR TEMP PRIME	PASS	99,31	1		09-28			
WB-39	GDA AZIMUTH MOTOR TEMP REDUNDANT	PASS	99,95	1		09-81			
WB-40	RIU 09A TEMP	PASS	99,04	1		09-18			
WB-41	RIU 09B TEMP	PASS	99,127	1		09-82			
WB-42	PWR CONV SEC VOLT MON, PRIMARY	ALOG	99,15	1		09-07			
WB-43	PWR CONV SEC VOLT MON, REDUNDANT	ALOG	99,79	1		09-71			
WB-44	KU TWTA PRIMARY HELIX CURRENT	ALOG	99,09	1		09-00			
WB-45	KU TWTA REDUNDANT HELIX CURRENT	ALOG	99,10	1		09-64			
WB-46	KU TWTA PRIMARY BUS CURRENT	ALOG	99,07	1		09-01			
WB-47	KU TWTA REDUNDANT BUS CURRENT	ALOG	99,08	1		09-65			
WB-48	X TWTA PRIMARY HELIX CURRENT	ALOG	99,73	1		09-05			
WB-49	X TWTA REDUNDANT HELIX CURRENT	ALOG	99,74	1		09-69			
WB-50	X TWTA PRIMARY BUS CURRENT	ALOG	99,71	1		09-06			
WB-51	X TWTA REDUNDANT BUS CURRENT	ALOG	99,72	1		09-70			
WB-52	AUTOTRACK RCVR PRI SIGNAL STRENGTH	ALOG	99,27	4		09-04			
WB-53	AUTOTRACK RCVR RED SIGNAL STRENGTH	ALOG	99,28	4		09-68			
WB-54	AUTOTRACK RCVR PRIMARY ELEV ERROR	ALOG	99,23	4		09-02			
WB-55	AUTOTRACK RCVR REDUNDANT ELEV ERROR	ALOG	99,24	4		09-66			
WB-56	AUTOTRACK RCVR PRIMARY AZIM ERROR	ALOG	99,25	4		09-03			
WB-57	AUTOTRACK RCVR REDUNDANT AZIM ERROR	ALOG	99,26	4		09-67			