Prepared for the
GEORGE C. MARSHALL
SPACE FLIGHT CENTER
Huntsville, Alabama

19 November, 1973

Contract No. NAS8-14000
MSFC-DRL-008A
Line Item No. 161S
IBM No. 73W-00315

Astrionics System Designers Handbook

Volume I

IBM

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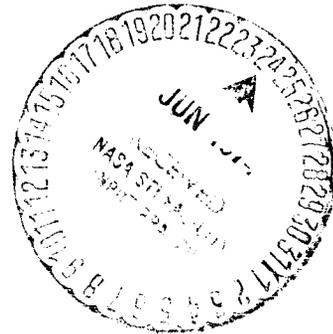
Astrionics System Designers Handbook

Volume I

Classification and Content Approval   _B̶ᵐ̲ ᵘᵃⁿ ᵇᵉˡᵘ,_

Data Manager Approval   _S Rudzkowski_

Program Office Approval   _J E Howard_

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SECTION I

INTRODUCTION

In recent months, much emphasis has been placed within the NASA, other Government agencies, and industry to use "off-the-shelf" hardware elements in new and advanced astrionics system designs. This cost effective approach has as its goal the reduction of R&D and testing costs through the application of proven and tested astrionics components. The ready availability to the designer of data facts for applicable system components is highly desirable. The Astrionics System Designers Handbook has as its objective this documenting of data facts to serve the anticipated requirements of the astrionics system designer.

Eleven NASA programs were selected as the reference base for the document. These programs are: ATS-F, ERTS-B, HEAO-A, OSO-I, Viking Orbiter, OAO-C, Skylab AM/MDA, Skylab ATM, Apollo 17 CSM, Apollo 17 LM and Mariner Mars 71. These represent a spectrum of programs ranging from those whose missions are complete to those still in advanced stages of definition. For each of these programs attempts have been made to secure the best documentation available which can describe subsystem and component (black box) characteristics. For some programs considerable success was achieved in obtaining required documentation; for other programs data was fragmentary.

Four subsystems were chosen for documentation: Communications, Data Management, Electrical Power and Guidance, Navigation and Control. For each of these subsystems the approach has been to document, through text and block diagram, the subsystem function, then go one step lower and document the characteristics and functions of components within the subsystem. To provide a degree of uniformity through the document, those components which were generally common to all programs were chosen for study. This means that special component designs, unique to a particular system application, are generally not included in the document. However, even with these ground rules all components were not present in all systems.

Sections 2, 3, 4, and 5 of the document describe the subsystem characteristics of the Communications, Data Management, Electrical Power and Guidance, Navigation and Control Subsystems respectively. Within each section, the subsystems are divided by programs with each program retaining the same identity, within the numbering system, throughout all sections, e.g., ATS-F data is found in subsections 2.1, 3.1, 4.1, and 5.1.

Sections 6, 7, 8, and 9 document components within the Communi-
cations, Data Management, Electrical Power and Guidance, Naviga-
tion and Control Subsystems respectively. Within these sections,
organizational emphasis within the numbering system was placed
upon the type of component. The second digit of each number
identifies the particular component type within the subsystem.
The third digit identifies the program and is the same digit
used in the subsystem descriptions. Thus, subsection 6.1.1
discusses a Communications Subsystem Component (6.X.X) which
is the S-band antenna (X.1.X) for the ATS-F program (X.X.1).
An S-band antenna for the ERTS-B program would be found in Sub-
section 6.1.2. Sections 10, 11, 12 and 13 present, in chart
form, a summary of key characteristics of like components.
Data for these charts is extracted from previous sections and
is given for quick reference and comparison of components.

2.1 ATS-F COMMUNICATIONS SUBSYSTEM

The ATS-F Communications Subsystem provides continuous ground communications and receives commands. It consists of the following subsystems:

o   Communications Transponder

o   Telemetry and Command Subsystem

o   Antenna

o   Experiments

A block diagram is found in Figure 2.1-1.

The transponder can be functionally divided into four major areas: receiver, IF amplifier assembly, frequency synthesizer, and transmitter. Supporting these major areas are the RF input/output circuitry, wideband data unit, monopulse detector, command distributor, and dc-dc converters. The receiver includes preamplifiers, monopulse modulators, mixers, filter, and the required interconnecting circuits. The IF amplifier consists of an IF input switch matrix, three identical IF amplifiers (f_c=150 MHz, Δf=40 MHz or 12 MHz, commandable) and an IF output switch matrix. The synthesizer uses a single frequency (100 MHz) oscillator from which it synthesizes all the other desired frequencies. It can operate in the coherent mode,wherein the VCO and all the frequencies derived from it are phaselocked to the received signal. In the noncoherent mode a temperature compensated crystal oscillator acts as the reference. The transmitter portion of the transponder is comprised of the up-converter, the drivers and the power amplifiers for C-Band, S-Band, and L-Band.

Command and Telemetry is divided into two major areas: command and the telemetry RF equipment. The Command function receives, decodes, and distributes discrete and data word commands to the spacecraft subsystems. It has a capacity of 512 discrete command addresses and 45 data word addresses. Each data word contains nine bits of data. Each command is sent back to ground and
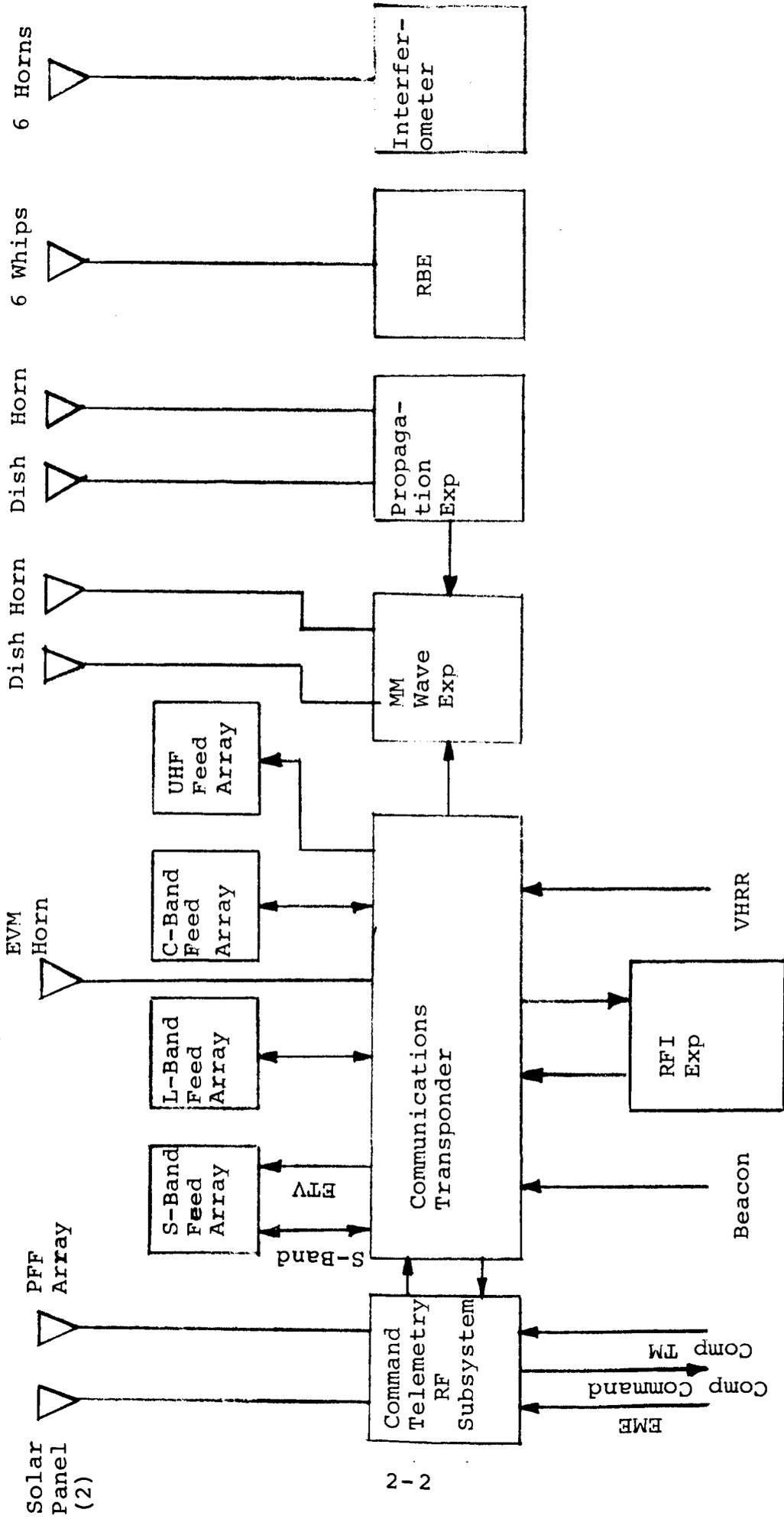
FIGURE 2.1-1. – ATS-F COMMUNICATIONS SUBSYSTEM BLOCK DIAGRAM

2-2

verified before execution. The telemetry RF equipment includes the Data Switching Unit (DSU), four transmitters and associated RF output equipment such as VHF switches, filters, diplexers, and power splitters. The DSU contains the Frequency Division Multiplexer (FDM), and switching networks for telemetry, command, Environment Measurements Experiment (EME), and earth sensor input signals. In the case of failure in the FDM unit, normal telemetry data and EME data can be switched directly to separate transmitters.

The antenna system consists of a feed array on the Prime Focus Feed (PFF) to the parabolic reflector and separate antennas on the Earth Viewing Module and Solar Panels. Each individual communication link (S-Band, L-Band etc.) has its own antennas at the PFF.

Each one of the experiments such as MM Wave, Propagation, Radio Beacon (RBE), Interferometer, RFI, High Resolution Radiometer, and EME have their own communication equipment such as transmitter, beacons, power amplifiers, receivers and associated RF hardware.

Design Status

This subsystem is scheduled to be flown as part of the planned Mid-1974 ATS-F Mission.

2.2   ERTS COMMUNICATION SUBSYSTEM

The ERTS Communication Subsystem (Figure 2.2-1) can be broken up into three major portions:

o   Wideband Telemetry

o   Narrowband Telemetry

o   Command

The wideband telemetry subsystem accepts and processes data from the return beam vidicon (RBV) cameras, the multispectral scanner (MSS), and both wideband video tape recorders. It consists of two 20-watt FM transmitters and associated filters, antennas, and signal conditioning equipment. The subsystem permits transmission of any two data sources simultaneously, either real time or recorded, over either of the two downlinks (one data source each). Commandable power-level traveling-wave-tube (TWT) amplifiers and shaped beam antennas provide maximum fidelity of the sensor data at minimum power. Cross-strapping and dual-mode operation (two data sources) with a single TWT amplifier is available in the event of hardware malfunction.

The narrowband telemetry subsystem transmits spacecraft and sensor housekeeping data to the STDN. Data is pulse code modulated (PCM) and transmitted in real time either over the VHF or Unified S-Band (USB) links at a 1 kbps rate. Up to 210 minutes can be stored on each of two narrowband tape recorders (NBTR) for subsequent playback at a 24 kbps rate.

The USB equipment has the capability to transmit on separate subcarriers real-time telemetry (768 kHz), playback data (597 kHz), DCS data (1.024 MHz) and pseudo-random ranging information simultaneously over the same 2,287.5 MHz carrier. The playback data can be derived from either of the NBTRs or either of the auxiliary tracks of the wide band video tape recorders (WBVTR).

FIGURE 2.2-1. – ERTS COMMUNICATION SUBSYSTEM BLOCK DIAGRAM

Only real-time or playback data (from either of the
NBTRs) can be transmitted at one time over the 137.86
MHz VHF equipment. All three of the ERTS receiving sites
will normally use the USB downlink.

Commanding can be performed via either the STDN VHF link
at 154.20 MHz or by the USB link at 2,106.4 MHz into
redundant sets of spacecraft receivers. Commands can be
any of 512 possible commands executable by the command/
clock or any of the 8 commands recognizable by the
Command Integrator Unit. A total of 30 command/clock
commands can be "stored" for execution outside the range
of the ground stations. All remote payload operations
are performed using stored commands.

Design Status

This subsystem is scheduled to be flown as part of the
planned late 1973 ERTS-B Mission.

2.3   HEAO COMMUNICATIONS SUBSYSTEM

The communications subsystem has two major functions: receiving command data from STDN and modulating and transmitting scientific and housekeeping data to the ground. Coherency of the downlink carrier to the received uplink is provided to enable range rate determination. In addition, PRN code modulation is turned around in the subsystem for ranging determination.

Frequency diversity is employed for both uplink and down-link communications to implement fully spherical coverage. Command data on two simultaneous S-Band uplink carriers in the 2025-2120 MHz band is received by either or both fixed-mounted antennas, demodulated by the transponder receivers and routed to the command decoders. For the downlink, experiment and spacecraft data is acquired and formatted by the Data Handling Subsystem in real time (at 25.6 kbps) and from the tape recorders (at 512 kbps). This data is modulated onto separate carriers in the 2200-2300 MHz band for transmission by the same two antennas.

When operating on different frequencies the sum of the approximately hemispherical antenna patterns results in 4 Pi steradian coverage. (Operating on a common frequency and radiating from physically separated antennas would produce interferometric sum and difference patterns and resultant deep nulls in the antenna patterns).

Figure 2.3-1 shows the Communication Subsystem block diagram.

Each transponder has a redundant receiver and transmitter for high system reliability. These are interconnected by a diplexer/hybrid and a coaxial switch respectively. Transponder operation is dependent upon both ground con-trol and signal presence in the transponder receiver. Each transponder has only one of its receivers ON con-tinuously. Switching to the redundant receiver is accom-plished by ground command through the companion trans-ponder. Transponder transmitter ON/OFF is controlled by command and/or signal presence status.
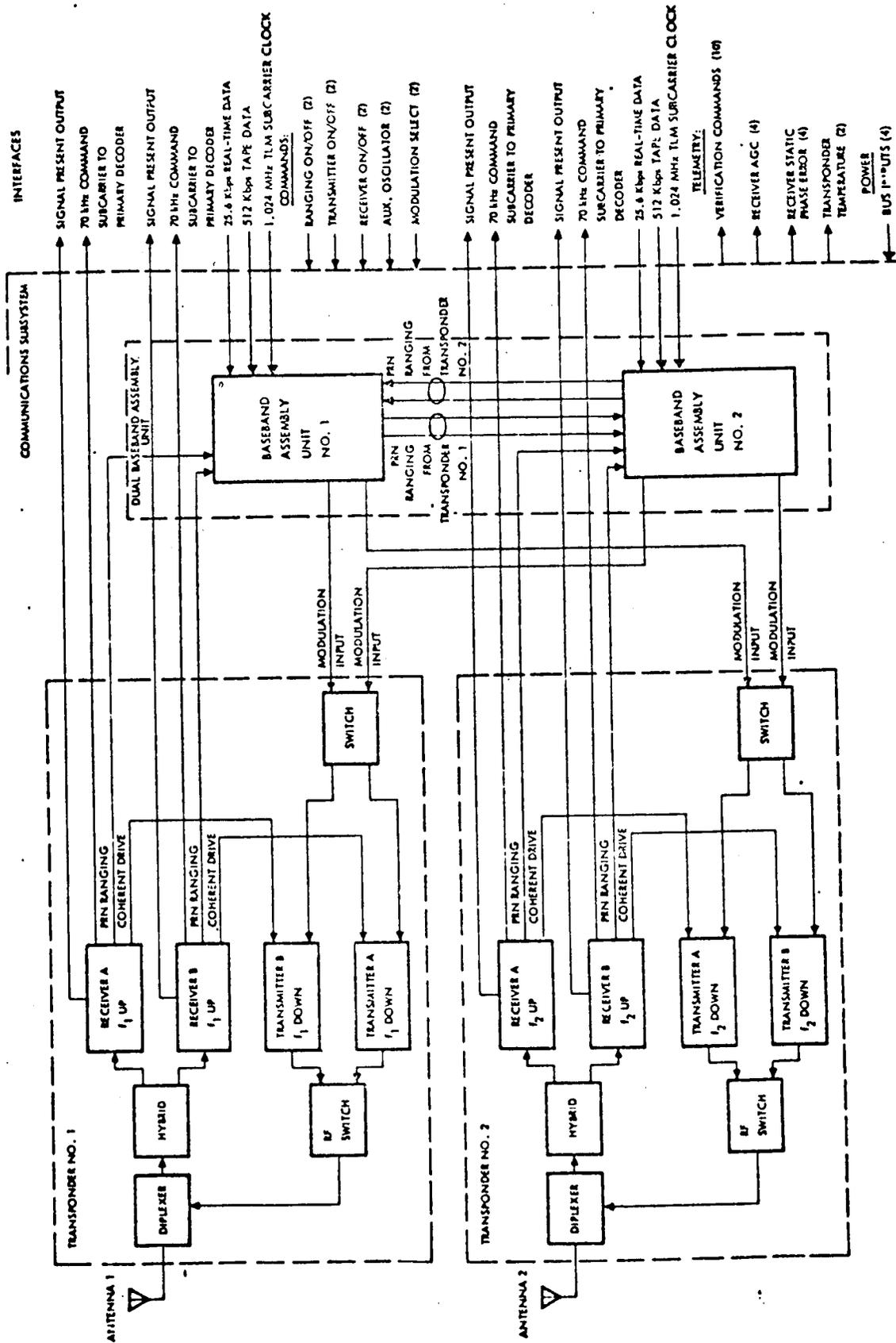
FIGURE 2.3-1. - COMMUNICATIONS SUBSYSTEM BLOCK DIAGRAM

The dual carrier technique employed is such that each antenna, with its associated redundant transponder, is assigned an uplink and downlink frequency (related by a 221/240 coherence ratio).

The transponder demodulates the uplink received carriers to provide: (1) the 70 KHz command subcarrier spectrum to the Primary Command Decoder, (2) the turn-around PRN ranging code to the Baseband Assembly Unit, (3) coherent RF signals to the transponder transmitter, and (4) status signals indicating signal presence to the Data Management Subsystem (telemetry). The Baseband Assembly Unit filters and combines the desired downlink signals (real time telemetry and tape data or the PRN ranging code) for eventual phase modulation of the downlink carrier. Real time data is first biphase modulated in the Baseband Assembly Unit onto a 1.024 MHz subcarrier supplied by the Data Management Subsystem before summation with either of the other two signals.

Design Status

The HEAO-A program is currently in a state of redefinition. This subsystem is a viable candidate for application in the 1977 HEAO-A Mission.

2.4   OSO-I COMMUNICATIONS SUBSYSTEM

The communications subsystem receives RF signals from
STDN ground stations, demodulates these signals into a
digital format, and after decoding and checking, either
stores the command for further processing or sends it to
a user as a pulse or magnitude command. Stored commands
are activated by events or time and are routed to users
in the same manner as commands from the ground. The
delays are programmed by "time tags" stored as part of
the command message in memory. These "time tags" are
referenced to an on-board spacecraft clock for execution
timing control. The subsystem is comprised of the major
units identified in Table 2.4-1.

A block diagram of the major communications subsystem
functions and interfaces is shown in Figure 2.4-1.
Communications link characteristics are given in
Table 2.4-2. A key feature of the subsystem design is
the use of remote decoder units, which are distributed
throughout the spacecraft and located in proximity to
the using subsystems and experiments.

The command messages are received by the omnidirectional
VHF antenna at a frequency of 149.520 MHz with a bit
error rate of less than 10^{-6}. Modulation is PCM/FSK-AM/AM.
Commands are accepted at a bit rate of 800 bits per
second with a tone frequency of 9100 Hz for a logical
"0" and 11,500 Hz for a logical "1". Two redundant
command receivers then RF amplify and convert the signal
to baseband frequencies. Each demodulator accepts the
output from the receiver it is connected to and trans-
lates the baseband input signal into digital data and
clock as well as a digital indication of the signal-
to-noise ratio. The outputs from both demodulators are
fed to both central decoders. Each central decoder
decides during each bit time which demodulator output
should be used as an input on the basis of the indicated
signal-to-noise ratio. The data bit stream resulting
from this operation is processed by the central decoder.

The central decoder checks for proper spacecraft address
and for errors in transmission by means of a polynomical
code check. If any code check (address or polynomial
code) fails, the unit inhibits further processing and
rejects the message. Upon verification, further decoding
is performed to select the desired decoder on either

TABLE 2.4-1. - COMMUNICATION SUBSYSTEM UNIT IDENTIFICATION

Item Number	Unit	Quantity	Part Number	Specification Number
1	VHF antenna and hybrid balun*	1	3280661-100	DS31331-166
2	Diplexer*	2	3280635-100	DS31331-198
3	VHF command receiver	2	3280520-100	DS31331-196
4	Demodulator/ central decoder	2	3280530-100	DS31331-181
5	Remote decoder	15	3280540-100	DS31331-182
6	Stored command processor	1	3280550-100	DS31331-183
7	Command memory assembly	1	3280560-100	PS31331-191
8	Multiple squib driver	2	3280570-100	DS31331-184

*Units common with data handling and telemetry subsystem

FIGURE 2.4-1. - COMMUNICATIONS SUBSYSTEM BLOCK DIAGRAM

TABLE 2.4-2. – COMMUNICATIONS LINK CHARACTERISTICS
(REFERENCE VALUES ONLY)

Ground transmitter power (250 watts)	54.0 dBm
Ground antenna gain	19.0 dB
Antenna pointing loss	-0.3 dB
Transmitter RF loss	-0.5 dB
Propagation loss (5 degrees elevation)	-142.6 dB
Polarization mismatch loss	-0.5 dB
Observatory antenna gain	-13.0 dB
Receiver RF loss	-1.4 dB
Received signal power	-85.3 dBm
Data Rate (800 bits/sec)	29.0 dB/Hz
Energy per bit (Eb)	-114.3 dBm/Hz
Noise spectral density	-198.6 dBm/HzK
System noise temperature (5 dB N. F.)	28.0 dBK
Receiver noise density (No)	-170.6 dBm/Hz
Bit energy/noise density ratio; Eb/No	56.3 dB
AM detection theoretical loss	-6.3 dB
AM detector implementation loss	-3.0 dB
Effective Eb/No	47.0 dB
Required Eb/No for 10^{-6} BER	14.3 dB
FSK-AM detection degradation	-4.0 dB
Excess Eb/No	28.7 dB
Squelch implementation loss	-6.1 dB
Excess operating margin	22.6 dB

the wheel, sail, or PIA portions of the spacecraft.The addressed remote decoder receives an instruction followed by an execute signal on a single signal wire. The remote decoder further decodes the message to one of 64 pulse commands or to one of four NRZ serial 16 bit magnitude commands. It should be noted from the block diagram that, where full redundancy exists between the antenna terminal and any command destination, immunity to mission failure due to a single unit failure is provided.

The demodulator/central decoder also recognizes a special memory load address which transfers data to be stored via the stored command processor into the command memory. The command memory has the capacity for 1360 stored commands (24 bits per command) which consist of absolute time-tagged commands (T) and relative time commands (T).

Design Status

This subsystem is scheduled to be flown as part of the planned 1974 OSO-I Mission.

2.5 VIKING ORBITER COMMUNICATIONS SUBSYSTEM

The Viking Orbiter Commumications subsystem is capable of receiving commands from the earth, receiving telemetry data from the Lander and relaying it to the earth, and transmitting Viking orbiter data to the earth. The Communications subsystem consists of the following subsystems:

o   Radio Frequency Subsystem (RFS)

o   Modulation Demodulation Subsystem (MDS)

o   Computer Command Subsystem (CCS)

o   Relay Radio Subsystem (RRS)

o   Relay Antenna Subsystem

o   S/X-Band Antenna Subsystem

A functional block diagram for the Viking Orbiter Communications Subsystem is found in Figure 2.5-1.

The RFS consists of the command receivers, telemetry transmitters and RF switching. High reliability is obtained through redundant receivers, exciters, TWTs, filters and preselector mixers.

The MDS has two functions: 1) demodulates and detects the command signal, and 2) modulates MDS generated subcarriers and mixes these signals into a composite telemetry signal for use by the RFS. There are redundant Command Detector Units, Telemetry Modulation Units and power supplies for reliability enhancement.

The CCS receives the detected command signal from the MDS, and processes and distributes the command.

The RRS receives a 380.963+5 MHz FSK signal on the conical-log-spiral relay antenna from the Viking Lander and provides
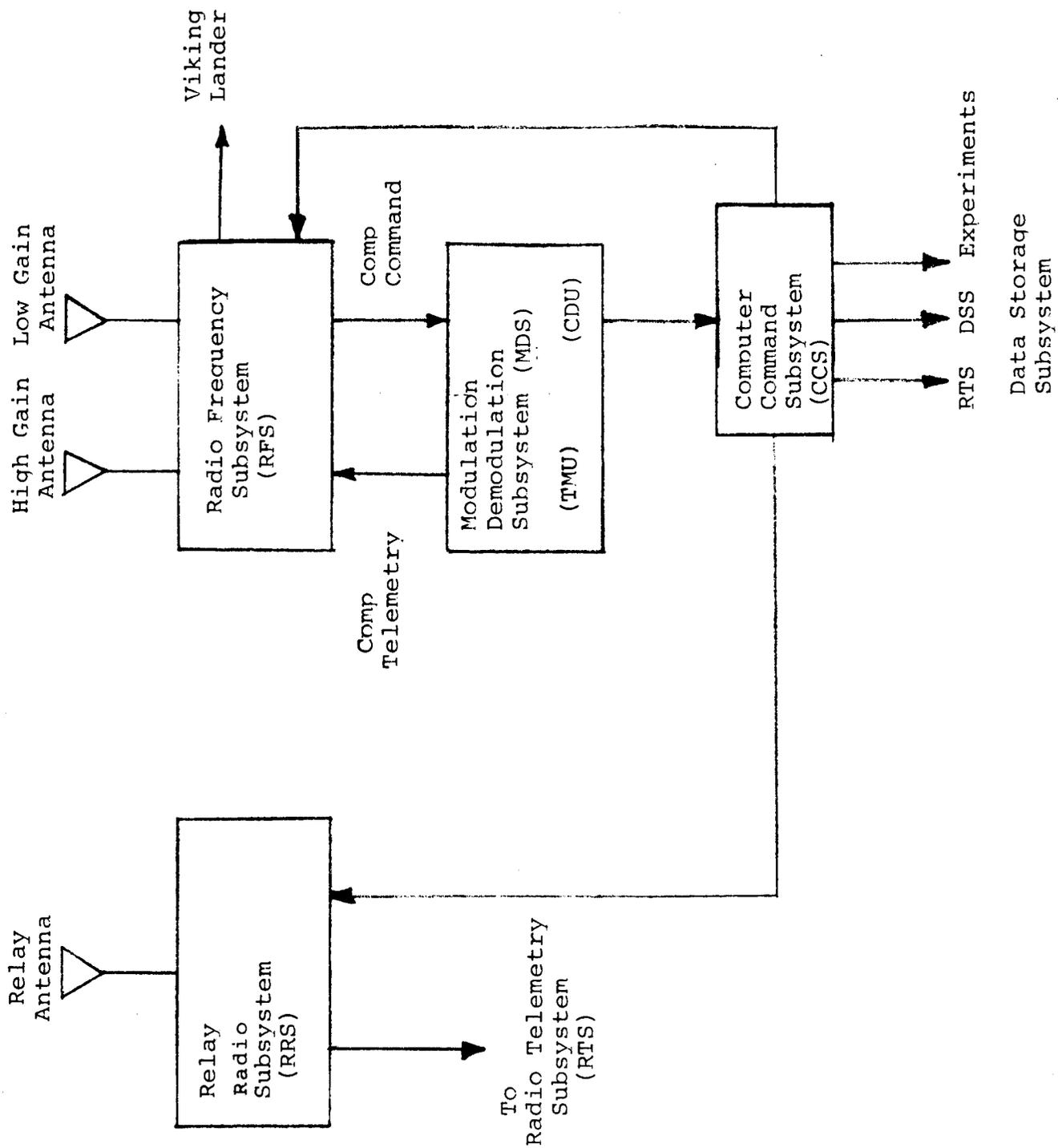
FIGURE 2.5-1. - VIKING ORBITER COMMUNICATIONS SUBSYSTEM

2-16

output signals to the 4 kbps and the 16 kbps rate channels in the Radio Telemetry System (RTS).

The S/X-band Antenna Subsystem consists of one high-gain antenna (HGA) and one low gain antenna (LGA). The HGA transmits on frequencies of 2295 $\pm$5 MHz and 8415 $\pm$20 MHz signal to the ground Deep Space Network and receives a frequency of 2115 $\pm$5 MHz. The LGA frequencies are 2295 $\pm$5 MHz for transmit and 2115 $\pm$5 MHz for receive.

Design Status

This subsystem is scheduled to be flown as part of the planned 1975 Viking Orbiter Mission.

2.6   OAO-C COMMUNICATIONS SUBSYSTEM

The OAO-C Communications Subsystem (Figure 2.6-1) performs the functions of telemetry data transmission to the ground and command reception from the ground. The command receivers are divided into two pairs with the AGC circuits interconnected to insure that the receiver with higher output signal will dominate the other. All four command receiver outputs are inter-connected in the video detector and give a video signal that is the sum of the signal plus noise of the four command receiver outputs. The command message output of the video detector is a serial, binary, NRZ signal with a 1042 bps bit rate.

Each radio tracking beacon (RTB) provides a continuous wave RF signal for tracking on the ground. The two transmitters are operated in a redundant manner so that only one transmitter is ON at any one time.

Each narrow band (NB) transmitter is capable of transmitting PCM digital information from the spacecraft data handling equipment (SDHE) or primary processor and data storage (PPDS) by phase modulating a 136.260 MHz carrier. Output power of 1.6 watts is provided. The two transmitters are operated in a redundant manner so that only one transmitter is ON at any one time.

The wide band (WB) transmitters transmit both analog and digital information by frequency modulating a 400.550 MHz carrier.

Both pairs of UHF and VHF antennas are located on opposite sides of the OAO and provide, as nearly possible, an omni-directional pattern through the entire 4 Pi steradians of the earth.

Design Status

This subsystem was flown as part of the 1972 QAO-C Mission.

FIGURE 2.6-1. - COMMUNICATIONS SUBSYSTEM BLOCK DIAGRAM

2.7   SKYLAB AM/MDA COMMUNICATION SYSTEM

The communication system provides the radio frequency (RF)
link between the Skylab and STDN. Instrumentation data are
downlinked to STDN and ground commands are uplinked from
STDN. The communication system provides the CSM with ranging
data from Skylab during the rendezvous maneuver in addition
to providing voice and television data for real time (RT)
downlinking to STDN. The interface with the caution and warning
system (C&WS) enables the communication system to provide an
indication of a caution or warning condition.

The communication system is divided into five subsystems: audio,
television, teleprinting, ranging, and RF.

The audio subsystem provides RT voice communication between
the crewmen and STDN via CSM S-band equipment. It also provides
1) delayed time (DT) voice communication to STDN via an inter-
face with the instrumentation system and 2) audio tones and
visual displays indicative of a caution or warning condition.

The television (TV) subsystem provides a distribution of
connections for the Apollo portable color TV camera, conditions
video signals from the TV camera, and provides for the selec-
tion of an ATM or AM/OWS video output to the CSM for trans-
mission to STDN. The TV subsystem consists of five TV input
stations and a VIDEO selector switch.

The teleprinting subsystem provides printed messages to the
crew from STDN. The messages are transmitted from STDN to the
Digital Command System (DCS),which transfers the data to the
teleprinting system. The Interface Electronics Unit (IEU)
accepts and decodes binary data from the DCS and transfers the
data to the teleprinter for message printout. A message sent
from STDN is composed of 30 bits with the first three bits re-
presenting the vehicle address and the second three bits the
system address.

The ranging subsystem transponds the ranging signal generated
by the CSM to enable the CSM ranging subsystem to compute and
display range and range rate between the CSM and the Skylab
during rendezvous.The ranging subsystem consists of a ranging
antenna, a VHF transceiver and a range tone transfer assembly
(RTTA).
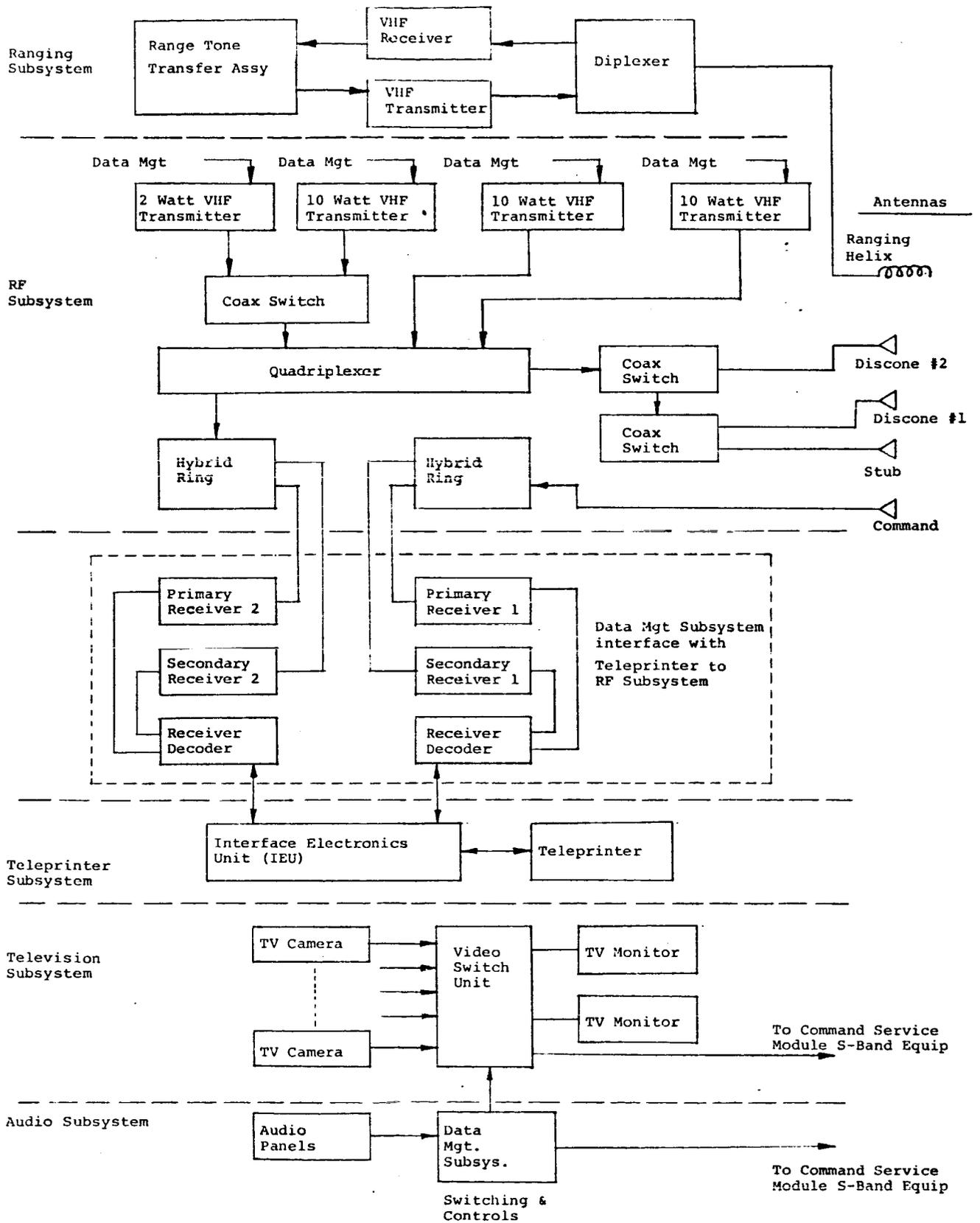
FIGURE 2.7. - SKYLAB AM/MDA COMMUNICATIONS SYSTEM

The RF subsystem provides for the transmission of data to
STDN and the reception of ground commands from STDN. It consists
of three 10-watt transmitters, one 2-watt transmitter, a
quadriplexer, two hybrid rings, four coaxial switches, a command
stub antenna, a launch stub antenna, and two discone antennas.

The 2-watt transmitter (as opposed to a 10-watt transmitter)
is used during the launch phase to transmit data through the
launch stub antenna to preclude corona. After orbital insertion,
the 2-watt transmitter is deactivated by ground command and
the 10-watt transmitters are activated.

Design Status

This subsystem was flown as part of the 1973 Skylab Mission.

2.8   SKYLAB ATM COMMUNICATION SYSTEM

The Communications System consists of the telemetry data transmission subsystem (Figure 2.8-1), the digital command subsystem (Figure 2.8-2), and the television subsystem (Figure 2.8-3).

The transmission subsystem consists of two very high frequency (VHF) transmitters, a voltage standing wave ratio (VSWR) measuring assembly, two coaxial switches, two radio frequency (RF) multicouplers, and two telemetry antennas. Input switching is provided such that either transmitter may transmit either the PCM/DDAS or the ASAP data format. Both transmitters may also transmit the same data simultaneously. The VSWR measuring assembly measures the incident and the reflected RF power at the output of each of the transmitters. The coaxial switches and the RF multicouplers allow either transmitter to be connected to either antenna independently or both transmitters to be connected simultaneously to either antenna.

The telemetry data transmission subsystem accepts 72 KBPS NRZL real-time data or 72 KBPS Manchester II biphase delayed time data from the data management subsystem and uses it to frequency modulate the 231.9 and 237.0 MHz carrier frequencies of the two VHF transmitters.

The digital command subsystem consists of two antennas, two directional couplers, two receivers, and two decoders. These components are configured to provide two independent, parallel systems. The two systems are connected in active redundancy and only one operational system is required for processing the command data transmitted by STDN. The system is designed such that STDN may address either, or both of the redundant systems.

Command data are transmitted by STDN in the form of a phase-shift-keyed/frequency modulated (PSK/FM) signal. The command data may be either an ATM switch selector command or an ATM digital computer (ATMDC) command. The 450 MHz UHF signal is received by either or both of the antennas. The antenna configuration is fixed with the Model 316 antenna providing input to the directional coupler in one system and the Model 356 antenna providing input to the directional coupler in the other system. The primary function of the directional coupler is to couple test inputs from the Electrical Support Equipment (ESE) to the command receiver and to isolate these test inputs from the antenna. The command receiver demodulates the UHF signal and supplies the resulting audio output to the command decoder. The command decoder further demodulates and decodes this audio output, verifies the resulting decoded data, and issues an output to the signal distribution circuitry.

The ATM television (TV) subsystem provides television data from the ATM experiments to the TV monitors located on the ATM control and display (C&D) console and to the television subsystem in the multiple docking adapter (MDA) for transmission to STDN via the telecommunication system in the Command Service Module (CSM).
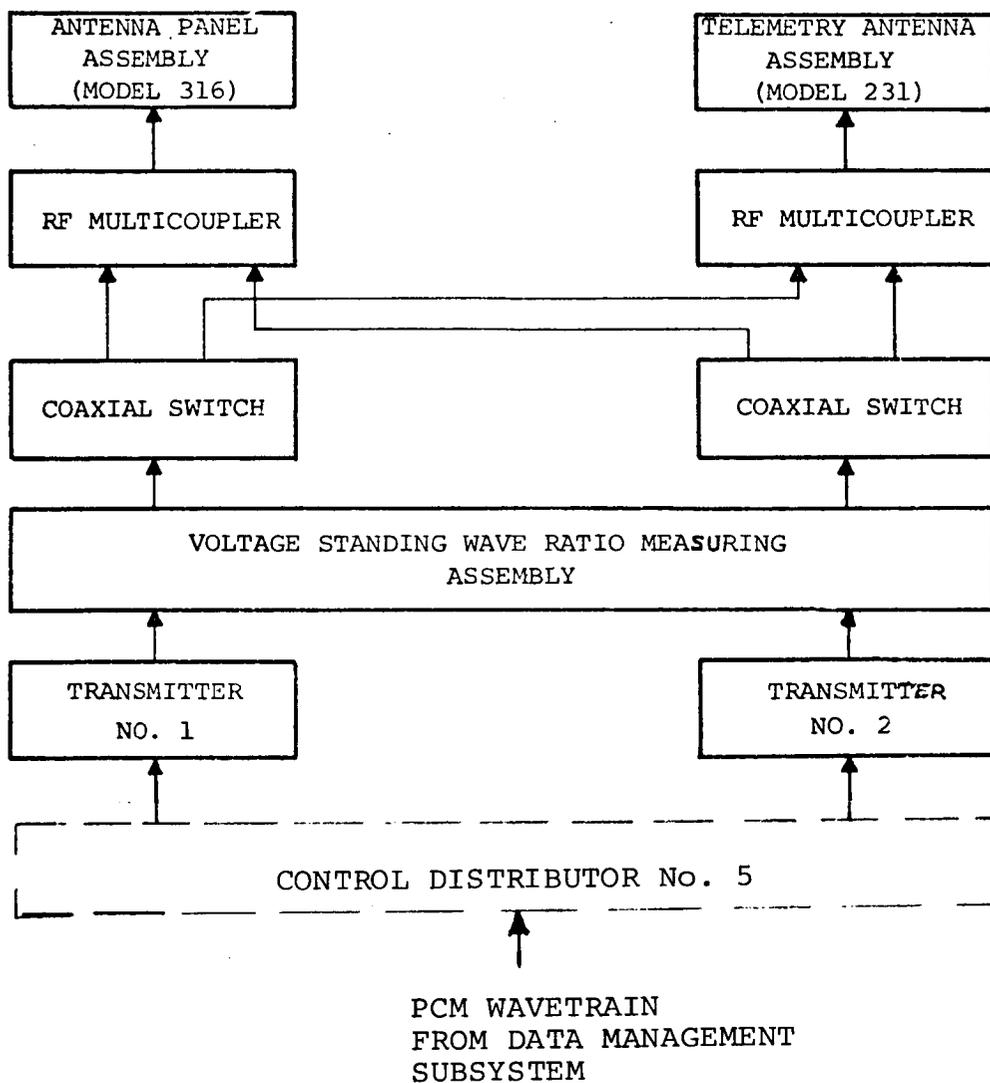
Figure 2.8-1 ATM TELEMETRY SUBSYSTEM

```
┌──────────────────────┐              ┌──────────────────────┐
│    ANTENNA PANEL     │              │   COMMAND ANTENNA    │
│ ASSEMBLY-MODEL 316   │              │ ASSEMBLY-MODEL 356   │
│      WING 710        │              │      WING 712        │
└──────────┬───────────┘              └──────────┬───────────┘
           │                                     │
           ▼                                     ▼
┌──────────────────────┐  ┌───────────────┐  ┌──────────────────────┐
│ COMMAND DIRECTIONAL  │◄─┤    GROUND     ├─►│ COMMAND DIRECTIONAL  │
│  COUPLER ASSEMBLY    │  │ ELECTRICAL    │  │  COUPLER ASSEMBLY    │
│      NO. 1           │  │ SUPPORT       │  │      NO. 2           │
└──────────┬───────────┘  │ EQUIPMENT     │  └──────────┬───────────┘
           │              └───────────────┘             │
           ▼                                             ▼
┌──────────────────────┐  ┌───────────────┐  ┌──────────────────────┐
│ COMMAND RECEIVER     │─►│    MEMORY     │◄─│ COMMAND RECEIVER     │
│      NO. 1           │  │ LOADING UNIT  │  │      NO. 2           │
└──────────┬───────────┘  └───────────────┘  └──────────┬───────────┘
           │                                             │
           ▼                                             ▼
┌──────────────────────┐                      ┌──────────────────────┐
│ COMMAND DECODER      │                      │ COMMAND DECODER      │
│      NO. 1           │                      │      NO. 2           │
└──────────┬───────────┘                      └──────────┬───────────┘
           │                                             │
           ▼                                             ▼
┌─────────────────────────────────────────────────────────────────────┐
│                   CONTROL DISTRIBUTOR NO. 1                          │
└─────────────────────────────────────────────────────────────────────┘
```

CONTROL DISTRIBUTOR NO. 1

ATM DIGITAL COMPUTER
NO. 1
NO. 2

SWITCH SELECTOR
NO. 1
NO. 2
NO. 3
NO. 4

Figure 2.8-2   ATM DIGITAL COMMAND SUBSYSTEM

2-25
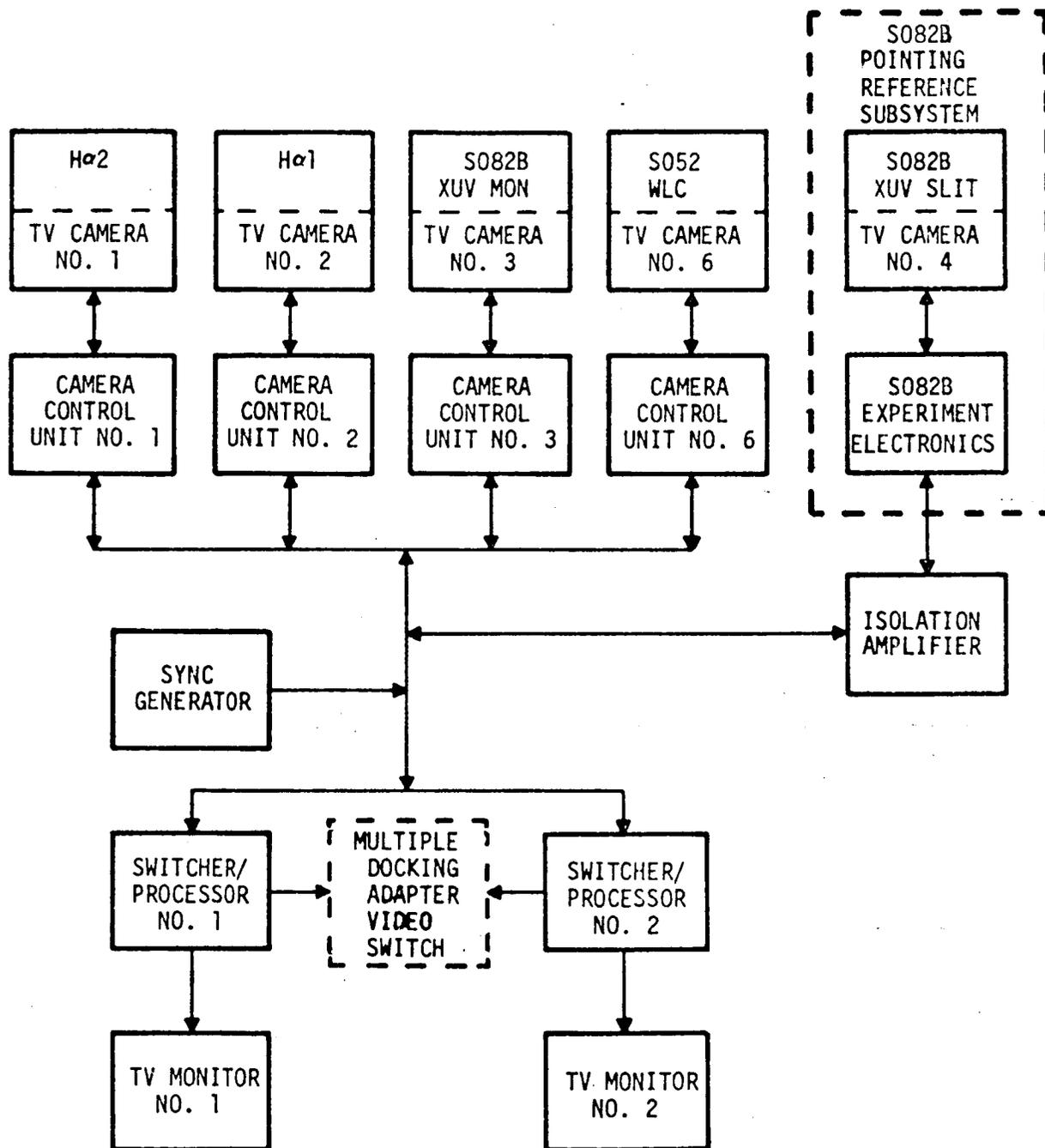
Figure 2.8-3   ATM TV SUBSYSTEM

The TV subsystem is comprised of five TV cameras, four camera control units, two switcher/processors, a sync generator, and two TV monitors. Each switcher/processor consists of an isolation amplifier and a video switch and sync adder.

Design Status

This subsystem was flown as part of the 1973 Skylab Mission.

2.11 MARINER MARS 71 COMMUNICATION SUBSYSTEM

The communications subsystem (Figure 2.11-1) has capabilities
for both uplink and downlink transmissions. Uplink communi-
cation in the sun-acquired attitude is achieved from separation
through the end of the mission; during non-sun periods it is
achieved to the maximum extent possible. Uplink communications
are through the low-gain and medium-gain antennas only. Down-
link communications with the SC are provided from prelaunch
through orbit insertion, and for at least three months there-
after. Transmissions from the spacecraft to the ground utilize
three different (low-gain, medium-gain, and 2-position high-
gain) antennas. Basically the communications subsystem is
broken up into three sub-subsystems: S-band antenna subsystem
(SBA), RF subsystem (RFS), and flight command subsystem (FCS).

The S-band antenna subsystem (SBA) receives and transmits
S-band signals between the Deep Space Instrumentation Facility
(DSIF) and the spacecraft. The subsystem consists of one high-
gain antenna, one low-gain antenna, one medium-gain antenna,
one high-gain antenna probe coupler, one low-gain antenna probe
coupler, one directional coupler for both low and medium-gain
antennas, and the necessary transmission lines and associated
connectors required to transfer RF energy to and from the radio
frequency sybsystem (RFS). A functional block diagram of the
SBA is found in Figure 2.11-2.

The radio frequency subsystem (RFS) performs the following
functions:

a)   Receives the RF signal transmitted to the space-
     craft from the stations of the Deep Space Instru-
     mentation facility (DSIF).

b)   Coherently translates the frequency of the received
     RF signal precisely by 240/221.

c)   Demodulates the received RF signal and sends a
     composite command signal to the spacecraft command
     subsystem.

d)   Detects the ranging signal transmitted to the space-
     craft from the stations of the DSIF.

e)   Modulates the transmitted signal with a composite
     telemetry signal.
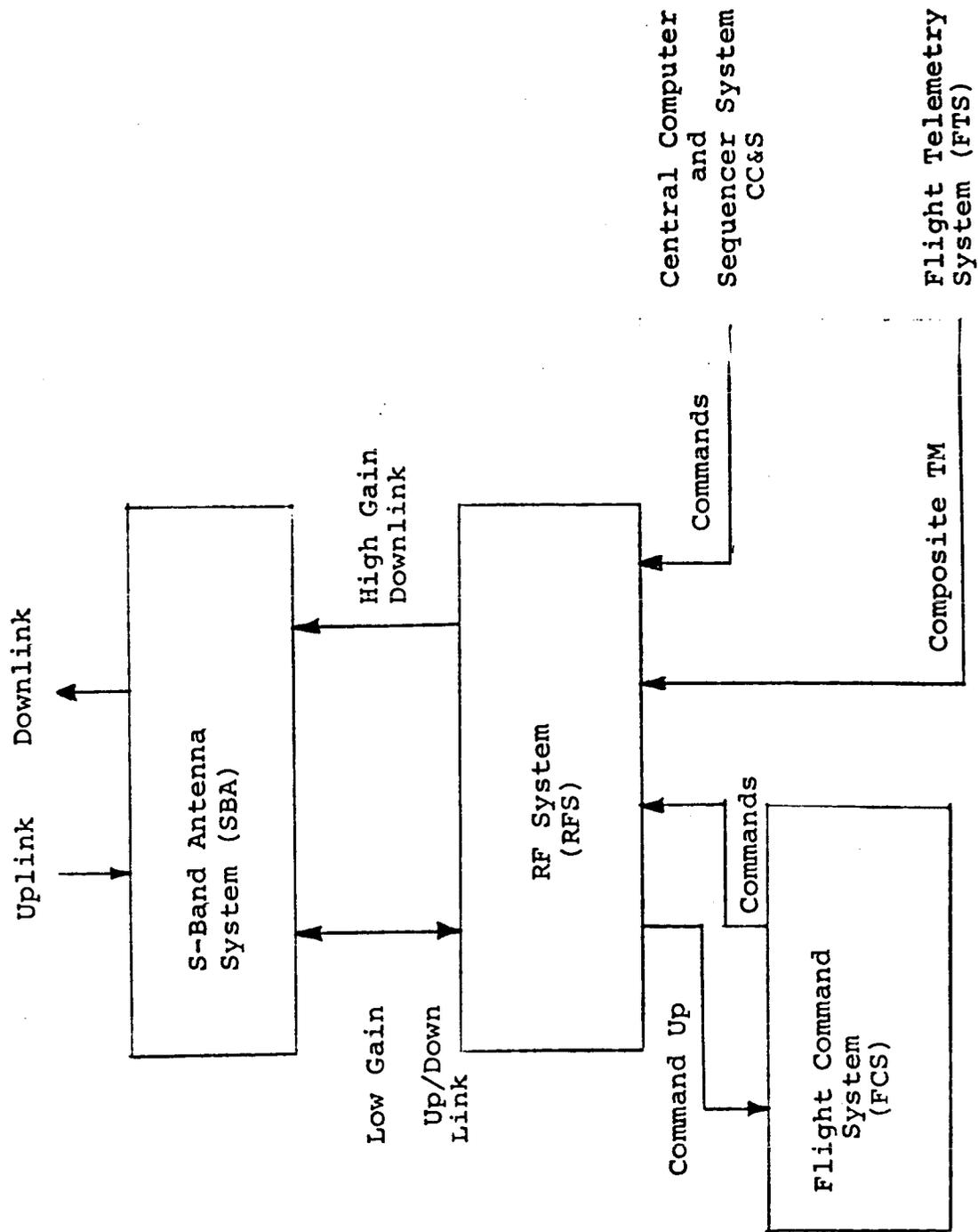
FIGURE 2.11-1. – SPACECRAFT COMMUNICATION SUBSYSTEM FUNCTIONAL BLOCK DIAGRAM

TRANSMITTING
ANTENNA

TRANSMITTING AND
RECEIVING ANTENNAS

HIGH-GAIN
ANTENNA

LOW-GAIN
ANTENNA

MEDIUM-GAIN
ANTENNA

UMBILICAL COUPLER
PROBE

DIRECTIONAL
COUPLER

| J3
R F SWITCH
ASSEMBLY | J3
DIPLEXER
SUBASSEMBLY |

RFS
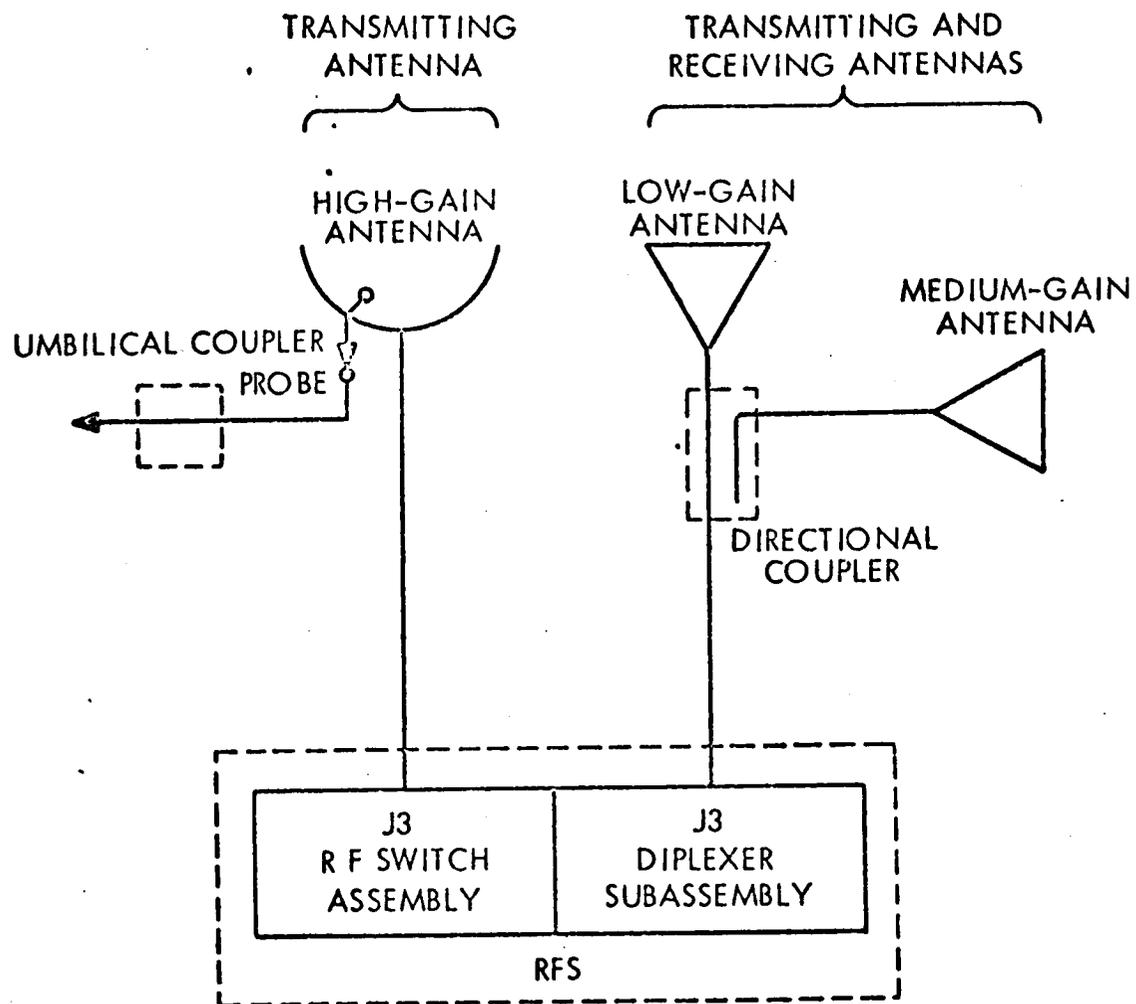
FIGURE 2.11-2. - S-BAND ANTENNA BLOCK DIAGRAM

f) Modulates the transmitted signal with the ranging signal.

g) Transmits to the stations of the DSIF a modulated RF signal that is phase coherent with either the received signal or with an internally generated frequency.

A block diagram of the RFS is shown in Figure 2.11-3.

The flight command subsystem (FCS) performs the following functions:

a) Receives from the spacecraft radio frequency subsystem (RFS) the composite command signal containing the command word information and synchronization information.

b) Automatically acquires phase coherence (lock-up) with the synchronization information, and establishes a phase reference signal and a bit synchronization signal.

c) Demodulates the command word information which is a biphase modulated sinusoidal subcarrier, using the phase reference established by the synchronization process, and detects and reconstructs the command word data bits.

d) Provides a detector lock signal indicating whether or not detector synchronization with the received signal has been established.

e) Decodes the command word and provides up to 98 discrete momentary switch closures, representing direct commands (DC), to the proper spacecraft user subsystems.

f) Decodes the command word and directs a serial binary word, representing coded command (CC) data, and bit synchronization information to the spacecraft central computer and sequencer (CC&S) subsystem, and the data automation subsystem (DAS).
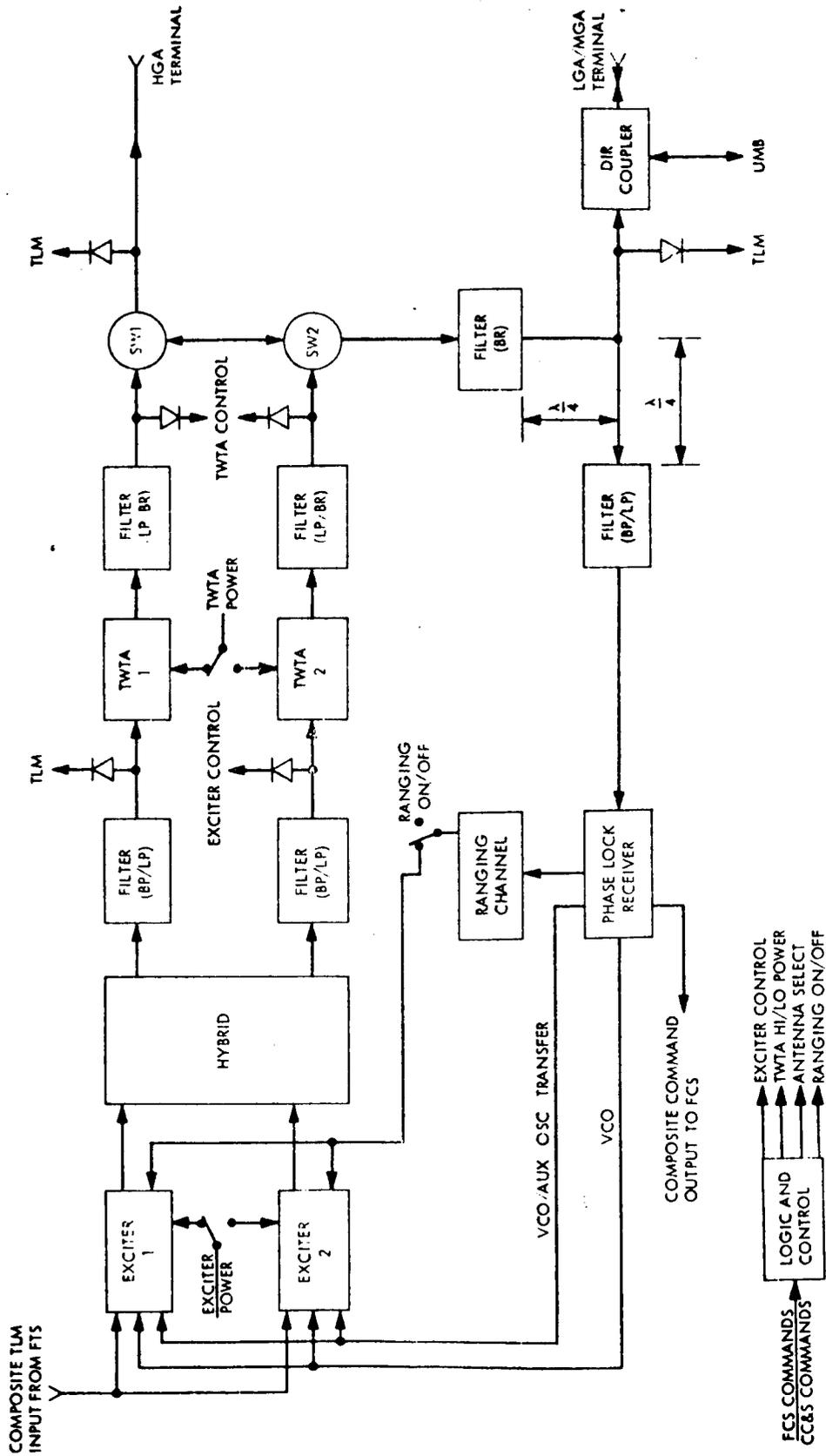
Figure 2.11-3. RADIO FREQUENCY SUBSYSTEM BLOCK DIAGRAM

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g) Decodes the command word and directs a serial,
    variable length pulse train, representing quanti-
    tative command (QC) data, to the scan subsystem.

h) Sends to the flight telemetry subsystem information
    indicating the operational status of the FCS.

i) Converts the spacecraft primary 2400 Hz ac power
    into ac and dc power required by the FCS.

Figure 2.11-4 is a block diagram of the FCS.

Design Status

This subsystem was flown as part of the 1971 Mariner Mars Mission.
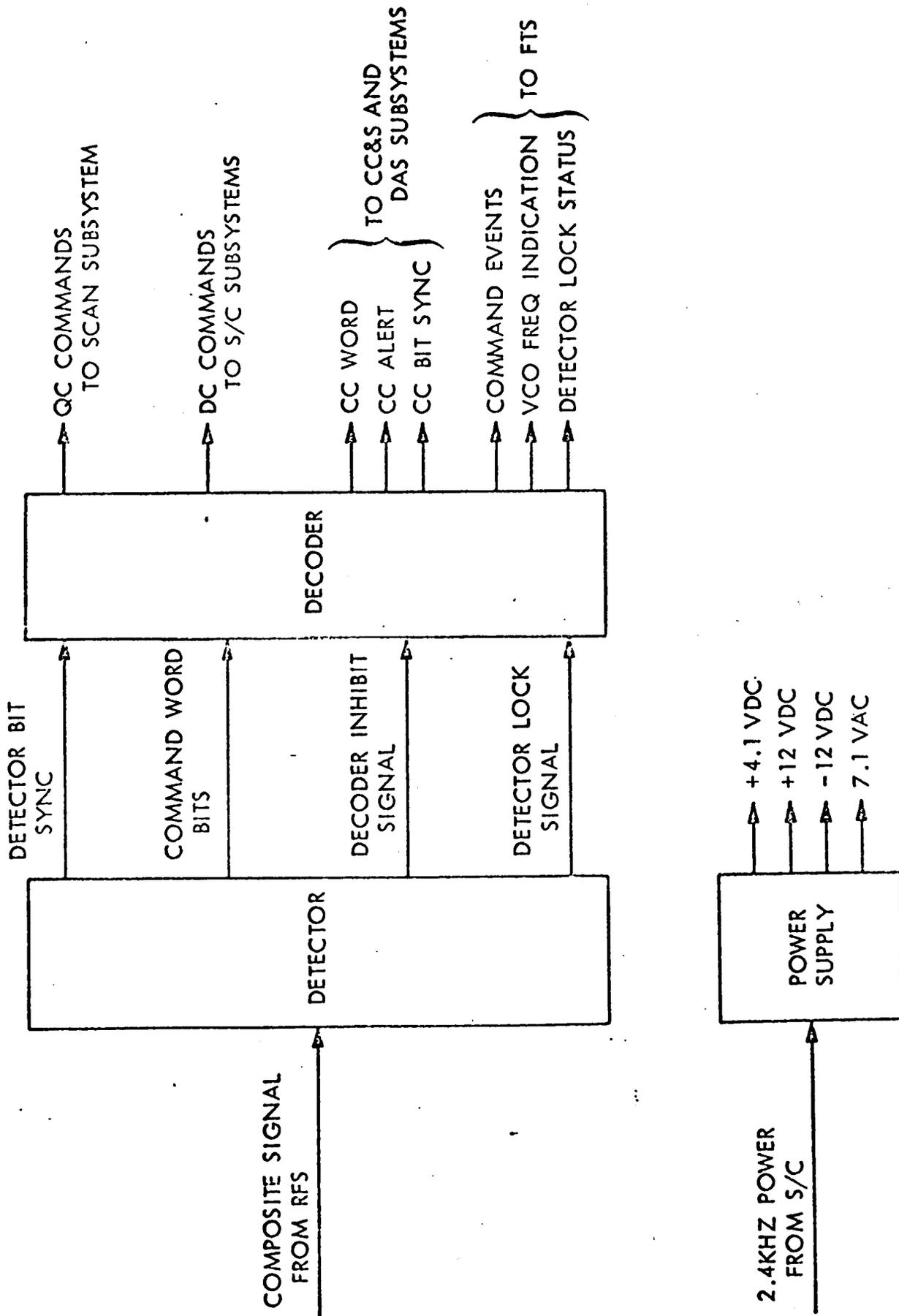
FIGURE 2.11-4. - FLIGHT COMMAND SUBSYSTEM FUNCTIONAL DIAGRAM

3.1   ATS-F DATA MANAGEMENT SUBSYSTEM

The primary functions of the ATS-F Data Management Subsystem
are to sample data inputs from digital and analog sources,
digitize analog signals, serialize the digital bits and provide
an output bit stream to the Data Switching Unit. The primary
component in the ATS-F Data Management Subsystem is the Data
Acquisition and Control Unit (DACU). There are two DACU in each
Data Management Subsystem. Both DACUs can be activated simul-
taneously. Operationally, both can be in normal mode, one can
be in normal mode while the other is in dwell mode, or both can
be in dwell mode on the same or different words and transmitting
via different transmitter frequencies. A block diagram of the
DACU is shown in Figure 3.1-1.

The DACU selects data from a fixed number of analog and digital
data sources in a sequential manner, forms 9-bit telemetry words,
and arranges them into a 128-word minor frame. This and all
other operations are controlled by the formatter. The major
components of the DACU are the digital multiplexer, analog
multiplexer, 9-bit analog-to-digital converter, and the formatter.
The digital multiplexer consists of 783 channels (87 nine-bit
words). The analog multiplexer accesses 276 analog channels which
are sensed (selected) one at a time. The selected channel data
is gated into the 9-bit analog-to-digital converter and then placed
into the 128-word telemetry format. The last 16 words of the format
are subcommutated 16 deep under the control of the formatter.

The DACU also has a dwell capability which allows a selected
minor frame channel (single word or subcom) to be telemetered
exclusively. The dwell mode is initiated by ground commands
and controlled by the DACU. When dwell mode is commanded a dwell
address is inserted into the DACU dwell control circuitry. This
address selects the data word to be transmitted at the higher
rate. An execute command then initiates this mode of operation.
The DACU also has an internal backup clock which is enabled only
when the clock select logic senses no signal from either of the
master oscillators.

Design Status

This subsystem is scheduled to be flown as part of the planned
Mid-1974 ATS-F Mission.
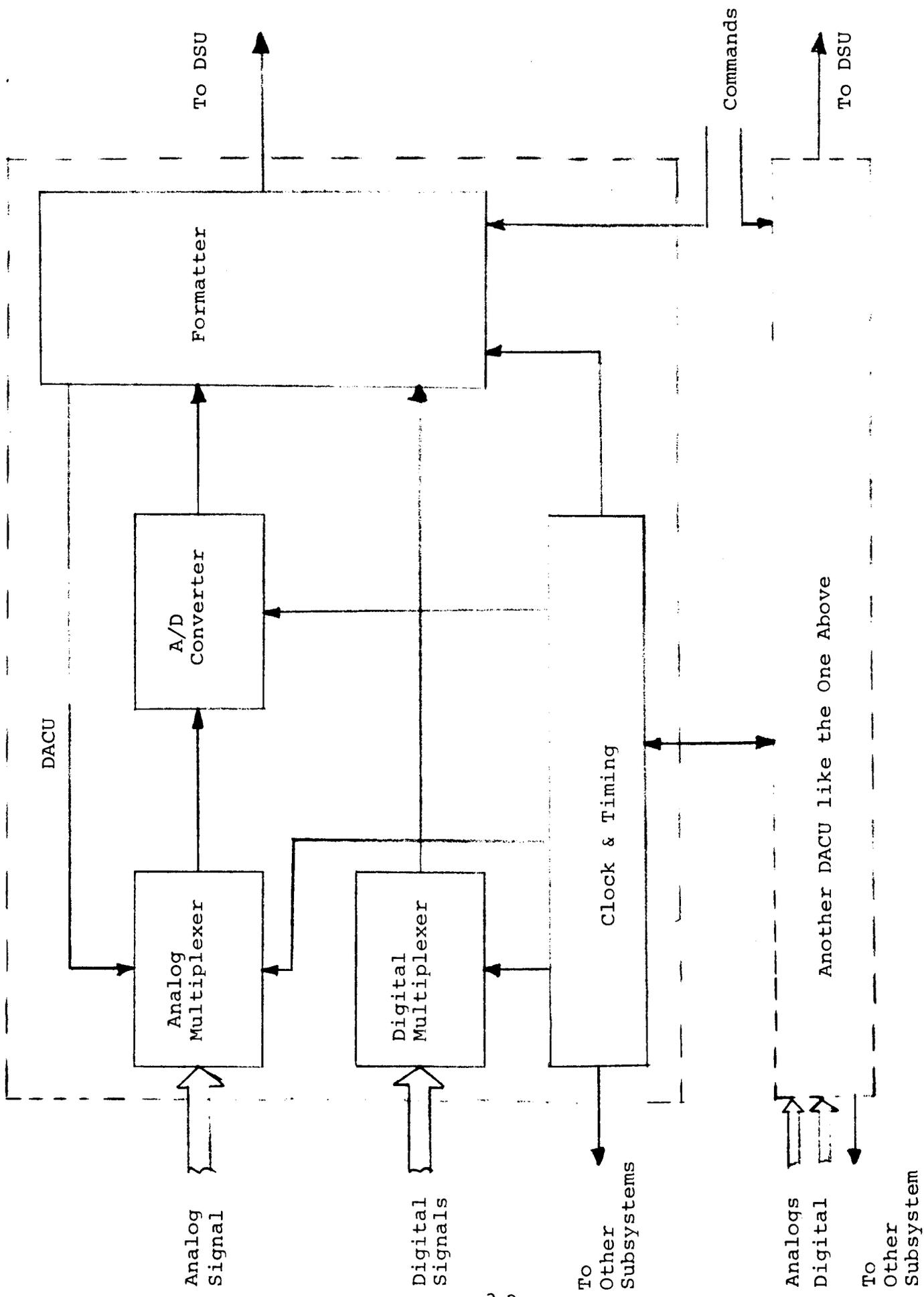
FIGURE 3.1-1   ATS-F DATA MANAGEMENT SUBSYSTEM BLOCK DIAGRAM

3-2

3.2   ERTS DATA MANAGEMENT SUBSYSTEM

The ERTS data management subsystem is capable of collecting, storing, and formatting data to be transmitted back to ground. All components are redundant for higher reliability. The four major components within the ERTS data management subsystem are as follows:

o   Versatile Information Processor (VIP)

o   Wideband Video Tape Recorder (WBVTR)

o   Narrowband Tape Recorder (NBTR)

o   Premodulation Processor (PMP)

A block diagram of the ERTS data management subsystem is shown in Figure 3.2-1.

The VIP samples 582 analog, 16 10-bit digital words, and 320 1-bit binary words at ratios between once per 16 seconds and five times per second. Data is digitized, time multiplexed, and formatted into a 1000 bps serial bit streams. The serial bit stream is recorded in biphase on the NBTR and may be transmitted simultaneously back to ground.

Each WBVTR records, stores and reproduces 30 minutes of data from the return beam Vidicon (RBV) cameras and multispectral scanner (MSS).

Each NBTR stores up to 210 minutes of data from the VIP for playback to ground at a 24 kbps rate.

The only part of the PMP in the data management subsystem is the oscillator/modulator section. Each oscillator/modulator section produces a modulating signal consisting of a combination of the following:
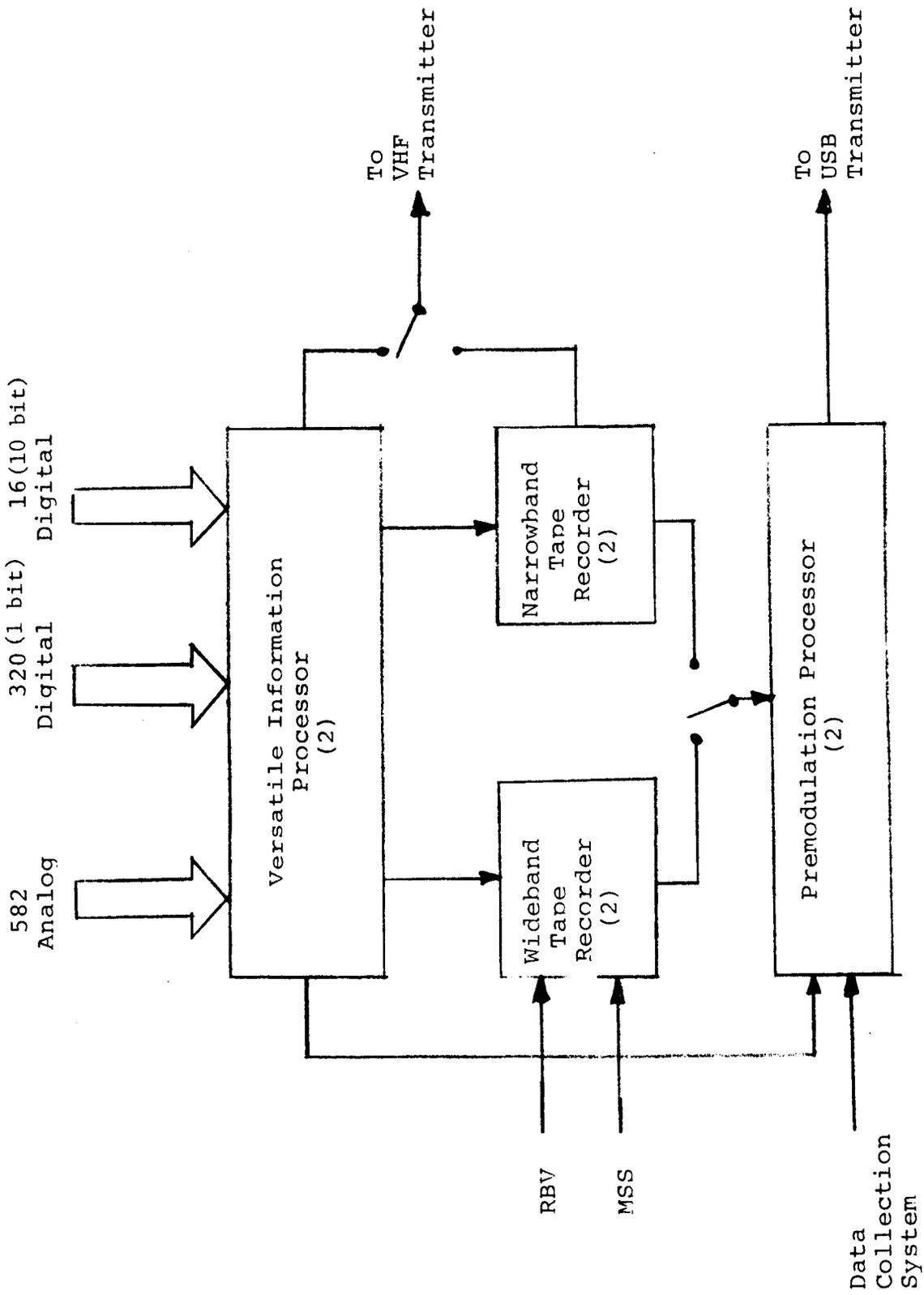
FIGURE 3.2-1   ERTS DATA MANAGEMENT SUBSYSTEM BLOCK DIAGRAM

o   1024 kHz from the data collection subsystem receiver.

o   768 kHz subcarrier oscillator (SCO) phase-shift keyed
        by PCM output of the telemetry processor.

o   597 kHz SCO phase-shift keyed by playback of stored
        telemetry data from any one of either narrowband tape
        recorder or the auxiliary track of either wideband tape
        recorder.

o   In addition, the ranging signal subcarrier may be
        added within the unified S-band equipment.

Design Status

This subsystem is scheduled to be flown as part of the planned
late 1973 ERTS-B Mission.

3.3   HEAO-A DATA MANAGEMENT SUBSYSTEM

The HEAO data management system demodulates and distributes ground orginated commands; samples and formats analog and digital telemetry data for real time transmission at 25.6 kbps; and simultaneously stores data in tape recorder units for later transmission at 512 kbps during ground station passage. In addition the subsystem provides precision timing signals to experiments and other spacecraft subsystems.

The subsystem contains eight major components: Central Clock Unit (CCU), Central Programming Unit (CPU), Remote Multiplexing Unit (RMU), Submultiplexer Unit (SUBMUX), Primary Command Decoder (PCD), Secondary Command Decoder (SCD), Tape Recorder Interface Unit (TRIU), and Tape Recorder Unit (TRU). Figure 3.3-1 illustrates the interrelationship of the subsytem components. The CCU generates a high stability clock reference (1 part in 10^{-9} stability per 24 hours) from which all subsystem timing is generated. The CPU sends channel addresses out to the RMUs and SUBMUXs which sample data. Sampled analog words are converted to 8-bit digital words within the RMU and transferred to the CPU. The RMUs also provide timing signals to the user.

Formatted data streams are transmitted from the CPU to the Baseband Assembly Unit for real time transmission, and to the tape recorder via the TRIU for data storage. The TRIU controls and provides data to the three tape recorders for storage. When the spacecraft is in contact with a ground station, the tape recorders may be commanded to dump the stored data at a 512 kpbs rate.

The PCD accepts a PSK modulated 70 KHz subcarrier from the transponder receiver, demodulates and authenticates the message, decodes the commands, and routes the commands to the SCDs located throughout the spacecraft subsystems and experiments. The command and telemetry functions are separate and independent of each other.

Design Status

The HEAO-A program is currently is a state of redefinition. This subsystem is a viable candidate for application in the 1977 HEAO-A Mission.

Figure 3.3-1   Command and Data Handling Subsystem
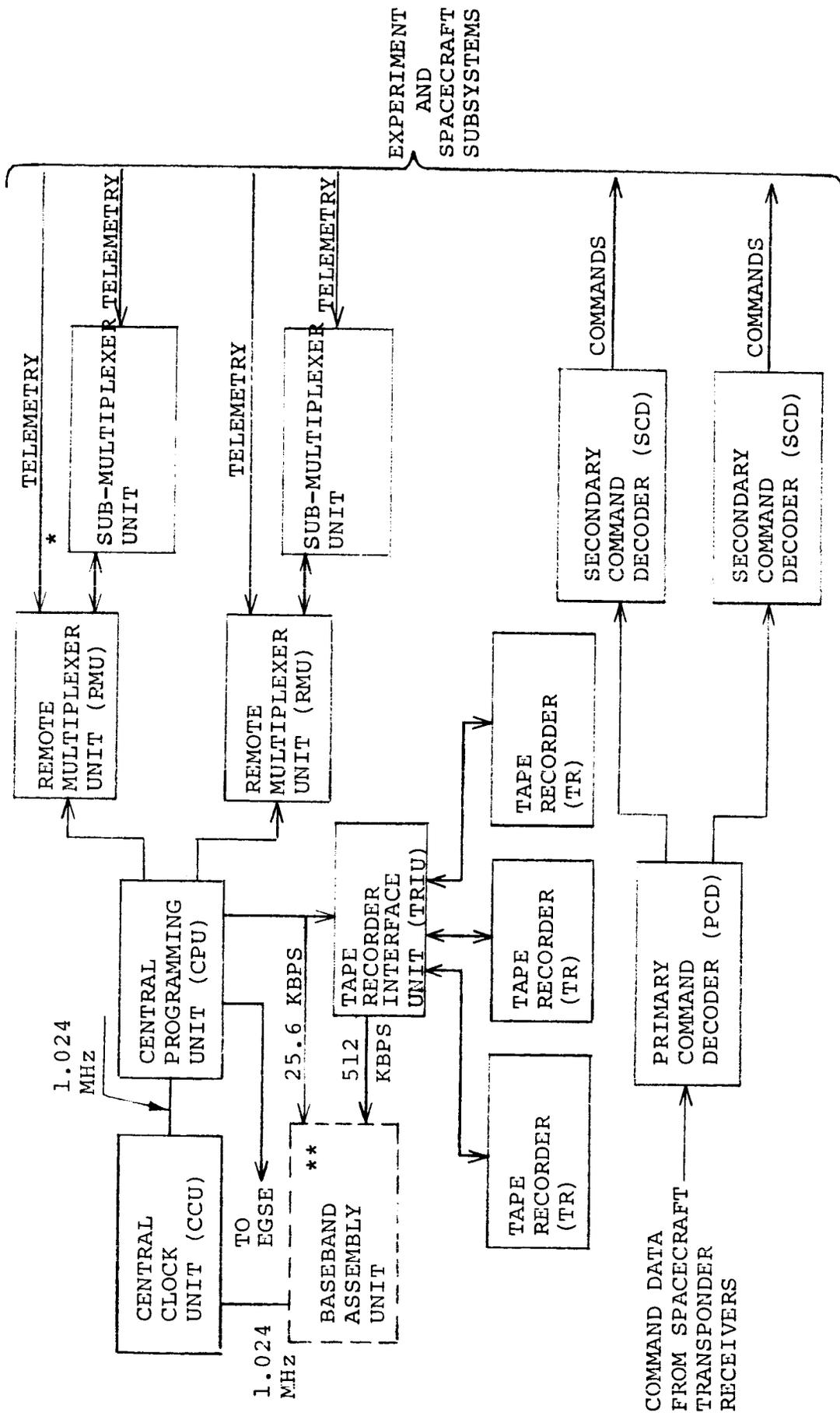
*SUBMUX LOCATED WITHIN EXPERIMENT
**BASEBAND LOCATED IN COMMUNICATIONS SUBSYSTEM

3.4   OSO-I DATA MANAGEMENT SUBSYSTEM

The data handling and telemetry subsystem (Figure 3.4-1) gathers analog and digital data from spacecraft subsystems and experiments, stores the data in redundant on-board tape recorders, and transmits the data (real time or recorded) to the ground station via the VHF or S-band downlinks. A spacecraft clock provides the time references to synchronize telemetry data handling. Its outputs are used by all other observatory subsystems and experiments as a synchronized time reference. A key feature of the telemetry subsystem design is the use of multiple, standard remote multiplexer units distributed throughout the observatory in proximity to the several subsystem and experiment units where the telemetry data originates. Table 3.4-1 lists the major components of OSO-1 data management subsystem.

The format generator is a central component of the telemetry processing and data storage group. It contains a fixed (hard wired) memory defining two unique telemetry frame formats. Either format may be selected by ground command to provide multiple telemetry modes to increase the data handling capability. Both formats may be selected concurrently for simultaneous real time telemetry transmission of one set of telemetry data while recording another set of telemetry data in an onboard tape recorder. Simultaneous operation under control of the two format generators is accomplished by interleaving time-shared interrogation signals to the remote multiplexers with both format generators powered. Simultaneous tape recording of data from both format generators is excluded.

The ratio of record to transmit time is 20. In normal operation one tape recorder can be commanded to lie in the record mode for 220 minutes and then commanded to perform a data dump to ground at the time compressed rate of 11 minutes. Simultaneous with the data dump of one recorder, the second recorder can be commanded to begin recording for an additional 220 minutes.

Design Status

This subsystem is scheduled to be flown as part of the planned 1974 OSO-I Mission.
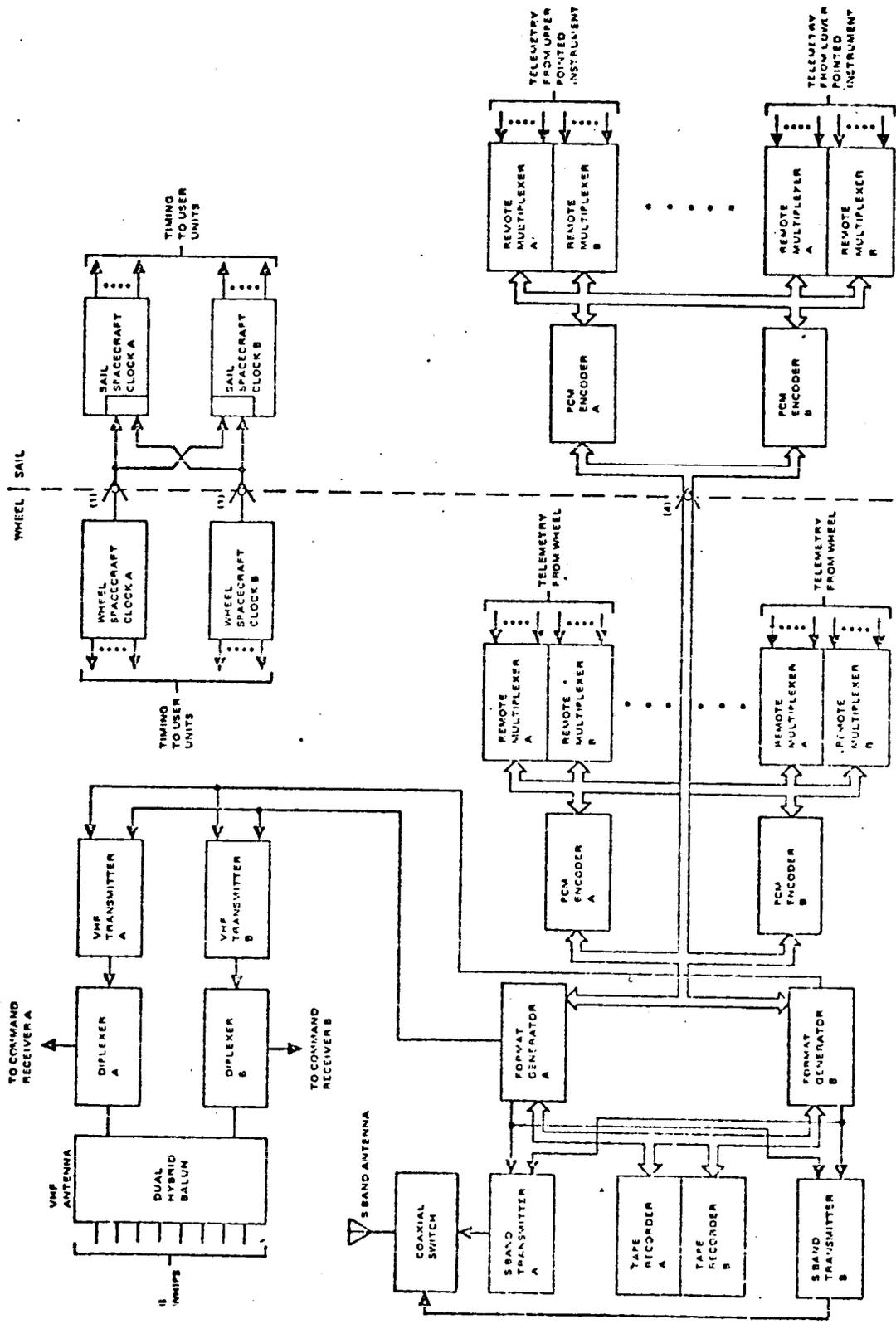
FIGURE 3.4-1. - DATA HANDLING AND TELEMETRY SUBSYSTEM BLOCK DIAGRAM

TABLE 3.4-1. - DATA HANDLING AND TELEMETRY
SUBSYSTEM UNIT IDENTIFICATION

Item No.	Component	Quantity	Part Number	Specification Number
1	Spacecraft clock, wheel	2	3280680-100	DS31331-161
2	Spacecraft clock, sail	2	3280690-100	DS31331-167
3	Format generator	2	3280610-100	DS31331-162
4	PCM encoder	4	3280620-100	DS31331-163
5	Dual remote multiplexer	12 on wheel 5 on sail	3280630-100	DS31331-164
6	Tape recorder	2	3280640-100	PS31331-193
7	VHF antenna and hybrid balun*	1	3280661-100	DS31331-166
8	Diplexer*	2	3280635-100	DS31331-198
9	VHF transmitter	2	3280670-100	DS31331-195
10	S-band antenna	1	3280660-100	DS31331-165
11	RF coaxial switch	1	908302-1	PS908302
12	S-band transmitter	2	3280650-100	DS31331-194

* Units common with the command subsystem.

3.5   VIKING ORBITER DATA MANAGEMENT SUBSYTEM

The Viking Orbiter Data Management Subsystem (Figure 3.5-1)
processes and formats for transmission to earth engineering,
infrared science, and visual imaging data from orbiter; relayed
data from the Viking Lander; and Viking Lander Capsule data
while it is attached to Orbiter. In addition, it processes
command data received from Earth. It consists of the following
sub-subsystems:

o   Flight Data Subsystem (FDS)

o   Modulation Demodulation Subsystem (MDS)

o   Relay Telemetry Subsystem (RTS)

o   Data Storage Subsystem (DSS)

The Flight Data Subsystem performs the following functions:

1)   Timing and Control - provide timing and control for
      the other subsystems   through redundant oscilla-
      tor chains, command decoder logic, engineering
      sequencing and control logic, and science sequencing
      and control logic.

2)   Process engineering data - processes digital data
      from external serial digital shift registers, timing
      pulses, and pulse counters; and analog data from
      voltage measurements, strain gage pressure measure-
      ments, potentiometer measurements and temperature
      measurements.

3)   Process infrared science data - interleaves the
      infrared data with the engineering data at a 1 kbps
      rate and transmits to Data Storage and Modulation
      Demodulation Subsystems.

4)   Process visual imaging data - accepts visual
      imaging data at a 2.112 MHz rate and processes it
      into 7 data tracks for the Data Storage Subsystem.

5)   Memory - two identical plated wire memories each
      with random access storage and retrieval for 1024
      eight bit words.
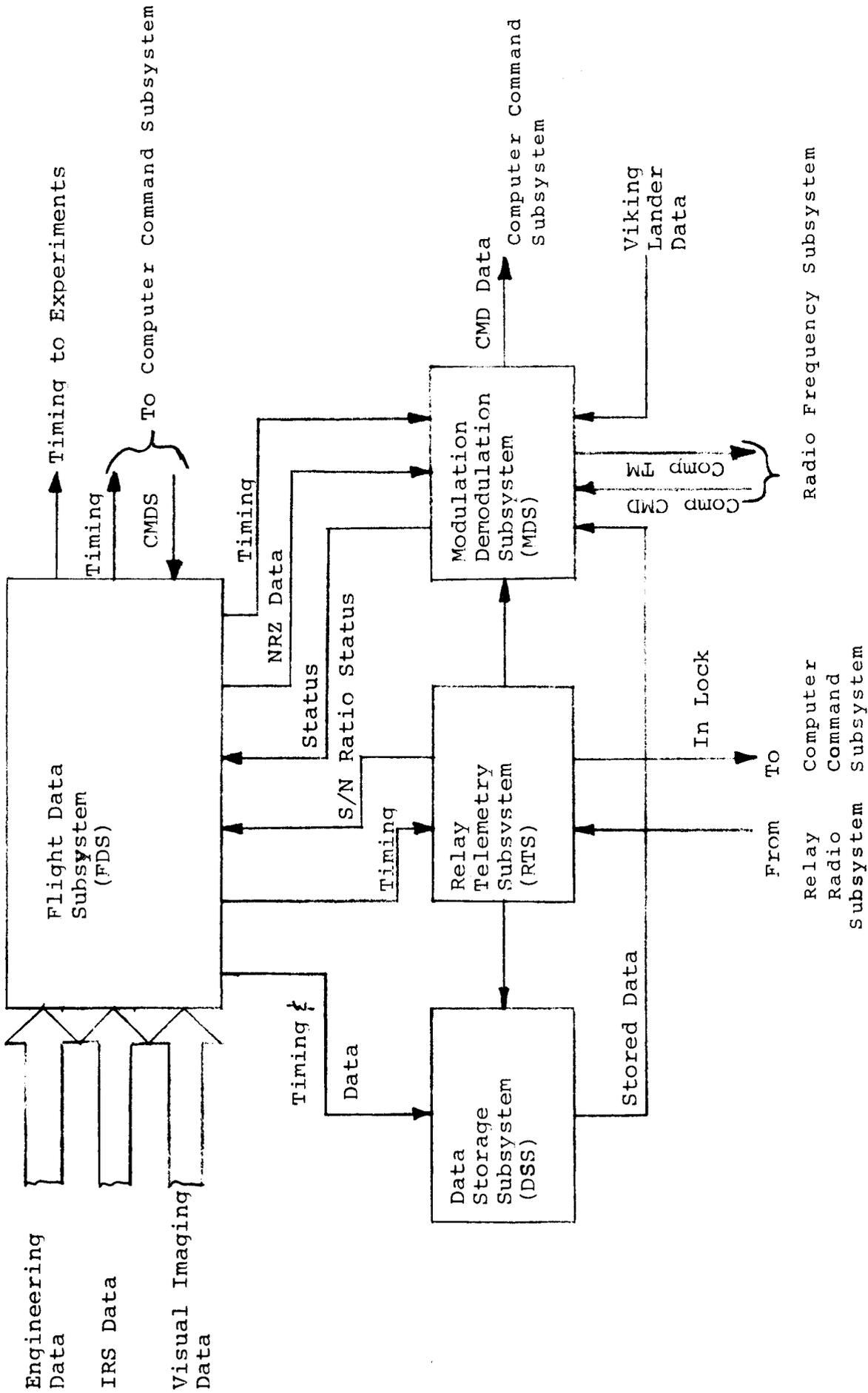
FIGURE 3.5-1   VIKING ORBITER DATA MANAGEMENT SUBSYSTEM

The Modulation Demodulation Subsystem (MDS) demodulates and detects the command signal obtained from the RF Subsystem, generates telemetry subcarrier frequencies, modulates the subcarriers and combines these subcarriers and their modulation into a composite telemetry signal for transmission back to Earth. The MDS consists of redundant Command Detector units and power supplies for higher reliability.

The Relay Telemetry Subsystem establishes sync with either a 4 kbps or 16 kbps waveform from the Relay Radio Subsystem, detects and restores the data to a NRZ format, and routes the data to either the Modulation Demodulation or the Data Storage Subsystems.

The Data Storage Subsystem receives data to be stored from the Flight Data Subsystem and the Relay Telemetry Subsystem and on command provides the data to the Modulation Demodulation Subsystem for transmission back to Earth.

Design Status

This subsystem is scheduled to be flown as part of the planned 1975 Viking Orbiter Mission.

3.6 OAO DATA MANAGEMENT SUBSYSTEM

The OAO system has two modes of operation for data transmission to the ground: real time and delayed. The real time mode establishes the requirements for controlling the Observatory, programming and performing experiments, gathering and preparing data from the Experiments and the Spacecraft's subsystems for transmission to the ground. The real time mode also establishes programs for controlling the spacecraft in the delayed mode of operation. During the real time mode, commands are sent to the Observatory and stored for execution at specified times in the delayed mode. These commands are decoded and distributed to the proper subsystems to control the Observatory; perform experiments; and gather, process and store data from the Experiment and the Spacecraft. The Data Management subsystem plays the role of controlling, by command, the real time and delayed modes of operation. The data management subsystem block diagram is shown in Figure 3.6-1.

Design Status

This subsystem was flown as part of the 1972 OAO-C Mission.
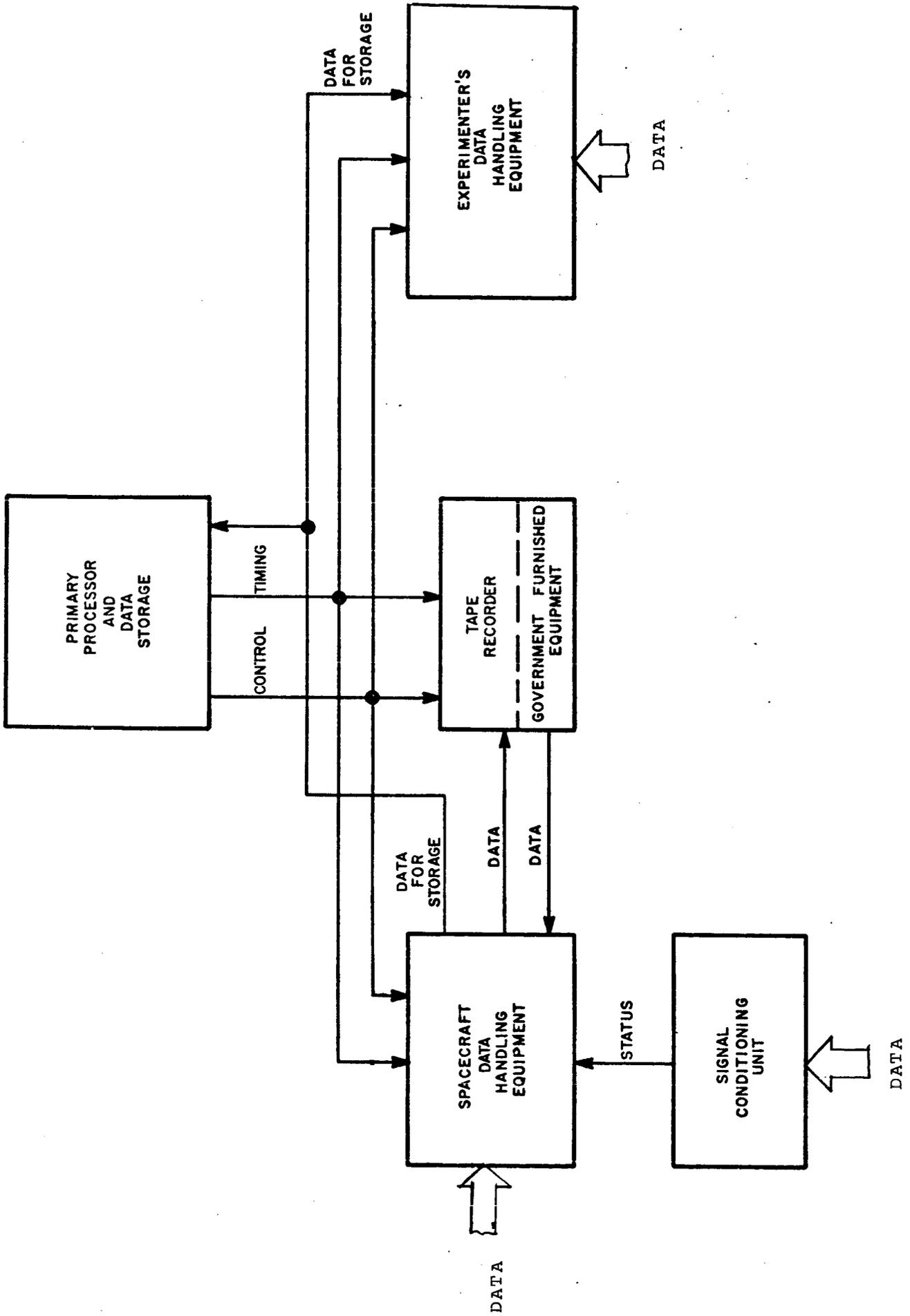
FIGURE 3.6-1 DATA MANAGEMENT SUBSYSTEM BLOCK DIAGRAM

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3.7-1   SKYLAB - OWS/AM/MDA DATA MANAGEMENT SYSTEM

The data management system monitors the Multiple Docking Adapter/
Airlock Module/Orbital Workshop (MDA/AM/OWS) systems, provides
data for onboard displays and onboard storage, and transmits
real time (RT) pulse code modulation (PCM), delayed time (DT)
PCM, and DT voice to the Space Flight Telemetry Data Network
(STDN).

The monitored data can be grouped into four categories:

o   Spacecraft systems parameters

o   Event occurence

o   Crew biomedical

o   Experiment

Because the Data Management System is a monitoring/data acquisi-
tion system, it interfaces with all other systems in terms of
measurements (pressure, temperature, etc). Figure 3.7-1 depicts
these interfaces. The Communication System provides the antennas
for transmission to the STDN and audio voice inputs for tape
recording. The Digital Command System/Time Reference System
(DCS/TRS) provides control discretes from the STDN and time
reference signals. The time is used for correlation of all RT
and DT PCM and DT VOICE. The Environmental Control System
(ECS) provides thermal conditioning for the equipment. The
Electrical Power System (EPS) supplies 24 to 30 vdc power.
The Crew System routes and controls power to EVA or IVA crewmen
for biomedical measurements.

The Data Management System consists of four major subelements
or subsystems, each discussed briefly in the following para-
graphs and shown in Figure 3.7-2. These are the Instrumentation
Power, PCM, Recording and Transmission subsystems.

```
┌──────────────────┐    ┌──────────────────┐    ┌──────────────────┐
│ COMM             │    │ DCS/TRS          │    │                  │
│  ● VOICE         │    │  ● CONTROL       │    │       ECS        │
│  ● ANTENNAS      │    │  ● TIMING        │    │                  │
│  ● SIA BIOMED PWR│    │                  │    │                  │
└──────────────────┘    └──────────────────┘    └──────────────────┘
         ↕                       ↕                        ↕
┌───────────────────────────────────────────────────────────────────┐
│              DATA  MANAGEMENT  SUBSYSTEM                            │
└───────────────────────────────────────────────────────────────────┘
         ↕                       ↕                        ↕
┌──────────────────┐    ┌──────────────────┐    ┌──────────────────┐
│                  │    │ EXPERIMENTS      │    │ CREW SYSTEM      │
│       EPS        │    │  ● TIMING        │    │                  │
│                  │    │  ● RECORDING     │    │  ● LSU BIOMED PWR│
│                  │    │  ● DATA MANAGEMENT│   │                  │
└──────────────────┘    └──────────────────┘    └──────────────────┘
```
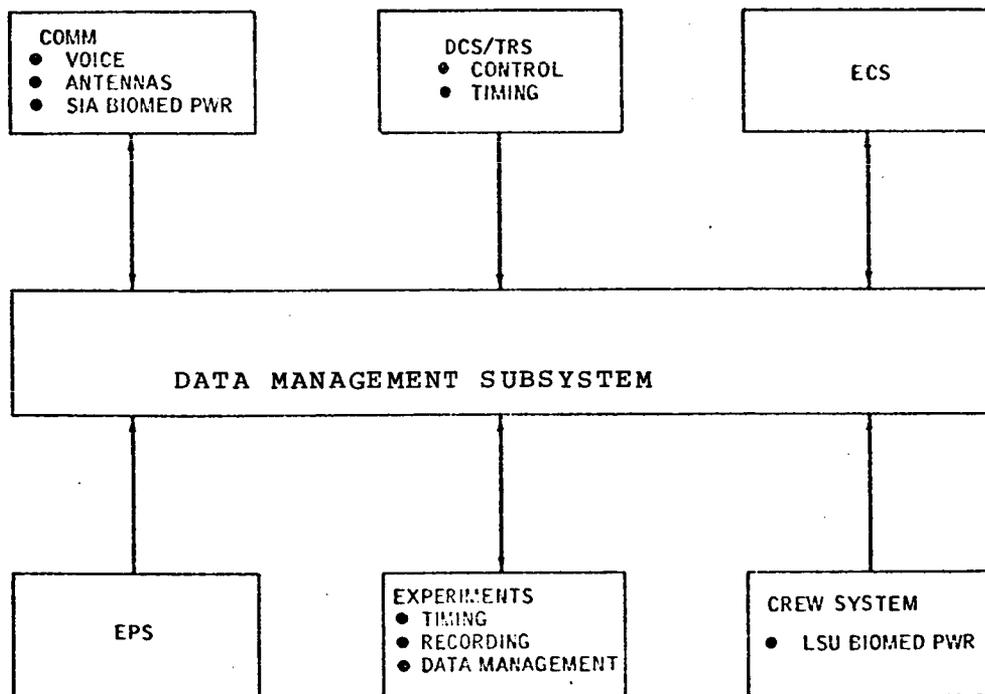
FIGURE 3.7-1   SYSTEM INTERFACES
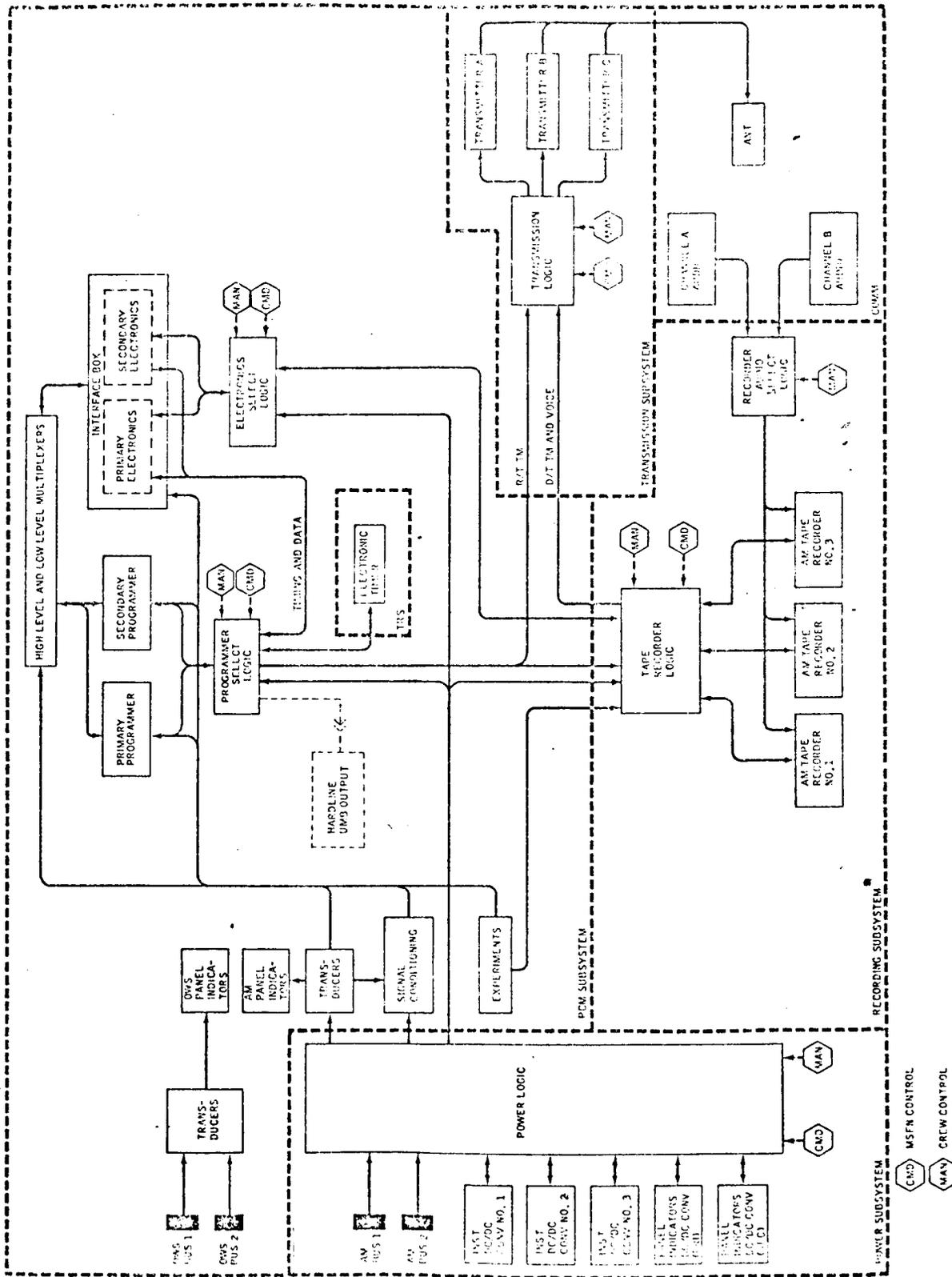
FIGURE 3.7-2 FUNCTIONAL SCHEMATIC

INSTRUMENTATION POWER SUBSYSTEM

The power subsystem consists of the MDA signal conditioner, three AM DC-DC converters, two AM panel indicator DC-DC converters, nine OWS DC-DC converters, and associated control and selection logic. During tape recording or transmission operations, the AM DC-DC converters supply conditioned power to the PCM subsystem and AM tape recorders. The AM panel indicator DC-DC converters supply conditioned power to the AM panel indicator transducers when the AM DC-DC converters are not active. The OWS displays are powered by the OWS display subsystem independent of the data management system. On/off control of the subsystem power supplies is controlled from STDN commands or manual switch operations for tape recording or transmissions.

PCM SUBSYSTEM

The PCM subsystem, consisting of the transducers, signal conditioners, multiplexers, programmers and interface box, is the heart of the system. It performs the tasks of:

o   Gathering all measurements

o   Conditioning transducer outputs to be compatible for input to a multiplexer

o   Encoding and formating of all measurements

o   Analog to digital conversion

o   Reconstituting elapsed time for outputting to experiments

o   Providing a 51.2 kbps real time bit stream to the transmission subsystem

o   Providing four recordable subframes to the recording subsystem

Elapsed time, reconstituted by the interface box for experiments, is a 24 bit word updated every 100 milliseconds by the interface box.

The real time telemetry (RT TM) format is an 8 bit binary
coded word transmitted, most significant bit first, at a rate
of 51.2 kbps. A complete measurement scan consists of 96 master
frames and requires 2.4 seconds. A master frame is composed
of 160 words, sampled 40 times per second, providing an output
of 6400 words per second. All encoding is performed using the
40 samples per second master frame scan rate as a base. The
encoding consists of submultiplexing or super commutating
input data to obtain sample rates of .416, 1.25, 10, 20, 40,
80, 160, and 320 samples per second.

A master frame is composed of subframes 1, 2, 3, 4, and 5;
synchronization and synchronization complement words; and
15 channels of direct insert high sample rate analog measure-
ments. Each subframe is composed of 16 words of the 160 word
master frame which at 40 samples per second provides 640 words
per second per subframe. Thus, the five subframes use 3200 words
of the 6400 words per second RT TM output. The direct insert
high sample rate analog measurements utilize 2960 words, and
the remaining 240 words are assigned to the synchronization and
synchronization complement words.

Subframes 1, 2, 3, and 4 are extracted from the RT TM format
and routed to the tape recorders for storage. Subframe 5 is
not recorded. Subframe 1 corresponds to DATA, subframe 2 to
EXP 1, subframe 3 to EXP 2, and subframe 4 to DATA 2. These
are outputed at a 5.12 kbps rate, 8 bits per word, 640 words
per second with the most significant bit first. A complete
subframe measurement scan requires 2.4 seconds.

Each PCM word consists of one of three types of data: analog,
discrete, or digital. Analog parameters use a complete 8 bit
word with zero percent of full scale represented as 00000001
and 100 percent represented as 11111110. Each PCM word for
discrete parameters contains eight measurements, one per bit.
Discrete words are composed of two types of measurements:
bilevel and bilevel pulse. In the bilevel, a true is represented
by a "one" and a false by a "zero". In the bilevel pulse para-
meter, true and false level representations are the inverse
of the bilevel parameter. Digital words are constructed by
using as many sequential 8 bit PCM words as required to
represent the respective digital word. For example, a 24 bit
digital word would sequentially occupy three 8 bit PCM words
in a subframe format. Figures 3.7-3 and 3.7-4 illustrate the
basic RT and DT PCM formats. The DT PCM is recorded in the
above formats, and dump is in reverse.
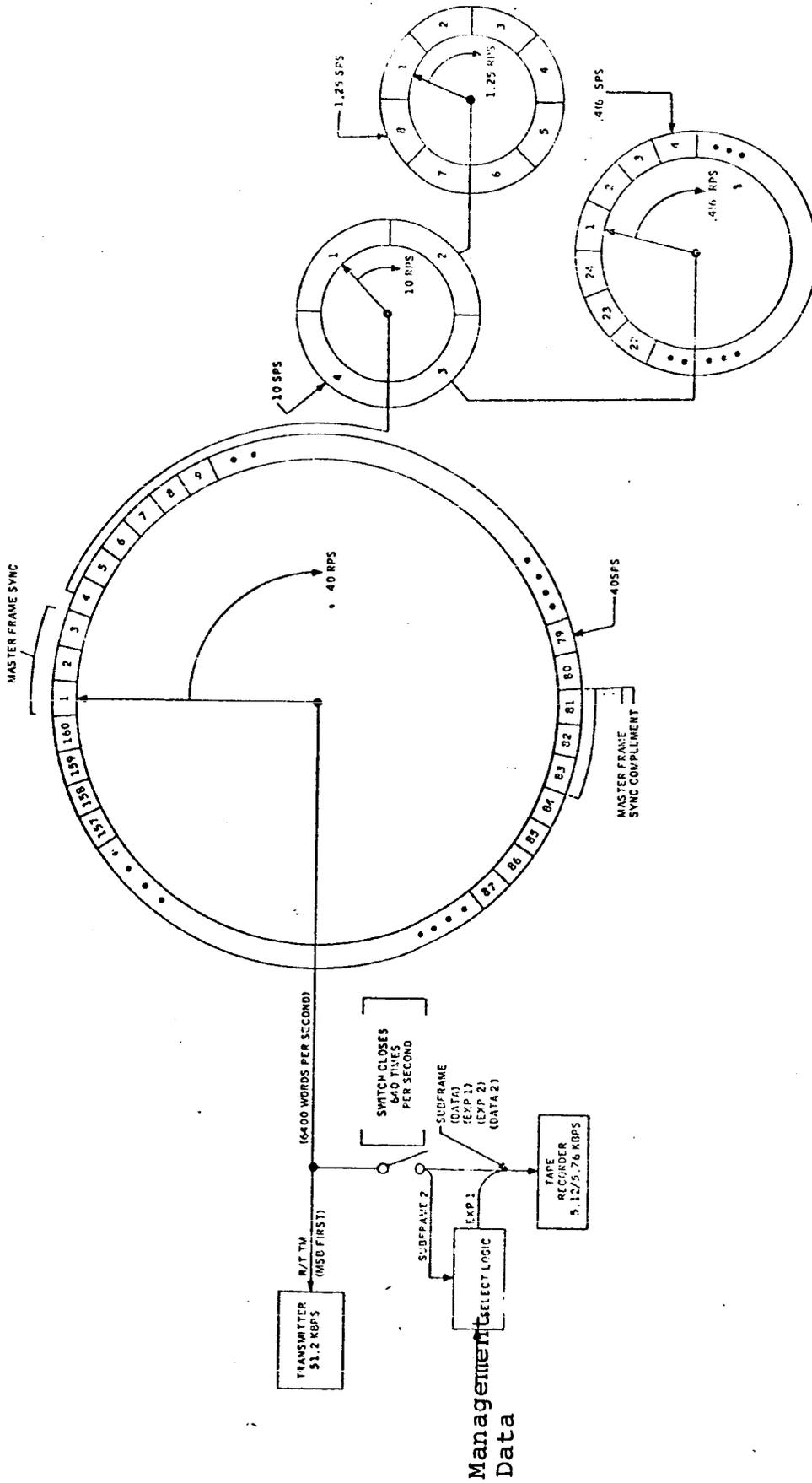
FIGURE 3.7-3 PCM FORMAT (SAMPLE RATES)

FIGURE 3.7-4 PCM FORMAT

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The multiplexing/encoding components sequentially sample all signals and put them into a serial PCM bit stream. All analog channels are time-multiplexed into one serial PAM stream. An analog to digital (A/D) converter encodes each analog pulse in the PAM stream into an 8 bit binary coded word. All the event channels (bilevel, bilevel pulse, and digital) are already in digital form. The event channels are sampled and time-multiplexed in sets of eight. The 8 bit coded analog measurements and the 8 bit sets of event measurements are sequenced into the output shift register to provide an output serial PCM bit stream. Preselected words of the serial PCM stream are stripped out into recordable PCM streams.

RECORDING SUBSYSTEM

The recording subsystem consists of tape recorders, recorder selection logic, and tape recording logic. It provides onboard information storage capability primarily when the vehicle is out of contact with STDN stations.

Three identical two-track tape recorders are available for use. The tracks are identified as A and B. Track A can record PCM inputs of 5.12 kbps. Track B can record voice inputs from 300 to 3000 Hz.

TRANSMISSION SUBSYSTEM

The transmission subsystem has the responsibility of downlinking to STDN R/T TM and all information stored in the recording subsystem. This subsystem is controlled by either STDN or the crew. There are four transmitters in the system: a 230.4 MHz (2 watt) launch and a 230.4 MHz (10 watt) orbit, both identified as transmitter A; a 246.3 MHz (10 watt) transmitter B, and a 235.0 MHz (10 watt) transmitter C.

Design Status

This subsystem was flown as part of the 1973 Skylab Mission.

The Digital Command System (DCS) and Time Reference System
(TRS) provide a data interface between the Space Flight Data
Network (STDN) and the Saturn Workshop (SWS). The DCS receives
and decodes real time commands uplinked from STDN to provide
ground control over various SWS systems during all mission
phases, and backs up the Instrument Unit (IU) command system
to activate the SWS. The TRS provides time reference data for
onboard display and time correlation of telemetered data. The
DCS provides real-time (RT) control over the TRS, and the TRS
provides time-dependent switching control over the DCS.

The DCS executes real-time commands from STDN, transfers STDN
time updates to the TRS, and transfers teleprinter messages to
the COMM teleprinting subsystem. The DCS (Figure 3.7-5) con-
sists of a primary and secondary receiver/decoder, four eight-
channel DCS relay modules and a 480-channel Command Relay Driver
Unit (CRDU).

Operating on either the primary or secondary receiver/decoder,
the DCS receives uplink messages through the RF subsystem. Each
receiver/decoder contains two receivers. Receiver No. 1 is
connected to a single antenna, receiver No. 2 to one of three
selectable antennas. Thus, each receiver/decoder has redundant
radio frequency reception capability.

Only one receiver/decoder can be commanded at a time. The
addressed receiver/decoder determines for which system (DCS
teleprinter, or TRS) the message is intended and routes it to
that system for further processing. A command message to the
DCS is routed by a receiver/decoder to the DCS relay modules
or the CRDU. If the command is for the DCS relay modules, a
relay is activated within the DCS relay modules to supply a
contact closure to the using SWS system. If the command is
for the CRDU, a solid state relay driver is activated to pro-
vide a control signal to the using SWS system. Teleprinting
messages are decoded and printed in the subsystem. Messages
to the TRS provide time update.

The TRS provides onboard time displays, generates time correla-
tion for instrumentation and experiments, initiates time de-
pendent switchover to redundant components within the DCS,
and initiates time dependent equipment reset via the DCS. The
TRS (Figure 3.7-6)   consists of a primary and secondary elec-
tronic timer, a primary and secondary time correlation buffer
(TCB), two GMT clocks, an event timer, and four portable timers.

Each electronic timer has three timing registers: an elapsed
time (Te) register, a time-to-go-to-redundant receiver/decoder
(Tr) register, and a time-to-go-to-equipment reset (Tx) register.
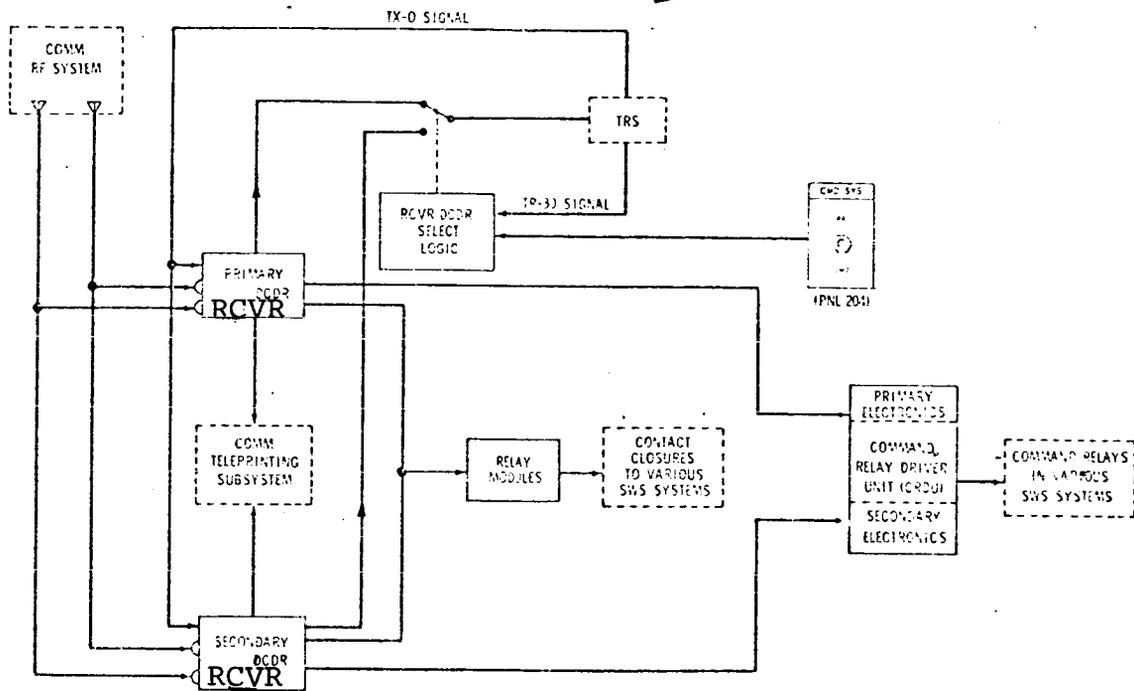
FIGURE 3.7-5 . DCS CONFIGURATION
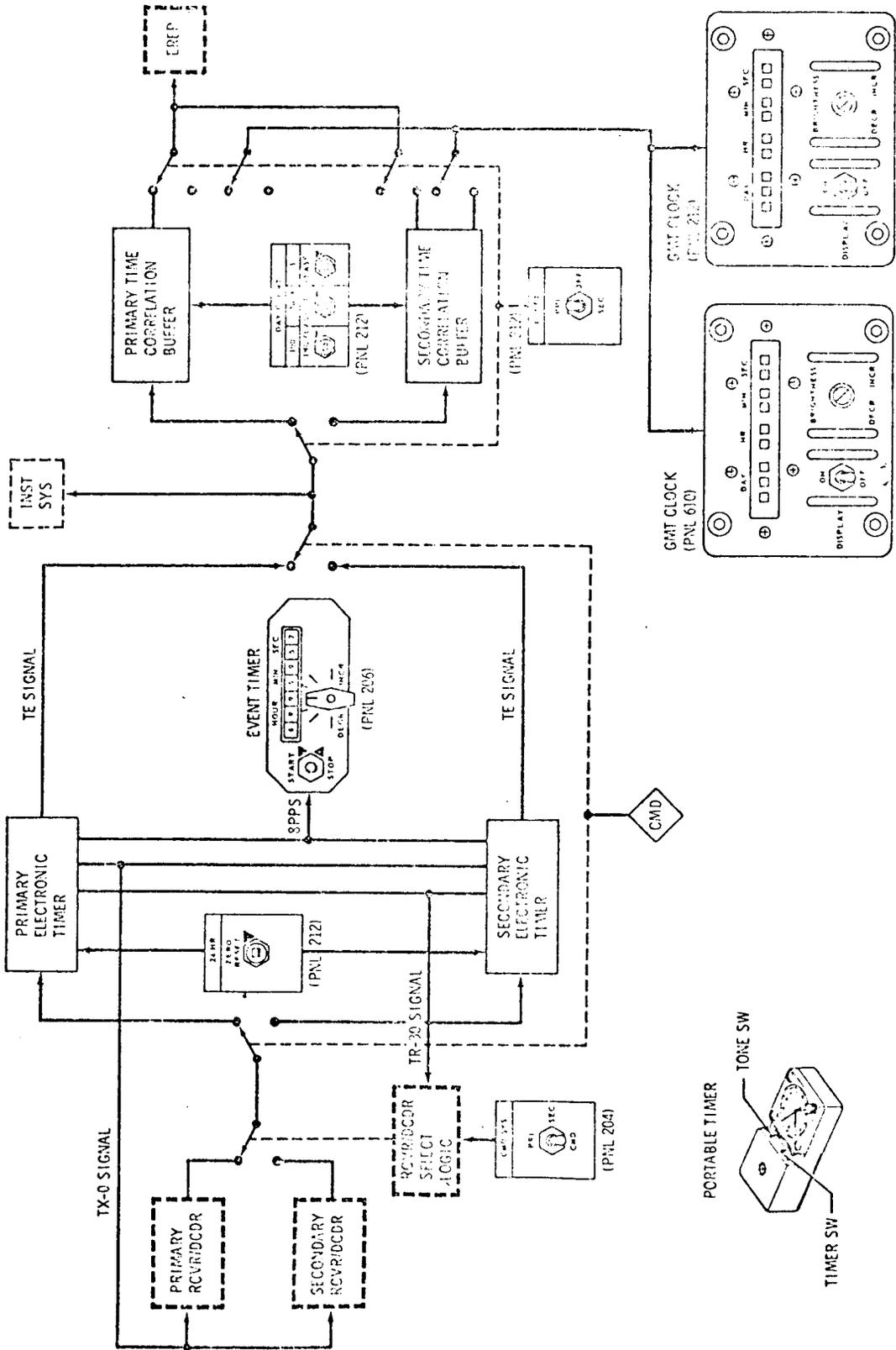
FIGURE 3.7-6   TRS CONFIGURATION

The selected electronic timer provides elapsed time outputs to instrumentation and the time correlation buffers, receives time updates for the Tx and Tr registers, and provides a timing pulse to the event timer.

The selected time correlation buffer receives elapsed time and converts it into a form acceptable to the GMT clocks and experiments.

The GMT clocks receive elapsed time and provide a digital display of time synchronized to Greenwich Meridian time (GMT). The maximum display capability of the clocks is 399 days, 23 hours, 59 minutes, and 59 seconds.

Timing pulses to the event timer provide a digital display of time that may be set to any desired indication by the crew to a maximum of 999 hours, 59 minutes, and 59 seconds.

The portable timer provides a time-remaining display, and an audio output at a time preselected by the crew. The maximum display (setting) is 11 hours, 59 minutes, and 59 seconds.

The AM DCS command word contains a maximum of 30 data bits, which are transmitted most significant bit (MSB) first (Figure 3.7-7). The addressed receiver/decoder receives the uplinked message and routes it to components within the DCS (relay module and CRDU), TRS (Tx and Tr), or teleprinter for processing.

Design Status

This subsystem was flown as part of the 1973 Skylab Mission.

VEHICLE SYSTEM
ADDRESS ADDRESS

OCTAL CHARACTER	1	2	3	4	5	6	7	8	9	10

BITS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

DCS { RELAY MODULE CRDU

1 1 1 — DATA BITS — ———————— NOT TRANSMITTED ————————
1 0 0 — DATA BITS ——→ 0 ←— ———————— ZEROS ————————

TRS { TX TR

COMM (TELEPRINTING)

1 1 0 ———————— DATA BITS ———————— ZEROS
0 1 0 ———————— DATA BITS ————————
0 0 1 ———————— DATA BITS ———————— NOT TRANSMITTED
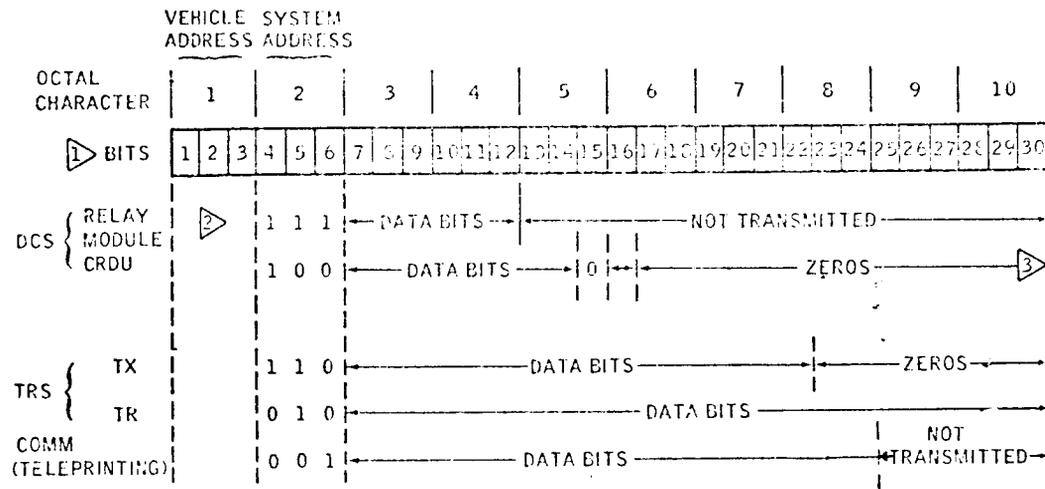
1▷ EACH BIT IS COMPOSED OF 5 SUB-BITS
BIT 1 IS TRANSMITTED FIRST

2▷ THE OAM VEHICLE ADDRESS FOR THE PRIMARY AND SECONDARY RCDR/DCDR IS
PRI RCVR/DCDR 010
SEC RCVR/DCDR 101

3▷ BIT 30 IS USED TO MAINTAIN ODD PARITY

FIGURE   3.7-7   COMMAND CODE FORMAT

3-28

3.8   SKYLAB ATM DATA MANAGEMENT SYSTEM

The data management system processes the performance data from the ATM subsystems and scientific experiments and provides this data to the communication system for transmission to spaceflight tracking and data network (STDN) ground stations.

Figures 3.8-1 and 3.8-2 show the ATM data management system and its interfaces.

The measuring subsystem includes nine signal conditioning racks (SCR's).   These racks accept and condition up to 360 signals from the various analog data sources and produce output signals in the 0 to 20 millivolt dc range.   Signals not requiring signal conditioning are routed directly to the multiplexing subsystem bypassing the signal conditioning racks.

The multiplexing subsystem accepts two forms of analog input data from the data sources; a nominal 0 to 20 millivolt dc level accepted by the remote analog sub-multiplexer (RASM's) and a nominal 0 to 5 vdc level accepted by the time division multiplexers (TDM's).   Two forms of digital input data are accepted: a nominal 0 or 5 vdc level and a nominal 0 or 28 vdc level. This data is accepted by the remote digital multiplexer (RDM) or by the PCM/DDAS.   Discrete data inputs from the data sources are nominally 0 or 5 vdc.   These data are accepted by the RDM's or by the pulse code modulated/digital data acquisition system (PCM/DDAS).

Each of the six Model 103 remote analog submultiplexers (RASM's) can accept up to 60 conditioned analog measurement signals in the 0 to 20 millivolt dc range.   Each input is sampled 12 times per second.

Each of the four Model 270 time division multiplexers (TDM's) can accept up to 270 analog measurements in the 0 to 5 vdc range. These inputs are accepted from the RASM's and directly from data sources having a 0 to 5 vdc analog output.   Each TDM contains 30 primary channels which are sampled 120 times per second.   Channels 1 through 27 are used for data channels.   Channel 28 is used for frame identification.   Channels 29 and 30 are used for amplitude reference and synchronization.   Channels 1 through 27 may be multiplexed externally to form 10 subchannels each, thus enabling the 270 data measurements.   Each TDM provides a pulse amplitude modulated (PAM) output to the PCM/DDAS.

Each of the six Model 410 remote digital multiplexers (RDM's) can accept 100 bits of digital measurement data from the data sources.   The RDM temporarily stores this information in ten magnetic core register (MCR) cards as ten 10-bit digital words. The ten 10-bit words remain in the parallel storage register until the PCM/DDAS is ready to accept them.
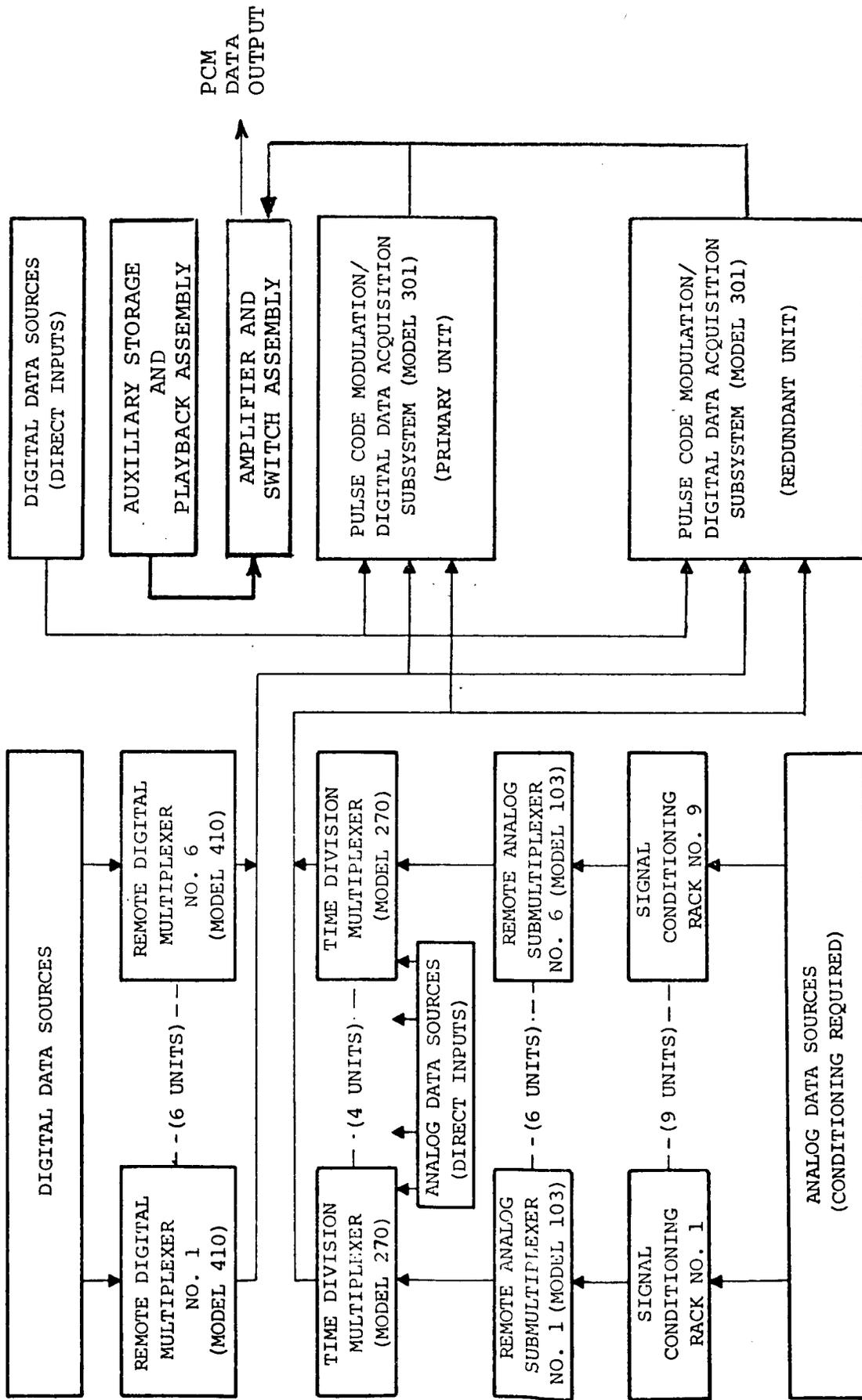
Figure 3.8-1 SKYLAB ATM DATA MANAGEMENT SUBSYSTEM BLOCK DIAGRAM
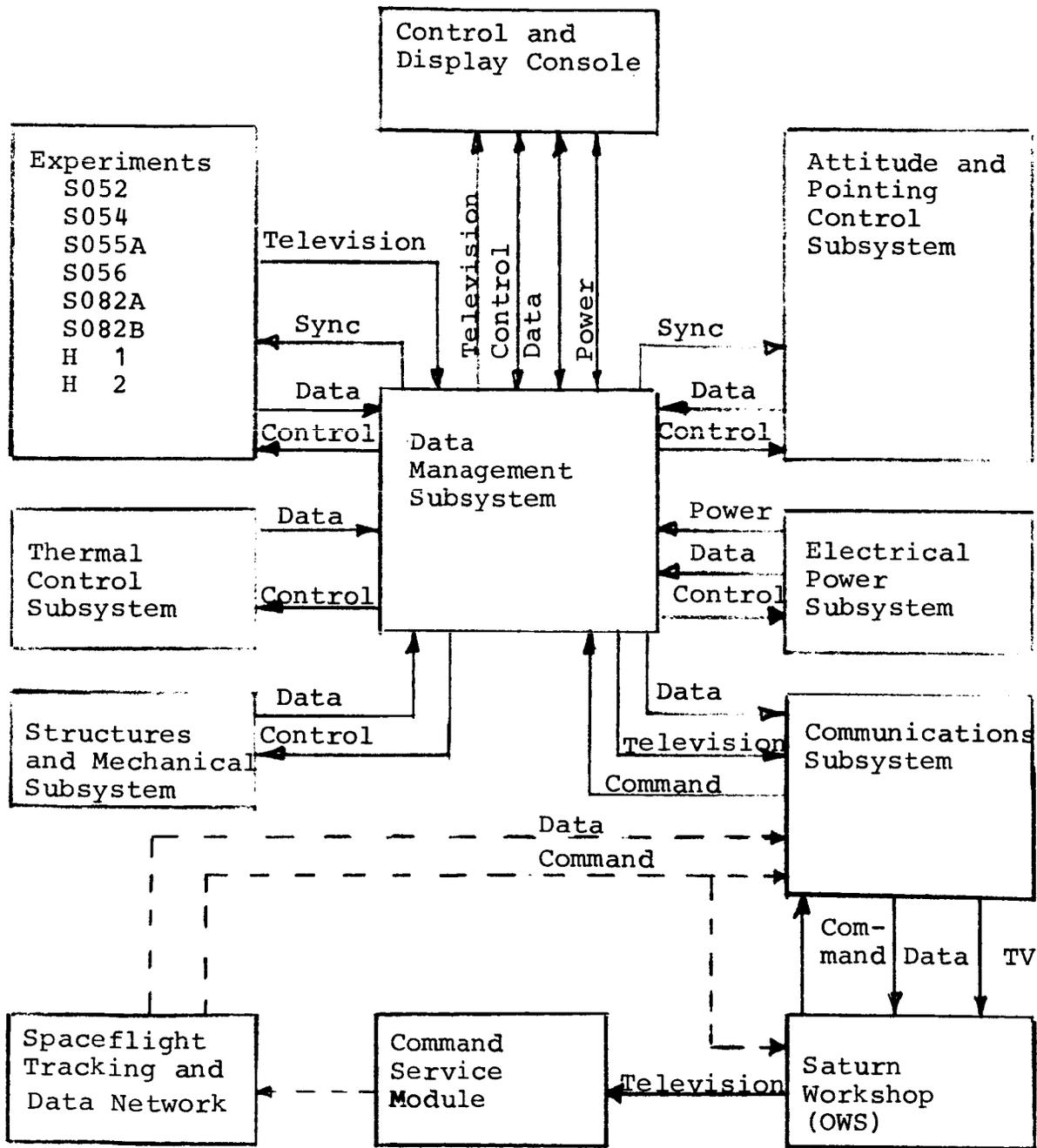
Figure 3.8-2 Skylab ATM Data Management Subsystem Interface
            Block Diagram

The PCM/DDAS accepts both analog data and digital data. The PCM/DDAS encodes the analog data from the TDM's into 10-bit digital words. These data are then combined with the digital data inputs from the RDM's, the direct PCM/DDAS digital input, and the frame sync words (FSW) generated within the PCM/DDAS. The PCM/DDAS arranges the FSW and data into a standard 72 KBPS NRZ format and provides the format as outputs to the amplifier and switch assembly (ASA). All sync signals for the data sources and the telemetry system are either generated in the PCM/DDAS or derived from signals generated in the PCM/DDAS.

The PCM/DDAS format is provided as three separate outputs. The outputs convey the same information in the following three different forms:

    a.   72 kilobits-per-second (KBPS) serial, non-return-to-zero level (NRZL) provided as a serial output through the ASA to modulate the transmitters.

    b.   Parallel NRZL - Provided as a 72 KBPS parallel output through the ASA to the auxiliary storage and playback assembly (ASAP) for recording and storage.

    c.   600 kHz VCO - a 600 kHz FM carrier modulated by the 72 KBPS serial data. Provided as a hardwire output via coaxial cable through the ASA to ground support equipment for prelaunch checkout.

The amplifier and switch assembly (ASA) serves principally as a data and synchronization signal switching interface for the telemetry system. This signal switching is controlled by the command system through the ATM switch selectors. The ASA provides selection of data outputs from either the primary or redundant PCM/DDAS and for the primary or redundant 1 PPS and 1/15 PPS sync signals. The selected PCM/DDAS data output is distributed to the telemetry transmitters for real-time data transmission and to the ASAP for delayed-time data selection and storage.

The ASA provides primary and redundant line drivers for all sync signals, parallel NRZL data, and tape recorder outputs. The ASA provides only switching for the PCM/DDAS 600 kHz voltage controlled oscillator (VCO) signal and the serial 72 KBPS NRZL data from the PCM/DDAS. The ASA also provides isolation between sync load groupings.

The auxiliary storage and playback assembly (ASAP) accepts the parallel PCM/DDAS format and sync signals from the PCM/DDAS routed through the ASA. Sync signals are 72 kHz, 3.5 kHz group A, and 4 PPS group A. The parallel PCM/DDAS format is at a rate of 7200 words-per-second (10 bits-per-word).

Sync signals of 1PPS and 1/15 PPS are derived within the ASAP assembly and applied to a portion of the data sources. These sync signals are used by the data sources to synchronize data to be stored by the ASAP and also to synchronize data for real-time transmission.

Design Status

This subsystem was flown as part of the 1973 Skylab Mission.

3.11   MARINER MARS DATA MANAGEMENT SUBSYSTEM

The Mariner Mars 1971 spacecraft transmits spacecraft engineering and scientific data to the ground Deep Space Network (DSN). Engineering data consists of those measurements required to monitor the performance and status of the spacecraft. Science data consists of scientific measurements made by the on-board instruments plus measurements made to monitor the performance and status of the instruments and the Data Automation System (DAS). All science data is first processed and formatted by the DAS and then sent to the flight telemetry subsystem (FTS). TV data and other scientific data taken at various times during the preorbital and orbital phases of the mission are stored in the onboard digital tape recorder and transmitted back to Earth prior to each subsequent picture-taking sequence.

The flight telemetry subsystem accepts four types of data from the other subsystems; analog voltages, discrete event pulses, return-to-zero (RZ) binary data, and non-return-to-zero (NRZ) binary data. Analog voltages are converted to   7-bit data words. Spacecraft engineering data are time-multiplexed and transmitted continuously throughout the mission. Two channels, only one of which can be used at a given time, are used to transmit science data. Science data are frequency multiplexed with the spacecraft engineering data. Figure 3.11-1 shows the functional flow paths for science and engineering data.

The engineering channel transmits data continuously throughout the flight. This channel contains either all real-time engineering data or all central computer and sequencer subsystem (CC&S) memory readout data. The data rates are 8-1/3 and 33-1/3 bps. Switching between engineering data and CC&S memory data is accomplished by ground command.

The low-rate channel operating at a 50 bps single data rate is used to transmit uncoded science data primarily during the orbital cruise phase of the mission. It is used periodically during interplanetary cruise to check out instrument status.

The high rate channel consists of either block-coded science data or block coded playback data. The block coding of these data streams is performed in the FTS. The high rate channel is the primary data channel for science return during the orbital phase of the mission.

Engineering measurements are prioritized as follows:

   a)   Measurements necessary for flight operations during a nominal mission.

   b)   Measurements which give positive verification of onboard events.

c) Measurements required for selecting between alter-
nate modes of operation.

d) Measurements of subsystem parameters directly affect-
ing system performance.

e) Measurements necessary to evaluate the performance
of subsystems not previously flown.

f) Measurements necessary to evaluate the performance
of subsystems previously flown.

Four data modes are available for the mission: Engineering,
Real-Time Science No. 1, Real-Time Science No. 2, and Playback.
These modes are selectable by both ground and CC&S command.

The engineering mode transmits data via the 8-1/3 and 33-1/3 bps
engineering channel. Either engineering telemetry or CC&S memory
data is available in the engineering mode.

The Real Time Science No. 1 mode simultaneously transmits data
via the engineering channel and the low rate channel. The science
channel transmits uncoded science data at 50 bps. The engineer-
ing channel is used at either 8-1/3 or 33-1/3 bps and carries
spacecraft telemetry or CC&S memory data.

The Real Time Science No. 2 mode simultaneously transmits data
via the engineering channel and high rate channel. The high rate
channel carries blockcoded science data at either 8.1 or 16.2
kbps. The 16.2 kbps rate provides a means of retrieving selected
TV data in the event of a tape recorder failure. The engineering
channel is used at either 8-1/3 or 33-1/3 bps and carries either
spacecraft telemetry or CC&S memory data.

The playback mode uses both the engineering channel and high
rate channel. The high rate channel transmits block coded
digital tape recorder data at selectable data rates of 16.2,
8.1, 4.05, 2.025, and 1.0125 kbps. The FTS block coder data
symbol rate is 32.6 times that of the digital tape recorder
playback rate. The engineering channel is used at either 8-1/3
or 33-1/3 bps and carries either spacecraft telemetry or CC&S
memory data.

Design Status

This subsystem was flown as part of the 1971 Mariner Mars Mission.
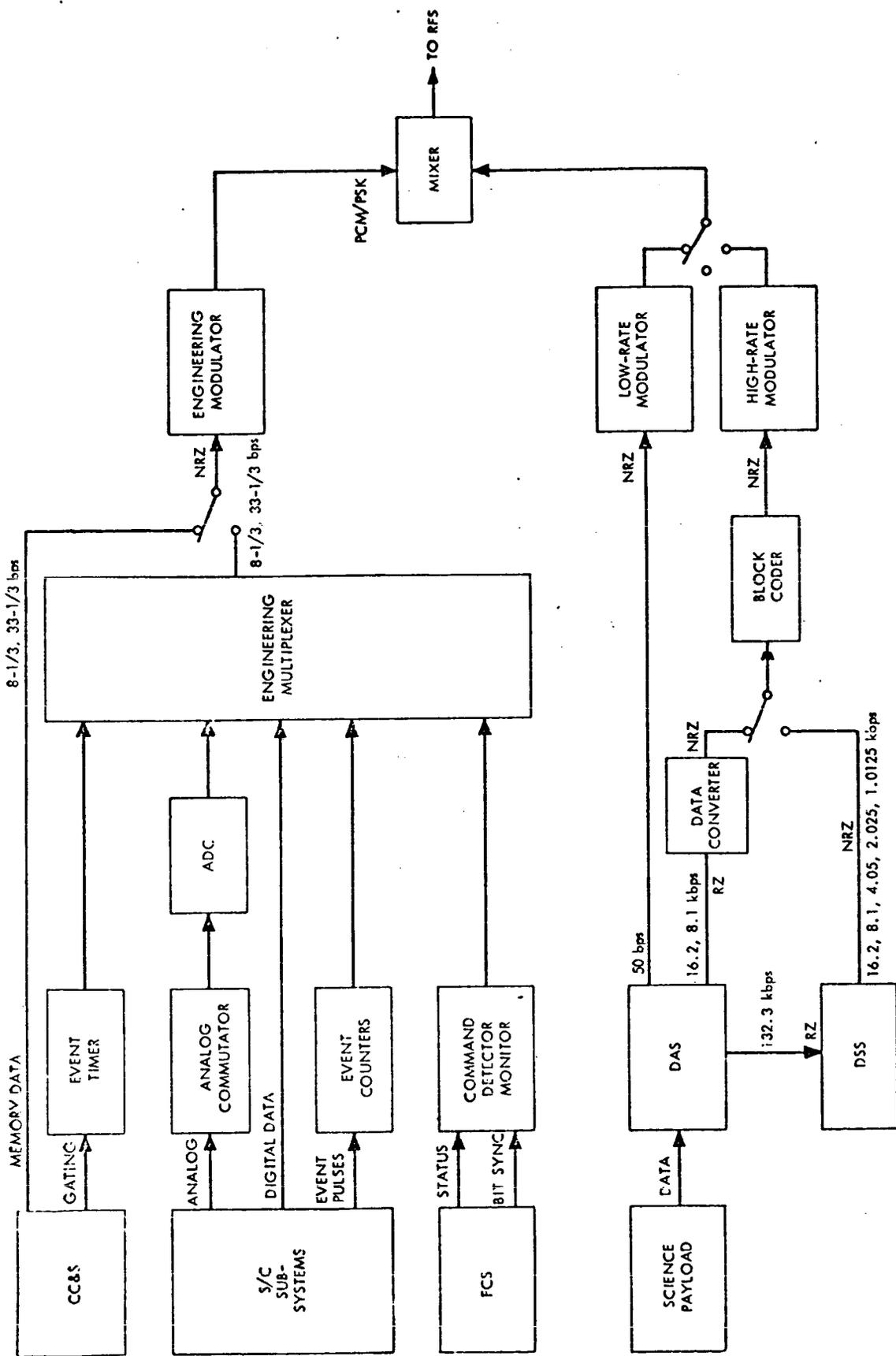
FIGURE 3.11-1   SPACECRAFT DATA HANDLING CONFIGURATION

4.1   ATS-F ELECTRICAL POWER SUBSYSTEM

The electrical power subsystem for ATS-F (Figure 4.1-1) derives power from two semi-cylindrical solar array panel assemblies that are located on the Y-axis of the spacecraft. Energy storage is provided by two 19-cell, 15 A-H, nickel-cadmium batteries which are discharged in parallel. Other components of the power subsystem are the Power Control Unit and the Power Regulation Unit. The electrical power subsystem is designed for a two year mission life.

Partial shunt regulation is used for regulating the solar array voltage. A boost regulator regulates the battery voltage. When excess power is available from the solar array, the battery chargers are enabled to recharge the batteries. Each battery has separate charge control circuits with current limited (1.5 amp max) charging and temperature compensated voltage control. When the array power exceeds the load power and battery charge requirements, the excess power is dissipated by shunt circuits. A common mode controller provides the necessary error signals for the three major modes of operation; the shunt mode, the charge mode, and the boost mode. These functional modes provide the regulation and charge control for the electrical power subsystem.

Design Status

This subsystem is scheduled to be flown as part of the planned mid-1974 ATS-F mission.
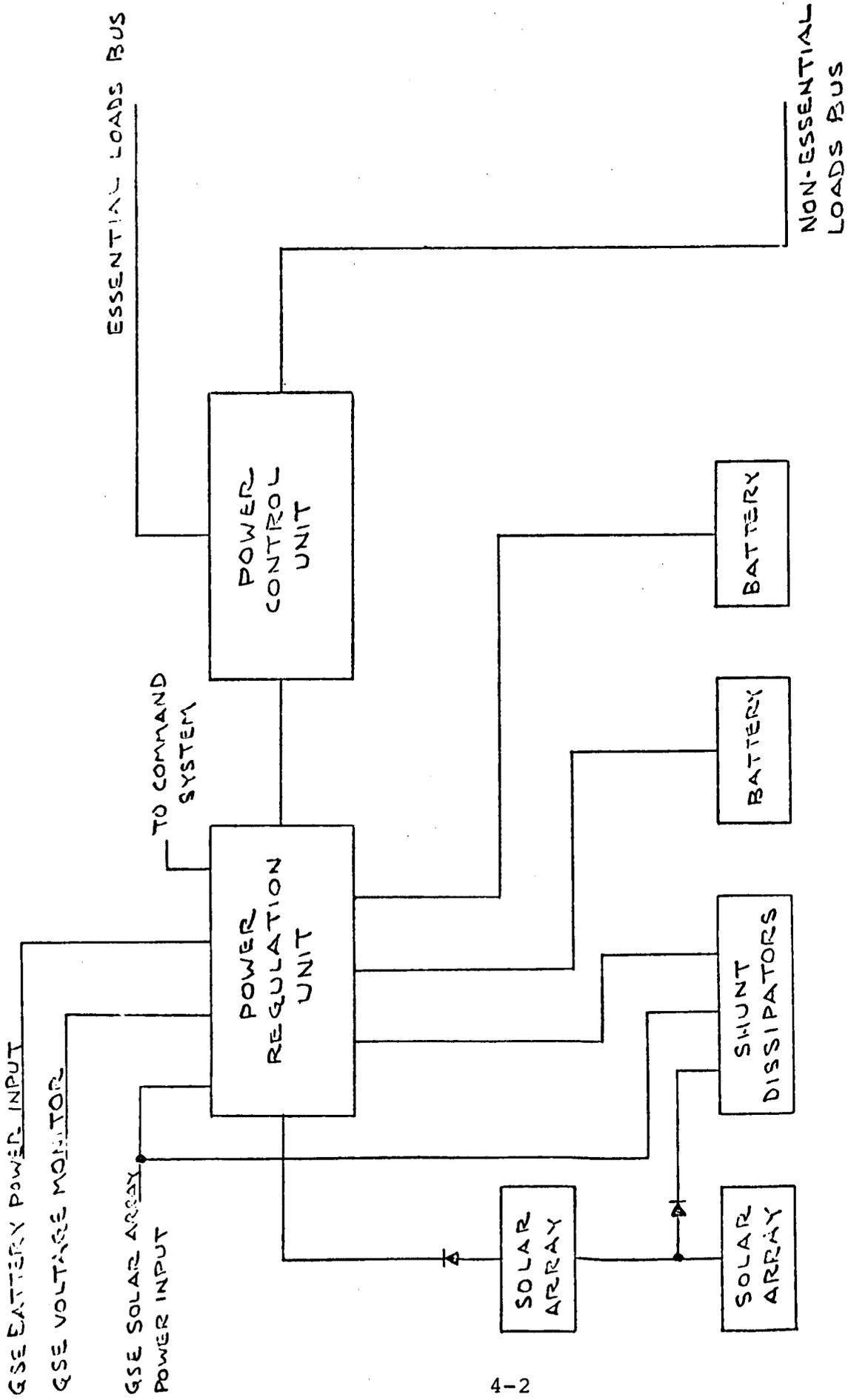
ATS-F POWER SUBSYSTEM

Figure 4.1-1

4-2

4.2   ERTS-B POWER SUBSYSTEM

The ERTS-B Power Subsystem (Figure 4.2-1) provides 24.5 VDC +0.5 volts to the service and payload subsystems of the spacecraft. The basic functions performed to accomplish this are:

    a.   Solar energy conversion to electrical power
    b.   Energy storage by electrochemical means
    c.   Power regulation

Spacecraft loads are supplied by pulse width modulated (PWM) regulators. During satellite night, PWM regulator input power is derived from the discharge of eight nickel-cadmium batteries. When the spacecraft enters the sunlight, solar-array power is supplied to the charge controllers for recharging the batteries and to the regulators for supplying spacecraft loads.

The Power Subsystem consists of eight identical storage modules, one power-control module, one payload regulator module, two solar-cell platforms, the auxiliary load controller, and power-management loads.

Design Status

This subsystem is scheduled to be flown as part of the planned late 1973 ERTS-B mission.

FUNCTIONAL BLOCK DIAGRAM OF POWER SUBSYSTEM

Figure 4.2-1

4.3   HEAO ELECTRICAL POWER SUBSYSTEM

The electrical system is comprised of the electrical power genera-
tion section (EPS) and the power distribution section (PDS).
The EPS consists of the solar array, batteries, maximum power
trackers, ampere hour meters, and power control units. The PDS
consists of power switching units, converters, and distribution
cables which connect the loads to the EPS. A simplified diagram
of the electrical system is shown in Figure 4.3-1.

The electrical section is divided into two halves of equal power
producing and storage capability which feed separate main power
buses. Two maximum power trackers (MPT) service each bus. The
MPT provides maximum utilization of array power by tracking the
array maximum power point in the presence of variations due to
temperature, illumination angle, or environmental degradation.
The power control units (PCU) contain solar array blocking
diodes, electronic circuit breakers, two battery chargers and
telemetry conditioning circuitry.

The PDS electrically integrates the spacecraft subsystems, the
experiments, and the orbit adjust system (OAS) into the observa-
tory. In addition, the PDS provides the observatory electrical
interface to the electrical ground support equipment (EGSE)
during integrated system testing and prelaunch checkout and also
the electrical interface to the boost vehicle via the orbit
adjust system (OAS). Units comprising the subsystem are the
power switching units for experiment, spacecraft, and OAS load
control, converters and the interconnecting harness for the dis-
tribution of power and signals. All functions are parallel redundant
including the cables.

Design Status

The HEAO-A program is currently in a state of redefinition. This
subsystem is a viable candidate for application in the 1977 HEAO-A
mission.
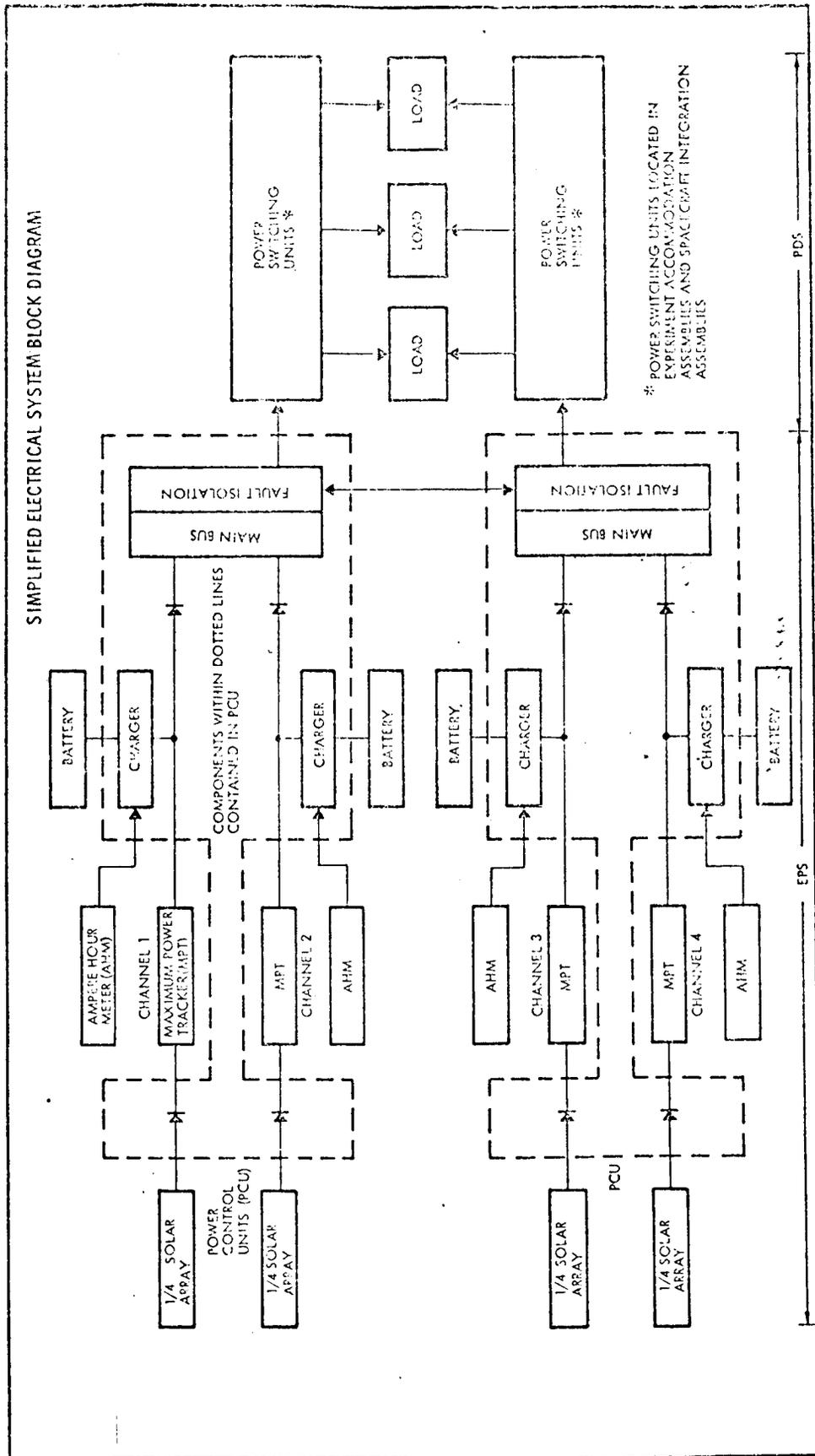
Figure 4.3-1. Simplified Electrical System Block Diagram

4.4   OSO I ELECTRICAL POWER SUBSYSTEM

The OSO I Electrical Power Subsystem (Figure 4.4-1) provides the on-board power required for all spacecraft subsystems and experiment instruments. The Electrical Power Subsystem executes commands (including load switching control), and provides the telemetry output signals necessary to establish the operating conditions and status during its one year mission life.

The solar panel provides prime power during the illuminated period of each orbit. During eclipses and periods of peak power, two batteries supply power.

The electrical power subsystem is capable of supplying 396 watts minimum at 32.0 volts output voltage at summer solstice at the end of a one year mission. Unregulated power is distributed at a nominal 28 VDC on essential, non-essential, and autorestore buses. The non-essential and autorestore buses are controlled as a function of undervoltage sensing. Regulated power is supplied to each experiment from the non-essential bus through redundant regulators. Protection is provided against both overload and undervoltage.

Design Status

This subsystem is scheduled to be flown as part of the planned 1974 OSO-I mission.
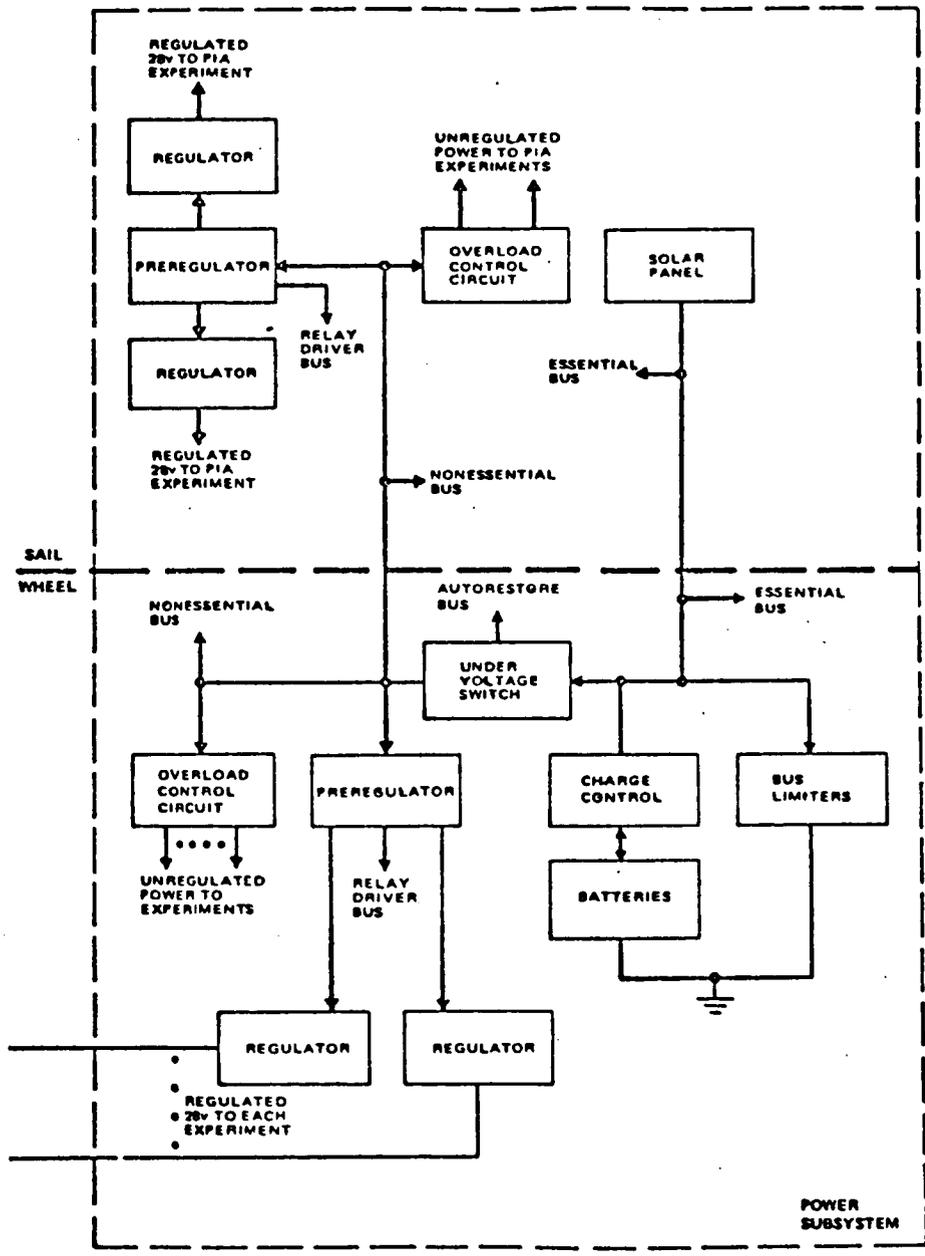
OBSERVATORY BLOCK DIAGRAM

Figure 4.4-1

4.6   OAO POWER SUPPLY SUBSYSTEM

The major equipments for the OAO power supply subsystem are shown in Figure 4.6-1. A solar cell array and three (3) secondary nickel cadmium batteries supply continuous power to the system loads during orbital light and dark periods, respectively. A dc-dc converter and a dc-ac inverter furnish power to each of the spacecraft subsystem equipments requiring regulated dc or ac input voltages. The nominal unregulated bus voltage is 28 volts dc, but may vary from 24 volts to 35 volts, depending on the particular voltage control mode.

The OAO power supply subsystem comprises the following major equipments:

- o   <u>Solar Cell Array</u> - Converts solar energy to electrical energy during the light portion of each orbit.

- o   <u>Nickel Cadmium Batteries</u> - Store electrical energy during each light period and supply spacecraft energy during each dark period.

- o   <u>Power Control Unit (PCU) and Power Regulator Unit (PRU)</u> - These two units control all aspects of power supply operation such as charge rate and mode, battery energy levels, battery charging bus connections, power supply operating modes, execution of power supply ground commands, and monitoring and control of battery temperature voltage levels.

- o   <u>Diode Box</u> - Provides a permanent connection through isolation diodes between each battery and the spacecraft load.

- o   <u>Regulator/Converter</u> - Converts 23 to 35 volt unregulated dc input to five levels of regulated dc output.

- o   <u>Inverter</u> - Provides regulated three, two, and one phase 400 Hz ac outputs from 23 to 35 volt unregulated dc input.

- o   <u>State of Charge Unit (SOCU)</u> - The SOCU monitors the state-of-charge of each battery. It functions as an auxiliary controller of the battery charging control system.

- o   <u>Power Distribution Unit</u> - Distributes electrical power (ac and dc) to spacecraft equipment. It consists of an unregulated power distribution
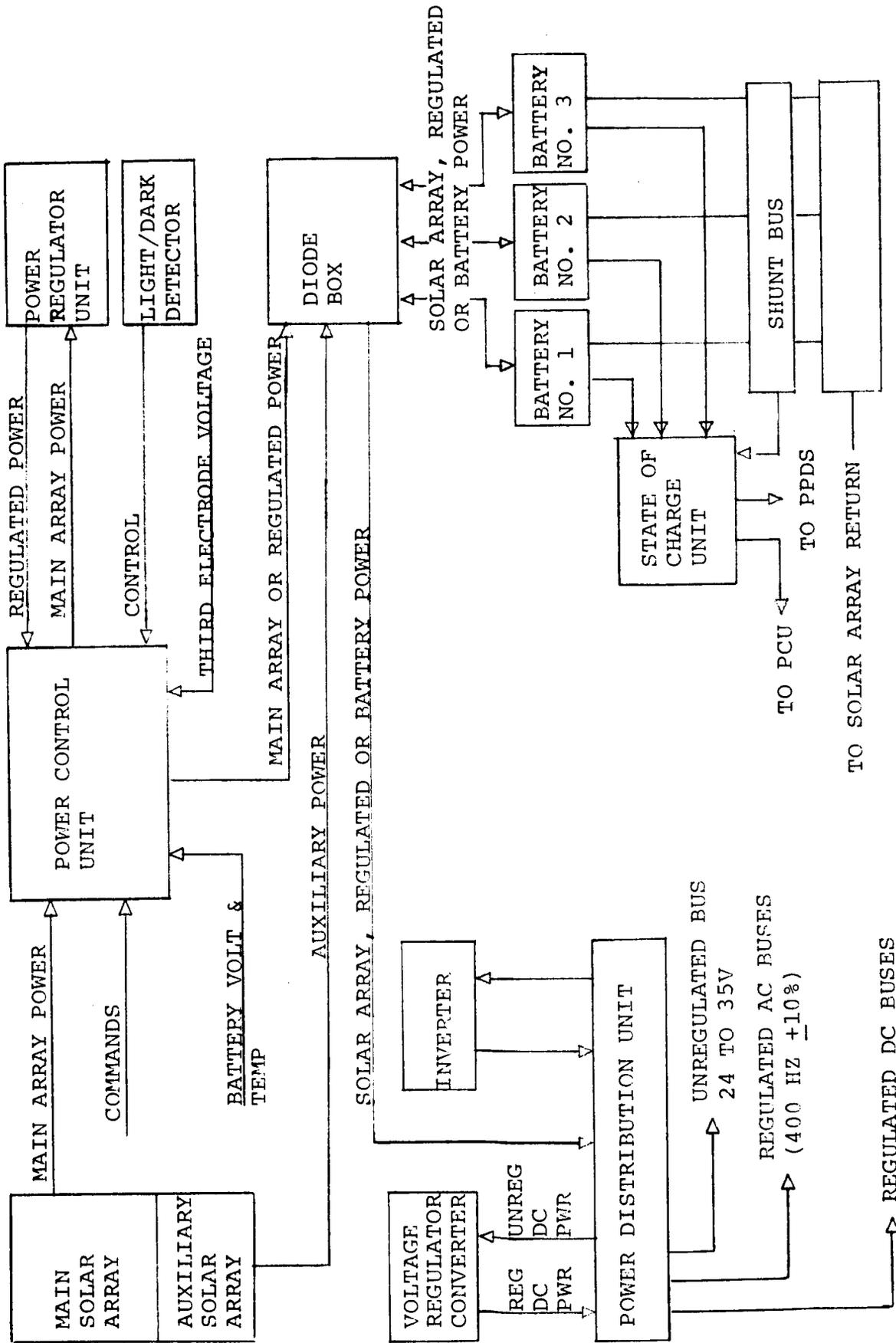
OAO-C POWER SUPPLY BLOCK DIAGRAM

Figure 4.6-1

unit and a regulated power unit. All non-
essential circuits are fused. Essential
circuits are fused for test only.

Design Status

This subsystem was flown as part of the 1972 OAO-C mission.

4.7   AM/MDA ELECTRICAL POWER SUBSYSTEM

The Orbital Workshop (OWS) Solar Array System (SAS), eight AM Power Conditioning Groups (PCG), power distribution, control, and monitor provisions external to SAS and PCG comprise the OWS/AM power system (Figure 4.7-1). Major SAS components are the solar array and deployment mechanisms. Each PCG consists of a battery charger, battery, and voltage regulator. The OWS solar array is divided into eight array groups. One array group and one PCG form one of eight independent power subsystems supplying power to AM buses. The power distribution system extends to the OWS, AM, MDA, CSM, and ATM. Loads receive power from both the AM system and the ATM system during parallel operation of the power systems. The OWS/AM system is capable of receiving power from the ATM power system during parallel operation.

The solar array, consisting of solar wings located on two sides of the OWS, supplies power for bus loads and battery charging during the sunlight phase of each orbit. The AM batteries supply power during the dark phase of each orbit. The power output from each array group can be switched to either one of two PCGs.

Each battery charger controls charging of a battery and provides regulated array and battery power to a bus voltage regulator. A charger bypass allows the array to supply power directly to the bus regulator when the charger is not operational.

A two-wire distribution system distributes power to equipment via redundant AM buses. Negative buses connect to an AM Single-Point Ground (SPG), which is removed after CSM to AM-ATM electrical mating. During CSM docked operation, the CSM provides the SPG. The AM main buses interconnect at the transfer buses with the ATM for parallel power systems operation. Upon completion of the OWS-CSM paralleling operation the fuel cells in the CSM are powered down and all CSM power is then supplied by the EPS. The OWS/AM system contains control switching activated either by the astronauts or from ground commands, diodes for circuit isolation, and circuit breakers for system protection.

Design Status

This subsystem was flown as part of the 1973 Skylab mission.
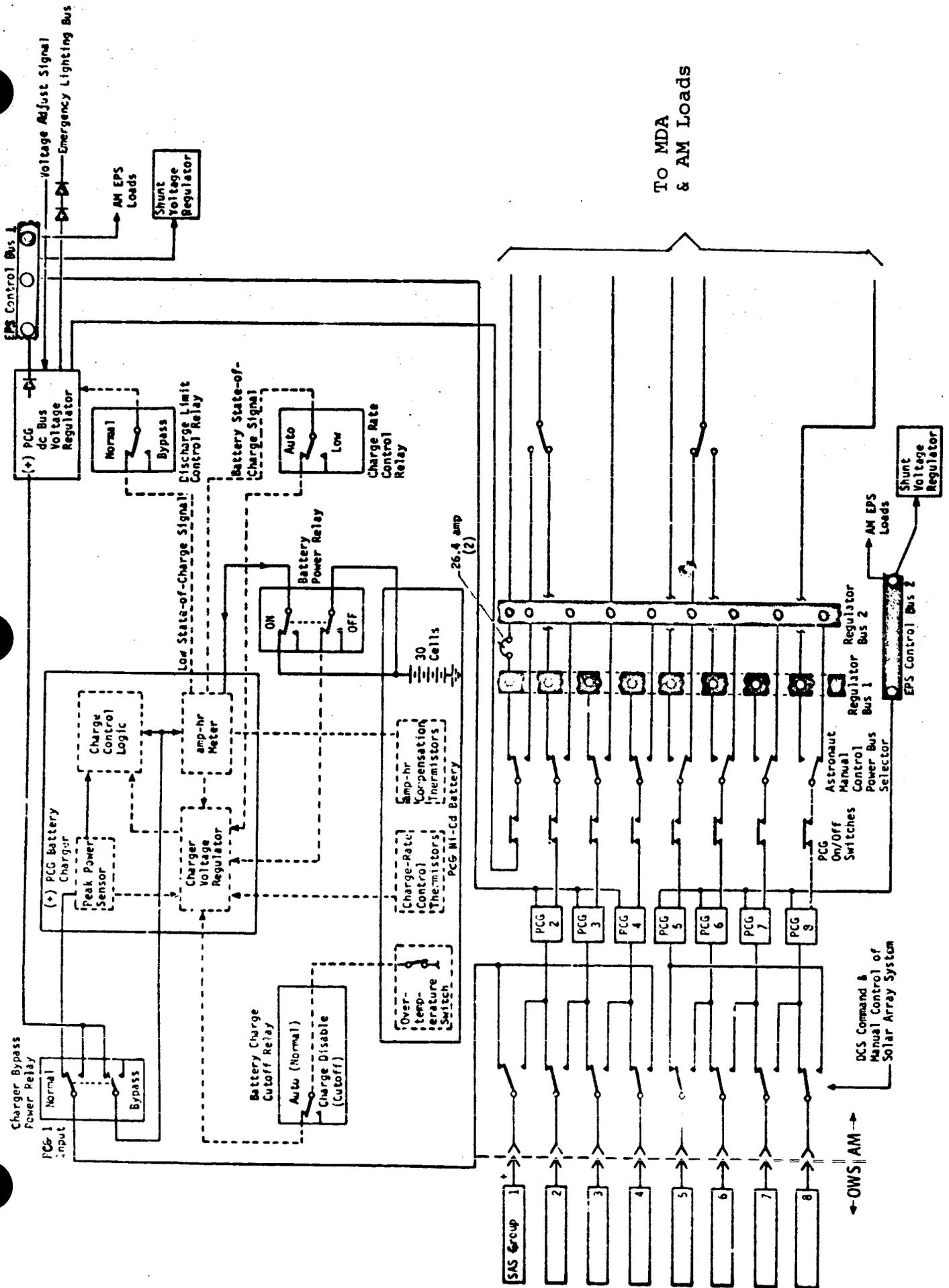
Figure 4.7-1. AM/MDA Electrical Power System

4.8   ATM ELECTRICAL POWER SUBSYSTEM

The ATM Electrical Power Subsystem (EPS) generates, conditions, stores, controls, and distributes 26.5 to 30.5 VDC power to the ATM system and experiment loads. The solar array, consisting of 18 independent sources, deployed from the ATM rack provides unregulated DC power during the sunlight portion of each orbit to 18 charger, battery, regulator modules (CBRM's). Each CBRM contains a battery to supply energy during eclipse portions of the orbit, a charger to condition the solar cell array power and control battery charging, and a regulator to regulate battery and/or cell array voltage and to regulate power drain or sharing between batteries. In addition, the CBRM's contain automatic protection and warning circuits, telemetry and astronaut display circuits for monitoring, a battery heater control circuit, and control circuits. Each CBRM regulator powers both ATM power buses through diodes as shown in Figure 4.8-1.

Design Status

This subsystem was flown as part of the 1973 Skylab mission.
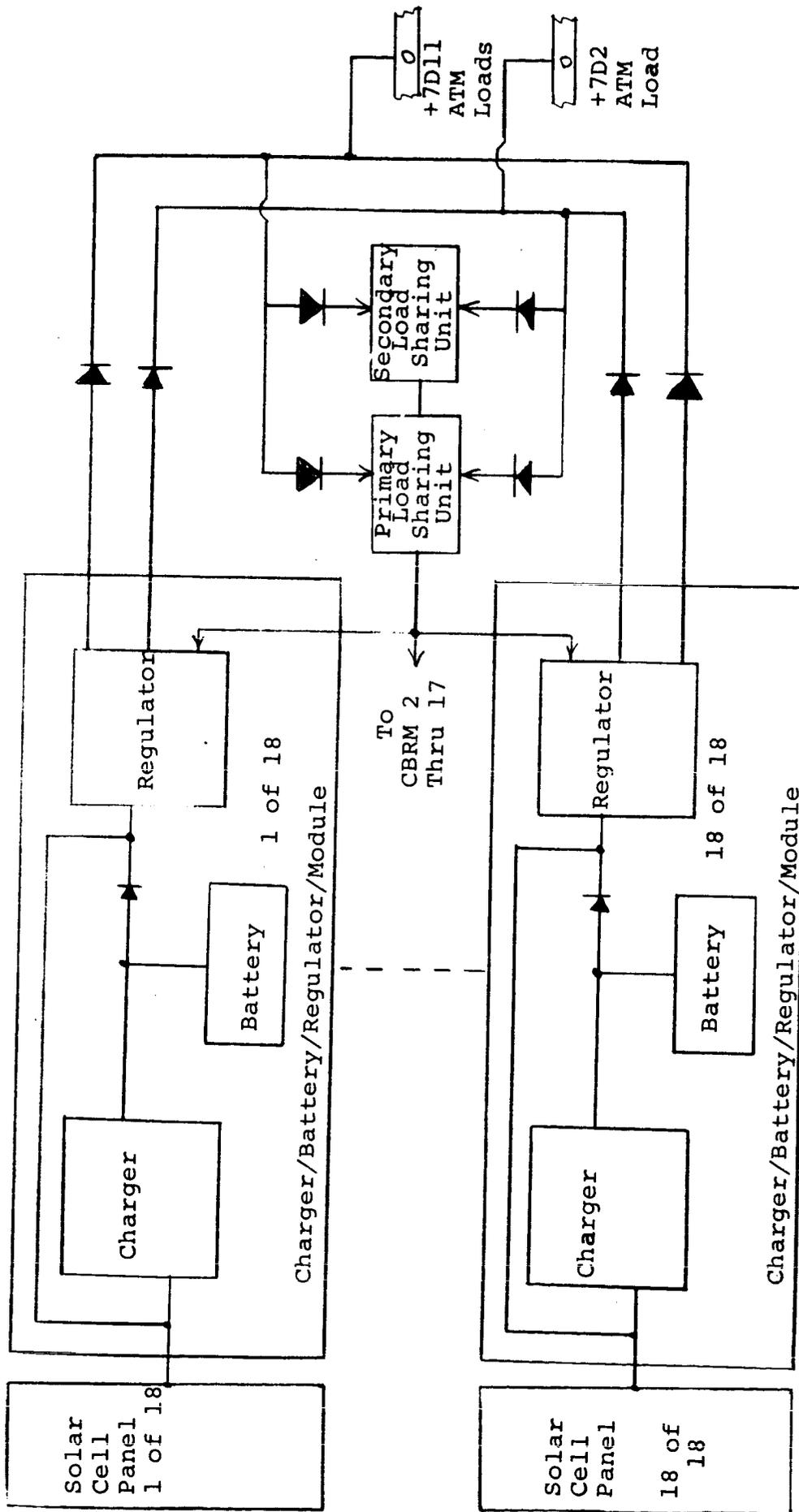
Figure 4.8-1. ATM Power Sub-system Block Diagram

4.9   APOLLO-17 CSM ELECTRICAL POWER SUBSYSTEM

The electrical power system consists of four general functional
areas made up of the following equipment:

    1.   Energy storage
          o   Cryogenics storage (H_2 and O_2)
          o   Entry & postlanding batteries (3)
          o   Pyrotechnic batteries (2)

    2.   Power generation
          o   Fuel cell power plant (3)

    3.   Power conversion
          o   Inverters (3)
          o   Battery charger (1)

    4.   Power distribution
          o   DC buses
          o   AC buses
          o   Bus sensing circuits
          o   Controls and displays

Energy storage consists of two hydrogen and two oxygen tanks
located in the service module for use by the fuel cells.
Energy storage also consists of five silver-oxide-zinc batteries,
located in the command module, for supplying sequencer power
and supplemental power for peak loads as well as backup for
two pyrotechnic batteries.

Power generation, provided by three bacon type fuel cell power
plants, located in the service module (SM), provides primary dc power
to the spacecraft systems until SM separation. Two of these
power plants are adequate to complete the mission.

Power conversion is accomplished with three solid state static
inverters that provide 115/200 volt cps 3 phase ac power up to
1250 volt amperes each. Any one converter is sufficient to
supply all spacecraft primary ac power. A second conversion
unit, the battery charger, maintains the three entry and post-
landing batteries in a fully charged state.

Design Status

This subsystem was flown as part of the 1972 Apollo-17 mission.
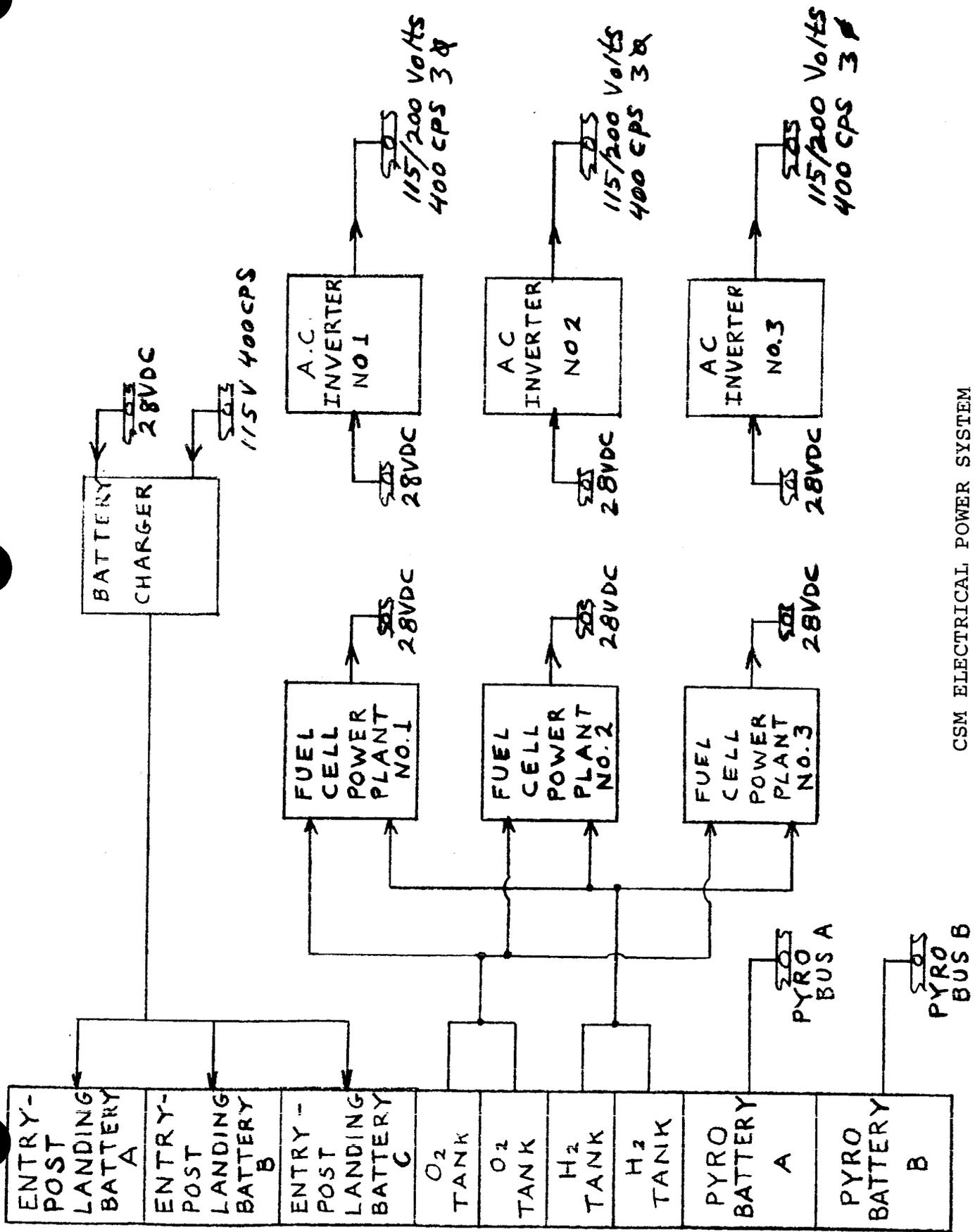
CSM ELECTRICAL POWER SYSTEM

Figure 4.9-1

4.10   LM ELECTRICAL POWER SUBSYSTEM FOR APOLLO 17

The Electrical Power Subsystem (EPS), principal source of electrical power for the LM, consists of a d-c section and an a-c section. Both sections supply operating power to respective electrical buses, which supply all LM subsystems through circuit breakers.

For LM 12 (Apollo 17), electrical power is supplied by five batteries (one, a lunar battery) in the descent stage and two in the ascent stage. Two descent stage batteries (No. 1 and 4) power the LM from T-30 minutes until after transposition and docking, at which time the LM receives electrical power from the CSM. After separation from the CSM, during the powered descent phase of the mission, four descent stage batteries are paralleled with the ascent stage batteries. Paralleling the batteries ensures minimum required voltage for all LM operations. During lunar stay, specific combinations of the five descent stage batteries can be paralleled to provide LM power.

Before lift-off from the lunar surface, ascent stage battery power is introduced, descent power is terminated, and descent feeder lines are deadfaced and severed. Ascent stage battery power is then used until after final docking and astronaut transfer to the CM.

The EPS batteries are controlled and protected by electrical control assemblies, a relay junction box, and a deadface relay box, in conjunction with the control and display panel. A battery control relay assembly adapts the lunar battery to the four descent battery control circuits. Primary a-c power is provided by two inverters, which supply 115 $\pm$2.5 volt, 400 $\pm$0.4 cps (synced condition), a-c power to LM subsystems. The operating frequency of the inverters is 400 $\pm$10 cps, in the nonsynced, free-running condition. Figure 4.10-1 is the functional block diagram of the Lunar Module Electrical Power Subsystem.

Design Status

This subsystem was flown as part of the 1972 Apollo-17 mission.
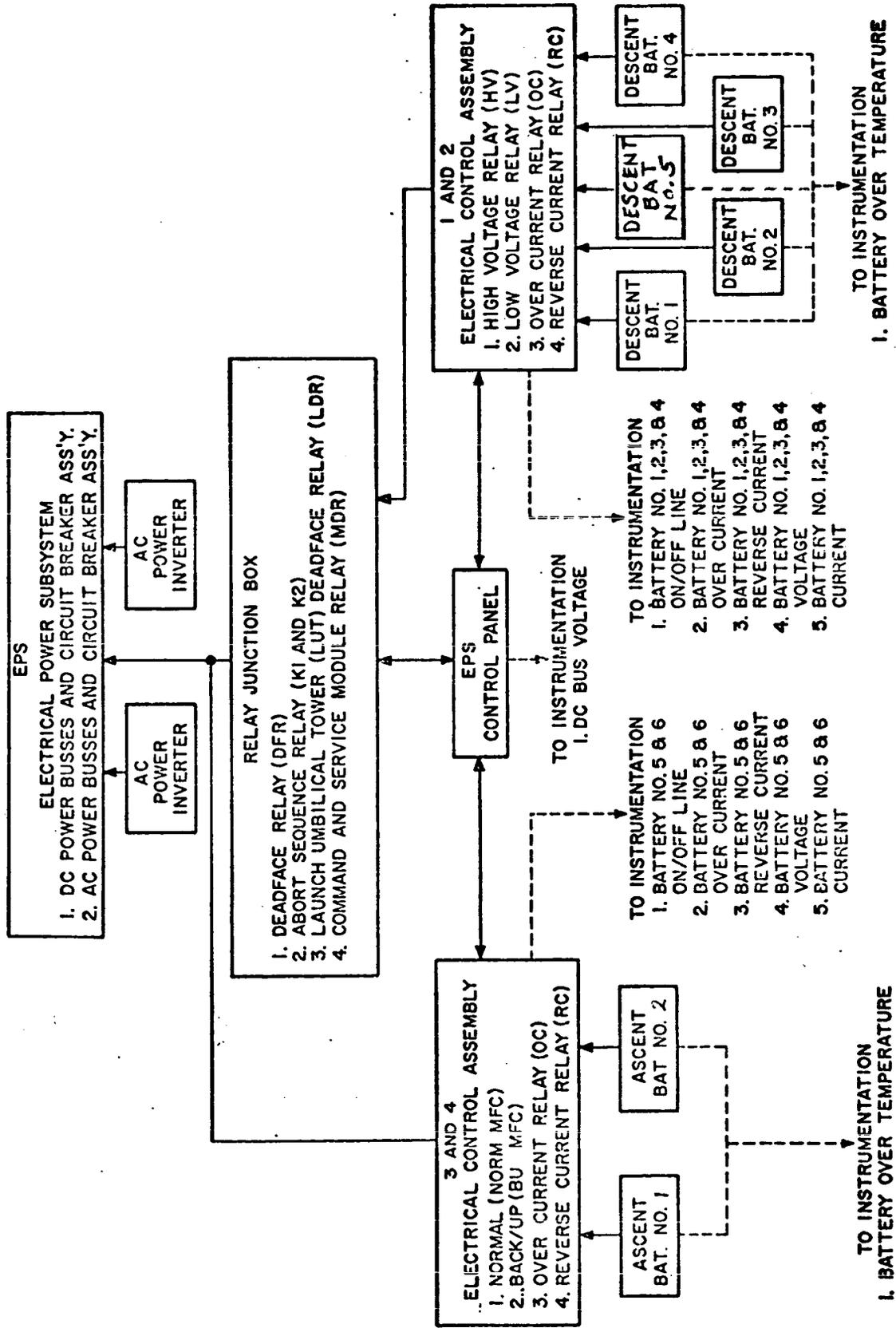
LM ELECTRICAL POWER SUBSYSTEM

Figure 4.10-1

4.11   MARINER MARS 71 ELECTRICAL POWER SUBSYSTEM

The Mariner Mars 71 power subsystem has three primary functions.
First, it must provide a central supply of electrical power to
operate the electrical equipment onboard the spacecraft. Second,
it must provide the required switching and control functions for
the effective management and distribution of that power. Third,
it must provide a central timing function for the spacecraft. As
shown in the functional block diagram (Figure 4.11-1), power is
derived from four photovoltaic solar panels and a rechargeable
(secondary) battery. Power from the battery and/or solar panels
is converted and distributed in the following forms:

   a.   2.4 kHz, single-phase, square-wave power for
         engineering and science subsystems and for the
         propulsion module and cone actuator heaters as
         required.

   b.   400 Hz, three-phase, quasi-square-wave power
         to the attitude control subsystem (A/C) for gyro
         motors.

   c.   400 Hz, single-phase, square-wave power to the
         scan control subsystem (SCAN).

   d.   Regulated 30 vdc power for the engine valve and
         gimbal actuators.

   e.   Unregulated dc power to the battery charger,
         heaters, and radio frequency subsystem (RFS)
         for the RF power supply.

The power distribution modules are designed to provide the
required switching and control functions for the effective
management and distribution of power. In the event of a solar
panel - battery share condition, the boost mode circuit
instantaneously provides sufficient power to drive the raw bus
operating point beyond the solar panel maximum power voltage.

Design Status

This subsystem was flown as part of the 1971 Mariner Mars mission.
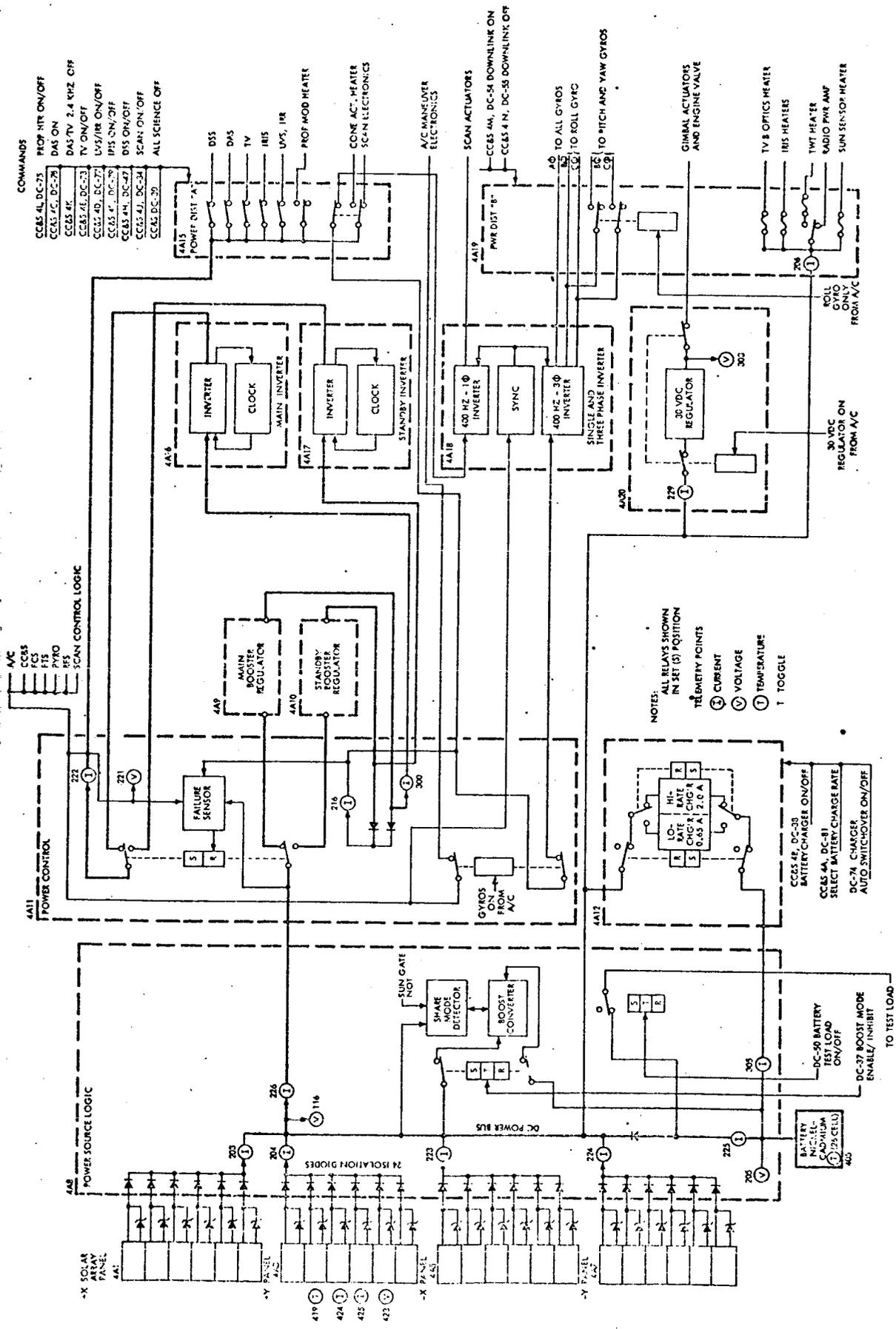
Figure 4.11-1. Mariner Mars 71 Power Subsystem Functional Block Diagram

5.1 ATS-F ATTITUDE CONTROL SUBSYSTEM

The Attitude Control Subsystem (ACS) (Figure 5.1-1) stabilizes and orients the spacecraft in three axes (Figure 5.1-2) after it has separated from the launch vehicle. The ACS uses radiant energy from the earth and light from Polaris for the prime attitude control references. It uses the digital operational controller as its prime controller, and the three inertia wheels and/or the attitude control jets of the spacecraft propulsion subsystem (SPS) as its control actuators. It receives commands from the command decoder and distribution (CDD) unit to perform various functions associated with onboard experiments and with ACS performance.

The ACS uses the attitude control jets of the SPS to unload the momentum wheels, to maintain attitude control during the orbit control mode, and for a minimum period of 6 months if the inertia wheels fail (jet only mode). Orbit control commands are relayed from the ground to the orbit control jets of the SPS. The ACS also generates and conditions status and monitoring signals for telemetering to the ground via the data acquisition and control unit (DACU) and receives ground commands to control wheels and jets via the ground attitude control (GAC) decoder as well as the CDD units.

The modes of operation in which the ACS is required to perform may be grouped in two categories, with a number of modes in each:

- o Acquisition modes
  - Rate damping
  - Sun acquisition
  - Earth acquisition
  - Polaris acquisition

- o Operational and experimental modes
  - Reference orientation (local vertical)
  - Pointing (offset from local vertical)
  - Slew/antenna pattern maneuvers
  - Station nulling (interferometer and monopulse)
  - Satellite tracking
  - Low jitter
  - Self-adaptive precision pointing spacecraft attitude control (SAPPSAC)
  - Orbit control (repositioning and stationkeeping)

Functions performed by the ACS include:

- o Acquisition of the reference local vertical orbit-plane orientation

- o Precision pointing anywhere on the earth's disc up to ± 10.0 degrees from local vertical
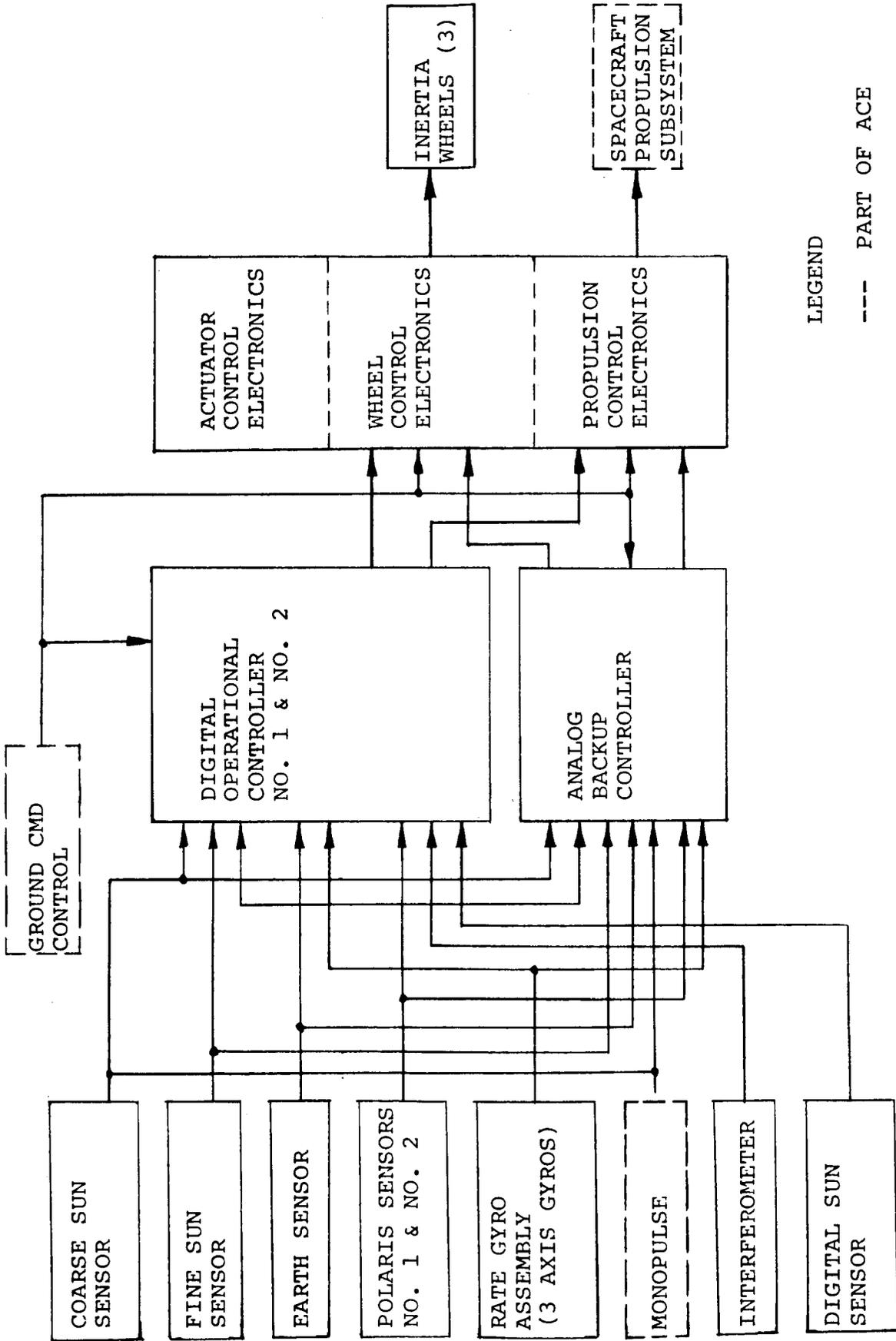
SIMPLIFIED ATTITUDE CONTROL SYSTEM (ACE)

Figure 5.1-1
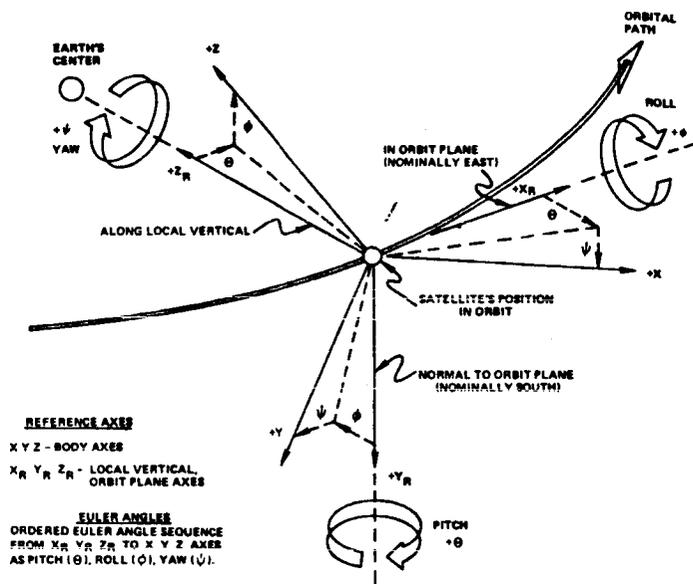
Figure 5.1-2.   ATS Axis Reference

o   Generation and execution of low altitude satellite
     tracking commands anywhere within +11.0 degrees from
     local vertical

o   Generation and execution of slew and antenna pattern
     measurement maneuver command within +5 degrees from
     the line-of-sight to the monitoring ground station in
     pitch and roll, nominally +11 degrees off the local
     vertical

o   Provision of a stable earth-referenced platform with
     low jitter amplitude and jitter rate.

The primary logic functions of the ACS are performed by the digital
operational controller (DOC) or the analog backup controller (ABC).
The primary set of sensors are the earth sensor for roll and pitch
and the Polaris sensor for yaw. Other sensors are: the rate gyro
assembly (RGA), the coarse and fine sun sensors, the digital sun
sensors, and the VHF, S- and C-band monopulse. Backup sensors are
available for each of the operational modes. The actuator control
electronics (ACE) and the three inertia wheels make up the remainder
of the subsystem. The components required to effect the thrust are
considered part of the spacecraft propulsion subsystem.

Design Status

This subsystem is scheduled to be flown as part of the planned
mid-1974 ATS-F mission.

5.2   ERTS-B ATTITUDE CONTROL SUBSYSTEM (ACS)

The Attitude Control Subsystem (ACS) provides stabilization about the spacecraft's roll, pitch, and yaw axes and control of the solar paddles' orientation, maintaining them nearly perpendicular to the sun vector. It consists of four attitude control loops and associated switching logic, telemetry and test outputs, necessary electrical power conversion circuits, and pneumatic supply storage tank and associated manifolding. Thermal environment control is also furnished.

Major ACS modules are as follows:

- o   Horizon scanners, signal processor and attitude computers
- o   Reaction wheels
- o   Rate measurement package
- o   Yaw axis rate gyro
- o   Pneumatics
- o   Solar array drive
- o   Pulse modulator

A simplified block diagram of the ACS is presented in Figure 5.2-1. Basically, spacecraft attitude errors are detected by the ACS sensors, and their processed output signals are used by the pulse modulators to command torquing mechanisms to correct the spacecraft orientation to that desired.

The ACS is required to maintain the alignment of the ERTS spacecraft body axes in an local earth-vertical/orbit-velocity orientation (Figure 5.2-2). The subsystem is capable of:

a.   Acquisition of the reference orientation from any initial attitude, and with angular rates of up to 5 degrees per second about the body axes.

b.   Pointing or tracking accuracy to the reference orientation to within 0.7 degree for the pitch and roll body axes and +0.7 degree for yaw, with the instantaneous angular rates about the space-craft body axes less than 0.04 degree per second with a design goal of 0.015 degrees per second.

c.   Independent, single-axis rotation of the solar paddles for sun tracking; for a correctly oriented orbit plane containing the earth sun vector, the sun tracking accuracy is better than 10 degrees for the nominal yaw orientation and better than 30 degrees for a 180 degree yaw error.

d,   Reacquisition of the reference orientation from any attitude should some disturbance temporarily interrupt attitude stabilization.

Design Status

This subsystem is scheduled to be flown as part of the planned late 1973 ERTS-B mission.
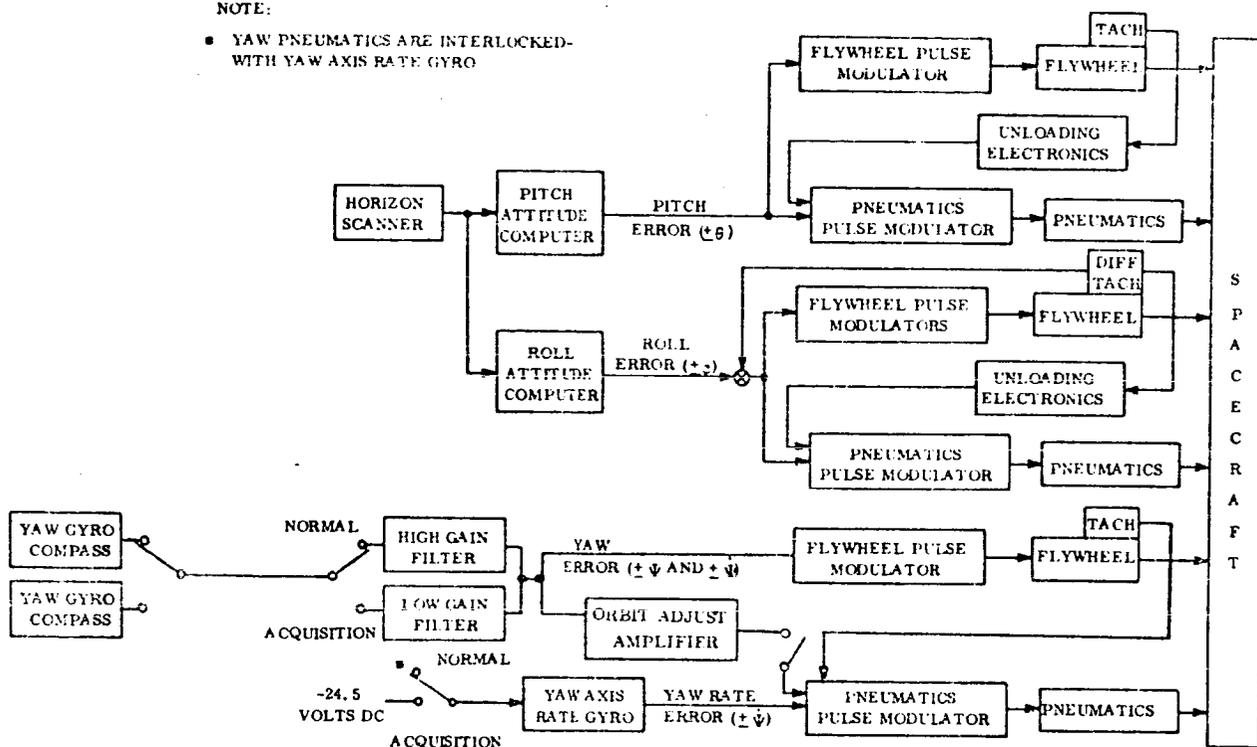
SIMPLIFIED BLOCK DIAGRAM OF THE ERTS ATTITUDE CONTROL SUBSYSTEM

Figure 5.2-1

ATTITUDE CONTROL
SUBSYSTEM

· SUN ⟶

+ PITCH AXIS
(+Y)

+ ROLL AXIS
(+X)
DIRECTION
IN ORBIT

+ YAW (LOCAL VERTICAL)
AXIS
(+ Z)

EARTH
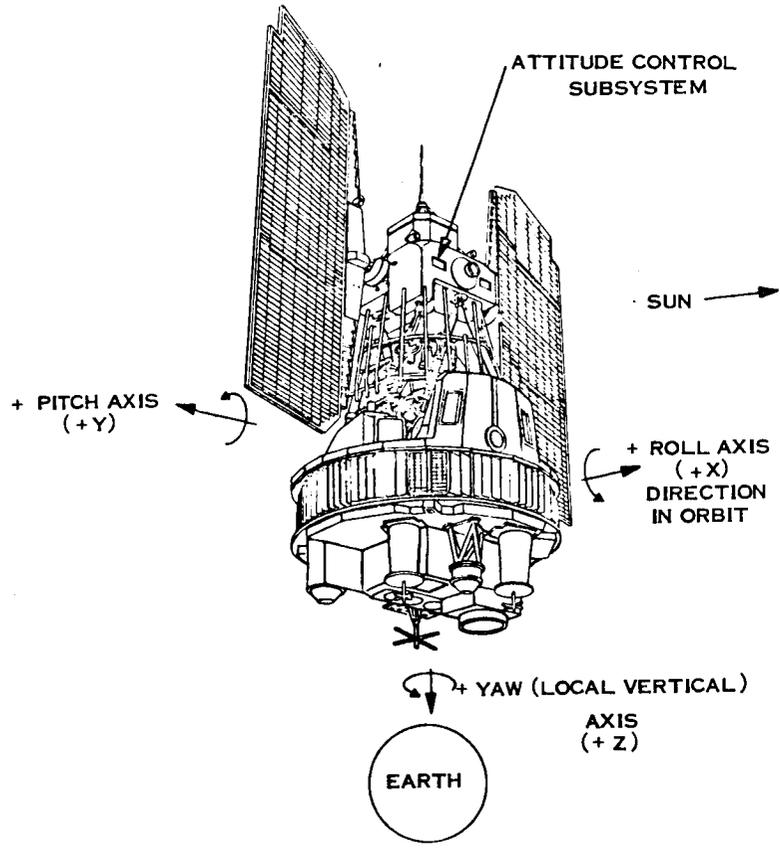
Figure 5.2-2.   ERTS Axis Reference

5.4   OSO-I CONTROL SUBSYSTEM

The OSO-I satellite uses three sun sensors, a star tracker, a magnetometer and two rate integrating gyros (one redundant) for manual (ground) control of the observatory spin rate, attitude, solar acquisition, Pointed Instrument Assembly (PIA) pointing and rastering, and data for aspect determination. A simplified block diagram is shown in Figure 5.4-1.

Following initial spinup on the booster and separation from the booster, the control subsystem provides initial maneuvers to adjust spin rate and reduce pitch angle to within ± 4 degrees. This is done via ground command based on measurements derived from wheel sun sensor data. After pitch acquisition, the sail sun sensor is used to acquire the sun in azimuth. Finally, the PIA sun sensor is used for fine pointing. The orbit night PIA azimuth pointing reference is provided by the rate integrating gyro. Coarse aspect sensing capability is provided by the wheel sun sensor and the magnetometer while fine aspect sensing capability is provided by the star sensor.

Design Status

This subsystem is scheduled to be flown as part of the planned 1974 OSO-I mission.
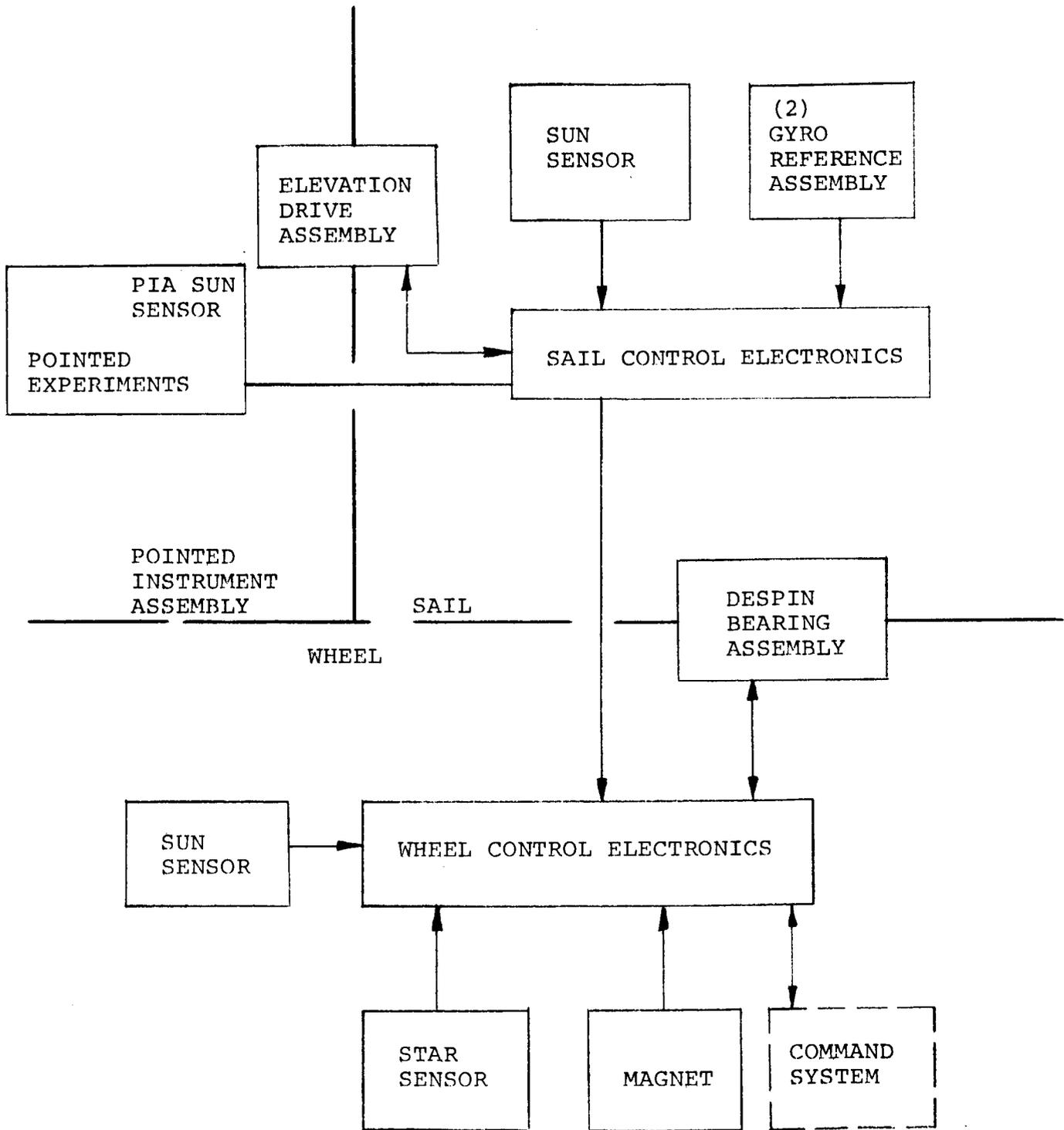
OSO-I ATTITUDE AND CONTROL SUBSYSTEM BLOCK DIAGRAM

Figure 5.4-1

5.6   OAO-C STABILIZATION AND CONTROL SUBSYSTEM

The OAO-C stabilization and control is performed by a complex system of sensors which can be switched in and out by ground command and/or automatic switching. Figure 5.6-1 is a simplified block diagram of this subsystem.

Basically initial stabilization and solar orientation is accomplished through use of the JRT 45 rate gyros, the coarse and fine sun sensors and the high and low thrust jets. Precision pointing mode uses the star trackers, high and low thrust jets and the fine inertia wheels.

Slewing to new position is performed about each axis sequentially, one axis at a time. It can be performed open loop using the gimballed star trackers and coarse inertia wheels or closed loop using the inertial reference unit and the coarse and fine inertia wheels.

Sunbathing control of the observatory's attitude is accomplished by use of the inertial reference unit in combination with the rate and position sensor equipment (RAPS). Daylight and dark modes are switched automatically by using the RAPS sun sensor assembly.

Pitch and yaw control can also be controlled from sensors in the experiments package.

Design Status

This subsystem was flown as part of the 1972 OAO-C mission.
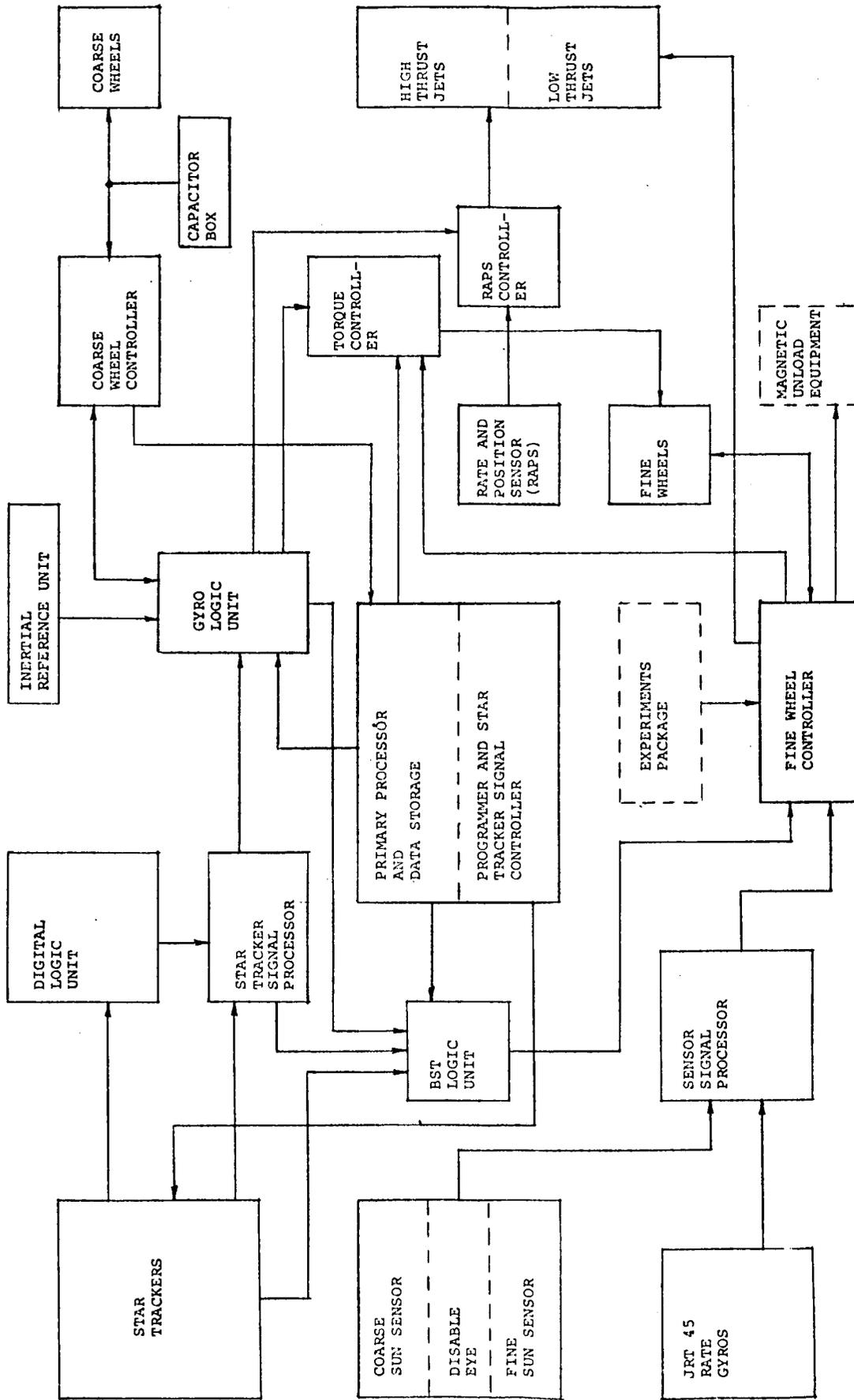
SIMPLIFIED BLOCK DIAGRAM
OAO-C STABILIZATION AND CONTROL SUBSYSTEM
Figure 5.6-1

5.8 ATM ATTITUDE AND POINTING CONTROL SUBSYSTEM

The Attitude and Pointing Control Subsystem (APCS) (Figure 5.8-1) provides three axes attitude stabilization and maneuvering capability for the Skylab Orbital Assembly (OA) and provides pointing control of the ATM experiment canister during solar experimentation periods. The major sections of the APCS are: the ATM digital computer (ATMDC); the workshop computer interface unit (WCIU); the thruster attitude control system (TACS); the control moment gyros (CMG); the ATM canister sensors, the ATM canister controls; and the experiment pointing control (EPC) system.

The APCS is controlled by the flight program which is executed by the ATMDC. The primary attitude of the Skylab is solar inertial and is defined as the $+Z_v$ axis pointed to within five degrees of the sun line.

The APCS is comprised of two complete control systems; the nested system and the EPC. The nested system can further be divided into the CMG and TACS control loops. The CMGs are used for overall vehicle control and operate in the deadband of the TACS (Figure 5.8-2). The TACS will assist the CMGs whenever vehicle disturbances require correction maneuvers greater than the capability of the CMGs or when the CMGs cannot absorb changes in vehicle momentum (i.e., saturation).

Two basic attitudes are used during mission performance: Solar Inertial (SI) and Z Local Vertical (Z-LV). All other attitude modes are attained by maneuvering or offsetting from one of these basic attitudes.

To meet the pointing requirements for solar experiments, the EPC is used to compensate for highly transient disturbance torques. The EPC operates independently of the nested system, using the canister mounted sensors, fine sun sensors and rate gyros. The EPC controls the experiment canister through two degrees of freedom flexure bearing pivots (+2 degrees about X and Y axes). The canister contains experiments, control sensors, and actuators.

Design Status

This subsystem was flown as part of the 1973 Skylab mission.
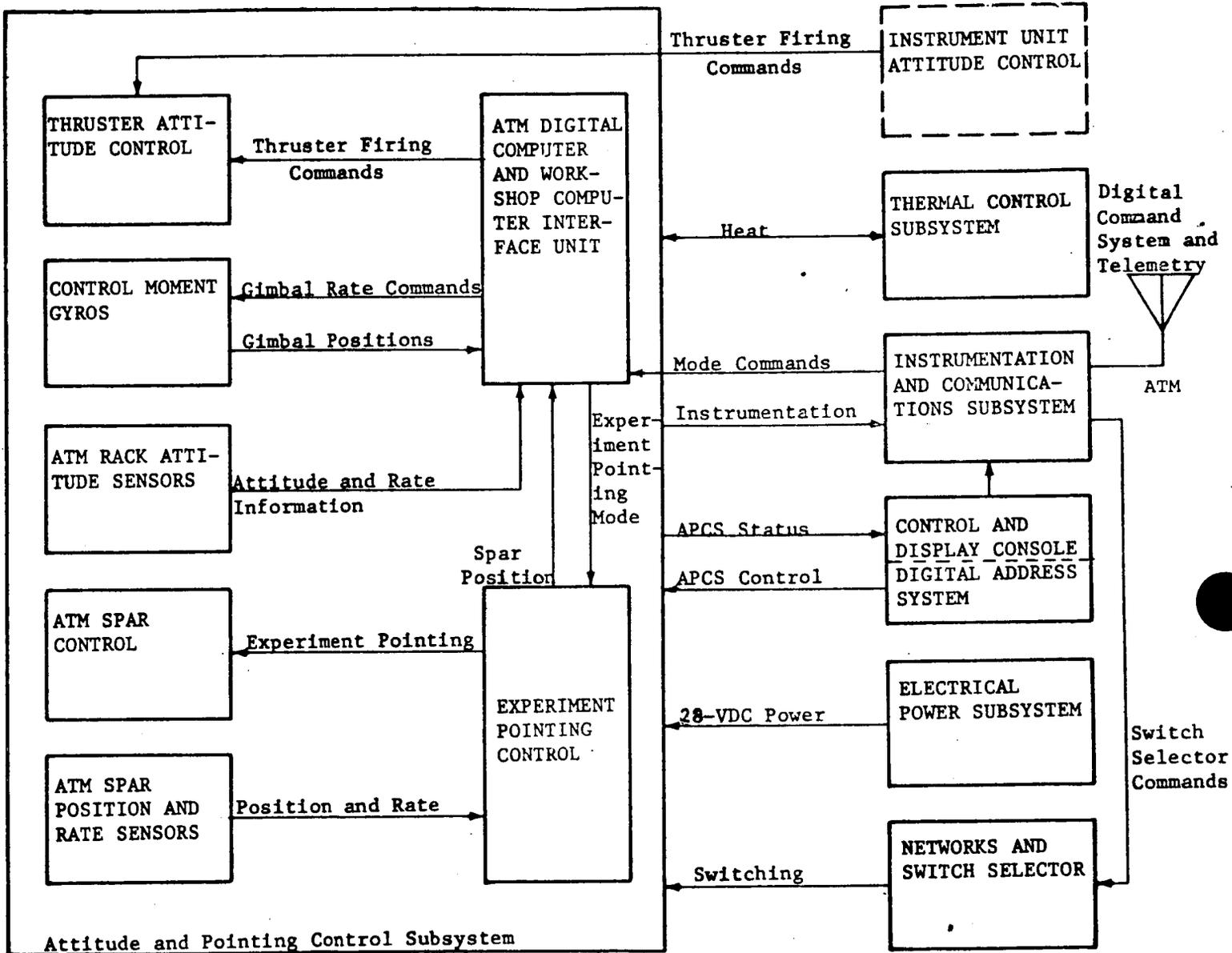
Figure 5.8-1.   ATM Subsystems
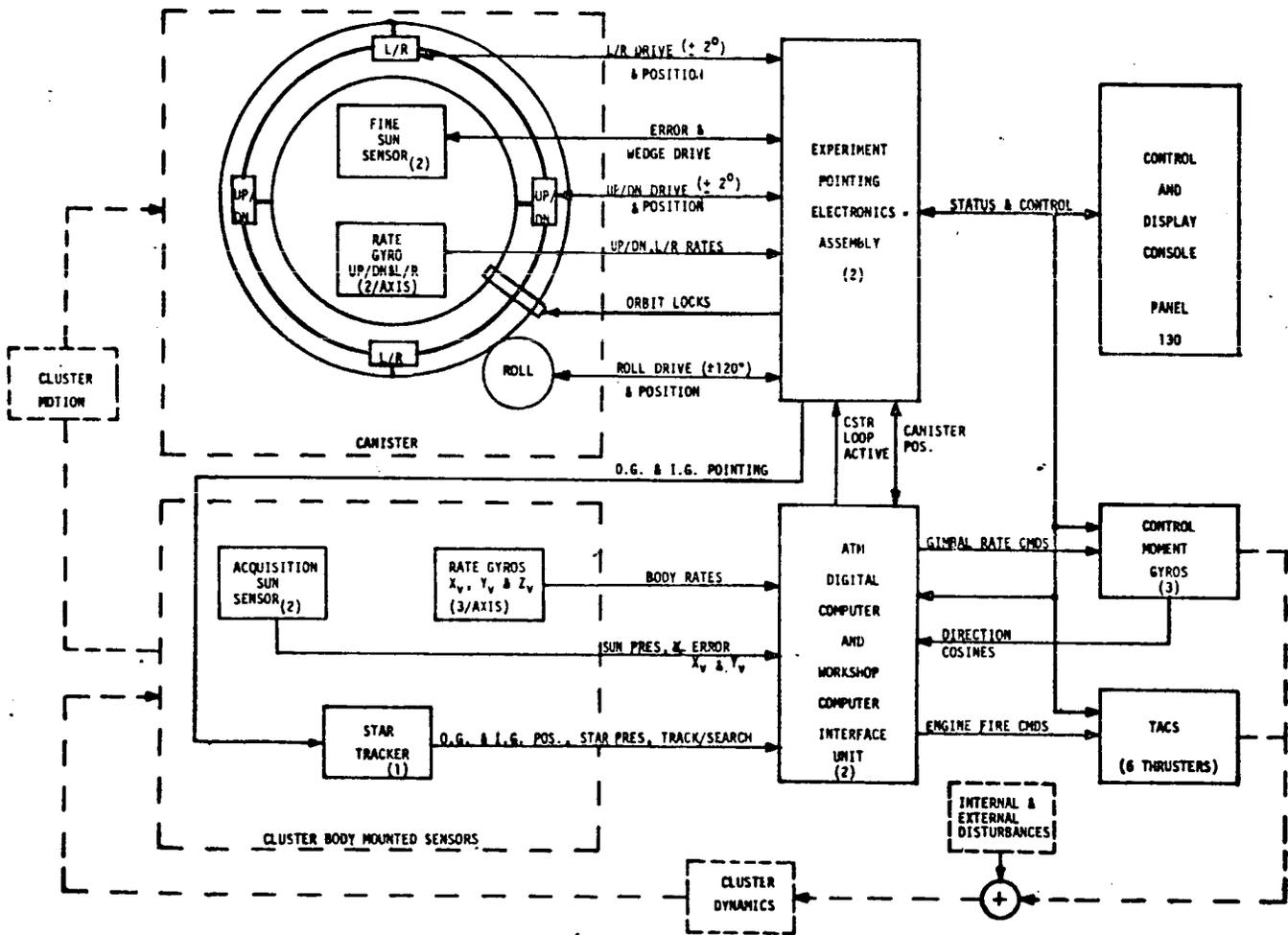
Figure 5.8-2.   ATM Attitude and Pointing Control Subsystem

5.9 APOLLO 17 CSM GUIDANCE, NAVIGATION AND CONTROL

The Apollo 17 CSM contains a guidance and navigation system and a stabilization and control system. The guidance and naviga- tion (G&N) system (Figure 5.9-1) is a semi-automatic system, directed and operated by the flight crew, to perform two basic functions: inertial guidance and optical navigation. The system consists of inertial, optical, and computer subsystems, each of which can be operated independently, if necessary. Thus, a failure in one subsystem will not disable the entire system.

The three subsystems, individually or in combination, can perform the following functions:

   a)   Periodically establish an inertial reference which is used for measurements and computations.

   b)   Align the inertial reference by precise optical sightings.

   c)   Calculate the position and velocity of the space- craft by optical navigation and inertial guidance.

   d)   Generate steering signal and thrust commands necessary to maintain the required S/C trajectory.

   e)   Provide the flight crew with a display of data which indicates the status of the G&N problem.

The inertial subsystem consists of an inertial measurement unit (IMU), associated hardware, and appropriate controls and displays. Its major functions involve: (1) measuring changes in spacecraft (S/C) attitude, (2) assisting in the generation of steering commands for the S/C stabilization and control system (SCS), and (3) measuring S/C velocity changes due to thrust. Various subsystem modes of operation can be initiated automati- cally by the computer subsystem or manually by the flight crew, either directly or through appropriate programming of the computer subsystem.

The optical subsystem consists of a scanning telescope, a sextant, associated hardware, and appropriate controls and displays. Its major functions involve: (1) providing the computer subsystem with data obtained by measuring angles between lines of sight to celestial objects, and (2) providing measurements for establish- ing the S/C inertial reference. The scanning telescope and sextant are used by the lunar module (LM) subsequent to separa- tion and during rendezvous. These sightings, when used in conjunc- tion with a catalog of celestial objects stored in the computer
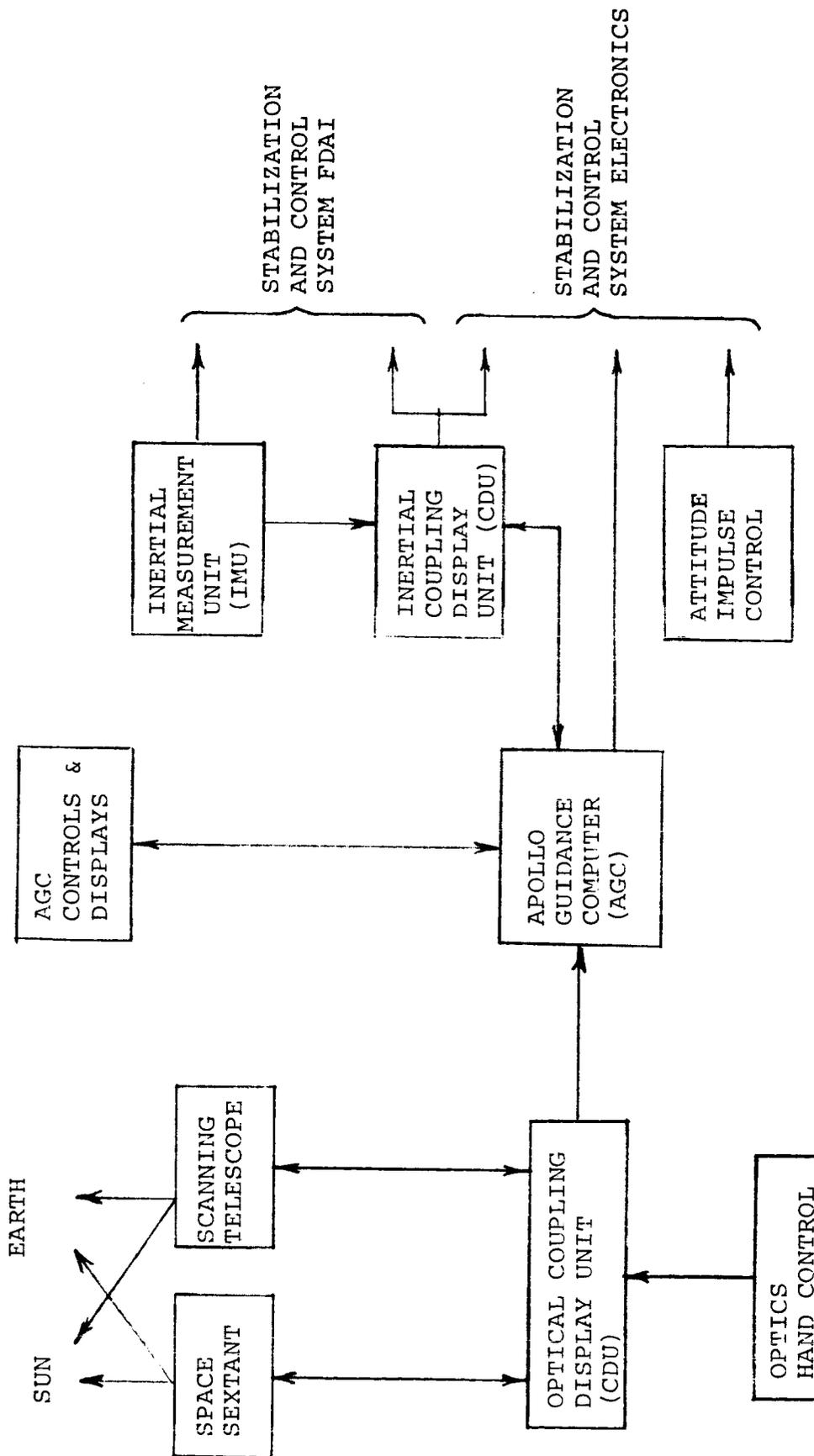
GUIDANCE AND NAVIGATION SYSTEM

Figure 5.9-1

subsystem, enable determination of the S/C position and orientation in space. Communication with ground tracking stations provides primary navigation information. The identity of celestial objects and the schedule of measurements is based on an optimum plan determined prior to launch.

The computer subsystem consists of an Apollo guidance computer (AGC) and appropriate controls and displays. Its major functions involve: (1) calculating steering signals and discrete thrust commands to keep the S/C on a desired trajectory, (2) positioning the IMU stable platform to an inertial reference defined by optical measurements, (3) performing limited G&N system malfunction isolation, and (4) supplying pertinent S/C condition information to appropriate display panels. The AGC is a general purpose digital computer employing a core memory, parallel operation, and a built-in self-check capability. Programs are stored in the AGC and manually or automatically selected to control and solve flight equations. Using information from navigation fixes, the AGC computes a desired trajectory and calculates necessary corrective attitude and thrust commands. Velocity corrections are measured by the inertial subsystem and controlled by the computer subsystem. Velocity corrections are not made continuously but are initiated at predetermined checkpoints in the flight to conserve rocket propellants. The G&N, SCS, SPS, and RCS systems combine to provide closed-loop control of the S/C velocity and attitude. The stabilization and control system (SCS) (Figure 5.9-2) provides control and monitoring of the spacecraft attitude. It also provides rate control of the service propulsion engine thrust vector and a backup inertial reference system. The system may be operated automatically or manually in various modes. The guidance and navigation system, service propulsion system, and the CSM reaction control system interface with the SCS. The major components of the SCS are: rate gyro assembly; attitude gyro/accelerometer assembly; pitch, yaw, and roll electronic control assemblies (ECAs); display/attitude gyro accelerometer assembly ECA; auxiliary ECA, velocity change indicator, gimbal position/attitude set indicator, flight director attitude indicator (FDAI), two rotation controls, and two translation controls. System controls and displays are located on the Command Module (C/M) main display console. The rate gyro assembly consists of three rate gyros mounted mutually 90° apart in X-, Y-, and Z-axes. The rate gyros provide signals representative of S/C attitude change rates. The rate is displayed on the FDAI and is used by the SCS for damping and stabilization. The attitude gyro accelerometer assembly consists of three body-mounted gyros (BMAGs), and a pendulous accelerometer mounted coincident with the X-axis. The BMAGs sense pitch-, yaw-, and roll-attitude changes and provide

MANUAL
CONTROLS

DIRECT
ROTATION
COMMANDS

TRANSLATION

ROTATION

STABILIZATION
AND CONTROL
SYSTEM
ELECTRONICS

SM

CM

GUIDANCE
AND
NAVIGATION
SYSTEM

RATE
GYRO
ASSEMBLY
(RGA)

FLIGHT DIRECTOR
ATTITUDE
INDICATOR
(FDAI)

BODY MOUNTED
ATTITUDE GYROS
(BMAG)

REACTION
CONTROL
ASSEMBLY
(RCS)

ATTITUDE SET
CONTROLS

ATTITUDE GYRO
COUPLER UNIT
(AGCU)

ΔV
DISPLAY

X-AXIS
ACCELEROMETER

SERVICE
PROPULSION
SYSTEM
(SPS)

GIMBAL
POSITION
INDICATOR
AND CONTROL

ENGINE
GIMBAL

STABILIZATION AND CONTROL SYSTEM

Figure 5.9-2

attitude-error signals to the FDAI for display, and to the SCS for attitude control. The accelerometer provides acceleration data for automatic termination of SPS thrusting and for display on the AV REMAINING indicator. The ECAs are electronic modules which process and condition the input and output electrical signals of the SCS components.

Design Status

This subsystem was flown as part of the 1972 Apollo-17 mission.

5.10   APOLLO 17 LM GUIDANCE NAVIGATION AND CONTROL

The Apollo 17 Lunar Module contains two guidance systems; the Primary Guidance, Navigation and Control (PGNCS) and the Abort Guidance Section (AGS) (Figure 5.10-1). The PGNCS provides the data measuring equipment, date processing capabilities and control functions necessary to accomplish descent, lunar landing, ascent, rendezvous and docking with the Command Service Module (CSM). To accomplish these goals the PGNCS performs the following functions: inertial guidance, navigation, and flight control. It also provides a means for establishing an inertial reference by use of an optical instrument.

The LM AGS is a navigation and guidance system used to effect rendezvous of the LM with the command service module in the event of a primary guidance system malfunction. The AGS is a strapped-down inertial system, one in which the inertial instruments are rigidly strapped to the vehicle rather than mounted on a stabilized platform. It takes outputs from the sensor assembly, the package made by United Aircraft, and converts these into an equivalent inertial reference frame with the aid of a special purpose, microminiature digital computer. It can provide commands for firing and shutting down engines; generate angles and drive attitude displays and make explicit guidance computations.

Design Status

This subsystem was flown as part of the 1972 Apollo-17 mission.
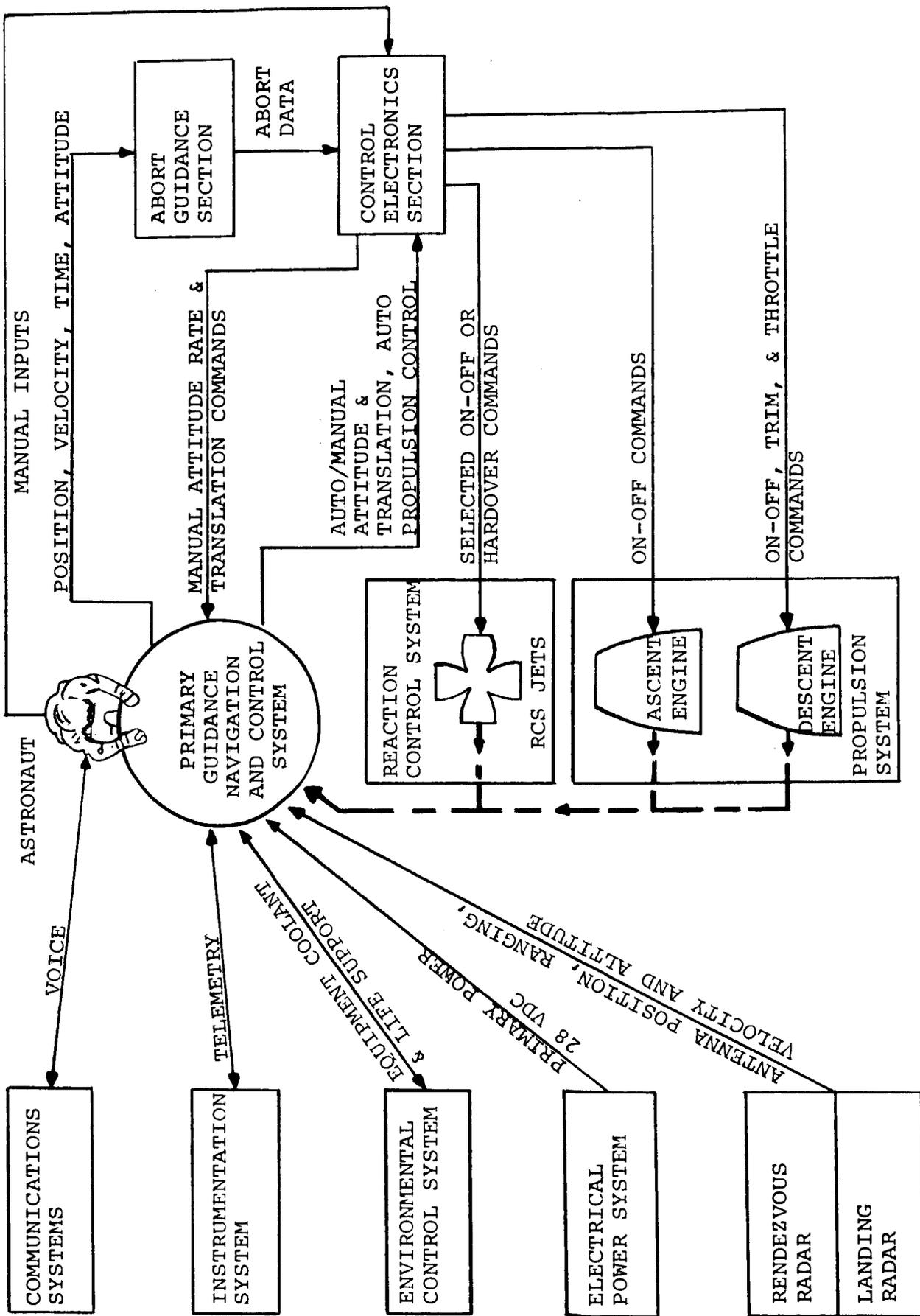
LM SUBSYSTEMS INTERFACE

Figure 5.10-1

5.11 MARINER MARS 71 ATTITUDE CONTROL SUBSYSTEM (A/C)

The Attitude Control Subsystem (A/C) is activated at spacecraft separation from the launch vehicle. It automatically orients the spacecraft with respect to the lines of sight to the Sun and the star Canopus. Upon receipt of commands from the central computer and sequencer (CC&S), the A/C orients the spacecraft to align the propulsion subsystem thrust axis in the direction commanded for the trajectory correction maneuver, orbit insertion maneuver, or orbit trim maneuver. During maneuvers, the A/C maintains vehicle orientation and stability in pitch and yaw by two axis gimbal control of the rocket engine and in roll by the reaction control assembly (RCA). An accelerometer signal is provided to the sequencer in the CC&S for control of the velocity magnitude. At the end of a maneuver sequence, a signal from the CC&S initiates A/C reorientation of the spacecraft to the Sun and Canopus.

Design Status

This subsystem was flown as part of the 1971 Mariner Mars mission.
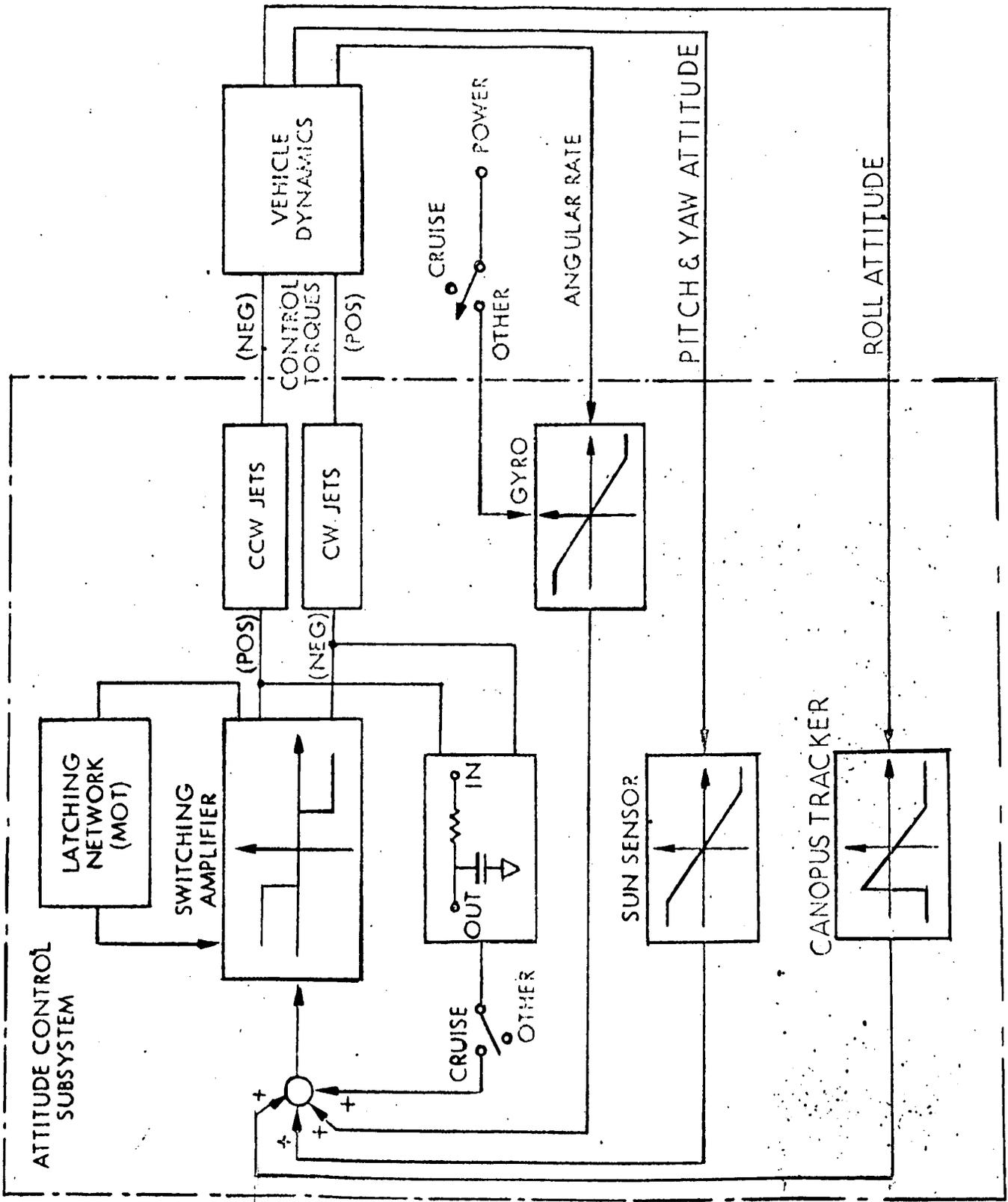
Figure 5.11-1. MARINER MARS 71 ATTITUDE CONTROL SUBSYSTEM

6.1.3 HEAO-A S BAND ANTENNAS

HEAO utilizes two different space-qualified conical log spiral
antennas. One antenna on top is flush mounted to the edge of
the structure while the second antenna is located on a boom that
is hard mounted to the base of the OAS stage. When considered
as operating together with the dual frequency transponders, the
antennas have a gain of greater than -3 dbi everywhere including
a 10-deg pattern overlap region.

The cardioidal pattern antenna mounted on the base of HEAO was
developed at TRW for the Air Force Model 35 program. It is a
right-hand circulary polarized two-arm conical log spiral shown
in Figure 6.1.3-1. The antenna includes a spiral assembly, a
radome, and base mounting provisions. The top-mounted hemispherical
pattern antenna shown in Figure 6.1.3-2 was also developed at TRW
and is the Program 169 design. The radiating element is on a
20-deg cone and is excited by a Robert's balun.

MODEL 35 CONICAL LOG-SPIRAL

COORDINATE REFERENCE

VOLTAGE PATTERN
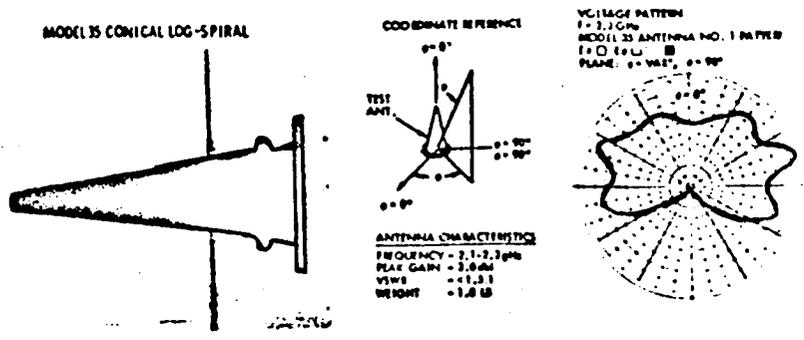
Figure 6.1.3-1. Model 35 Antenna

PROGRAM 169 CONICAL LOG-SPIRAL

COORDINATE REFERENCE

VOLTAGE PATTERN
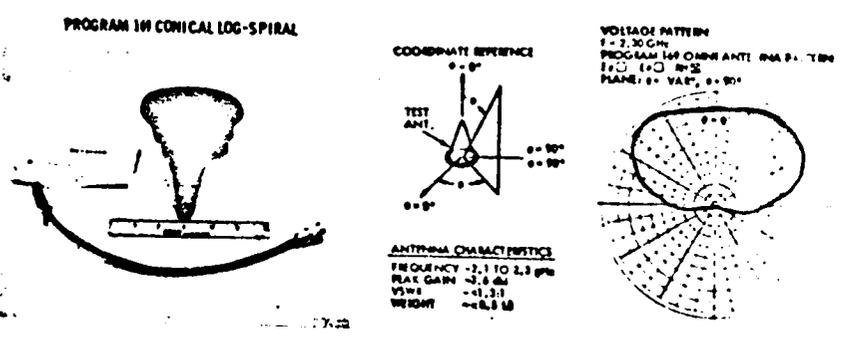
Figure 6.1.3-2. Program 169 Antenna

6.1.3 CONICAL LOG SPIRAL ANTENNAS (S-BAND)

General Description

Program: HEAO-A
Vendor: TRW
Part Number:

Performance Characteristics

Power Rating: 2 watt (tested to 5 watts)
Frequency/VSWR: 2089.371 to 2275 MHz/1.5:1 over the
                    operating frequencies
Gain: -3 dbi minimum spherical coverage using 2 antennas
          and frequency diversity.
Polarization: Right hand circularly
3db Beamwidth: Program 169-150°; Model 35-230°

Physical Characteristics

Size: Model 35 antenna: 29.5 cm (11.6 in) high by 12.0 cm
          (4.74 in) diameter: Program 169 antenna 8.9 cm
          (3.5 in) by 12.7 cm (5.0 in)
Weight: 0.45 Kg (1 pound) each

References

"Preliminary Requirements Review Volume III-B Subsystem Require-
ments and Data Communication Subsystem", TRW No. 17622-301-001-001,
TRW Systems Group, Redondo Beach, Cal. 24 July 1972.

HEAO Phase B Final Report, Volume II Section 5 Subsystem
Definition prepared for MSFC by TRW (contract No. NAS8-26273)
April 23, 1971

Design Status

The HEAO-A program is currently in a state of redefinition. This
component is a viable candidate for application in the 1977
HEAO-A mission.

6.1.4   OSO-I S-BAND ANTENNA

General Description

Program: OSO-I Spacecraft
Vendor: Hughes
Part Number: 3280660-100

Performance Characteristics

Type: Cavity-backed circumferenced slot
Frequency: 2212.5 to 2218.5 MHz
Bandwidth: 6 MHz
Beamwidth: Omnidirectional
VSWR: 1.4
Gain: -6dbi over 95% of 4 Pi steradian (using remote STADAN facility with diversity combining polarization)

Physical Characteristics

Size:
Weight: 6.98 Kg (15.3 lbs)

Environment: Hughes spec SS31331-003

References

Hughes Specifications DS-31331-165, SS31331-003

Design Status

This component is scheduled to be flown as part of the planned 1974 OSO-I mission.

6.1.5   VIKING ORBITER S/X-BAND ANTENNA SUBSYSTEM

The S/X-Band antenna subsystem consists of one high gain antenna (HGA), one low gain antenna (LGA), two dual frequency rotary joints, plus the necessary RF transmission lines and associated connectors. The HGA is used on the Orbiter to transmit a 2295 +5 MHz and 8415 +20 MHz signal to the Deep Space Information Facility (DSIF) stations and receive 2115 +5 MHz. The LGA transmits a 2295 MHz signal and receives a 2115 MHz signal. The HGA consists of a 1.47 meter circular aperture paraboloidal reflector.

6.1.5-1   S-BAND ANTENNA, LOW GAIN ANTENNA

General Description

Program: Viking Orbiter 1975
Vendor:
Part Number: 17LG1

Performance Characteristics

Type: Aperture design, open-ended circular waveguide
         with a conical ground plane
Power Rating: Up to 60 watts
Frequency: Transmit - 2295 +5 MHz
              Receive - 2115 +5 MHz
Gain: Measured at 0° cone angle
         7.2 db @ 2115 +5 MHz
         7.8 db @ 2295 +5 MHz
VSWR: 1.3:1
Polarization: Left hand circular
Bandwidth: 10 MHz and 40 MHz
Beamwidth: 92° (2295 MHz), 92° (2145 MHz)

Physical Characteristics

Size: Conical ground plane inside diameter 27.4 cm (10.8 in)
         waveguide inner diameter 9.84 cm (3.878 in.), length
         1.92 m   (75.8 in)
Weight: 1.7 Kg (3.75 lbs)

References

Viking Orbiter 1975 Flight Equipment, S/X-Band Antenna Subsystem,
Des. Req. V075-2017-1, 1 March 1972.

Design Status

This component is scheduled to be flown as part of the planned
1975 Viking Orbiter mission.

6.1.5-2   S/X-BAND ANTENNA, HIGH GAIN ANTENNA

General Description

Program: Viking Orbiter 1975
Vendor:
Part Number: 17HG1

Performance Characteristics

Type: Circular aperture paraboloidal reflector S-Band
          & X-Band LHC feed
Power Rating: Up to 60 watts
Frequency: Transmit - 2295 +5 MHz
                        -8415 +20 MHz
               Receive - 2115 +5 MHz
Gain: On boresite axis (relative to RHC Isotropic Radiator)
          28.5 db @ 2295 +5 MHz
          27.5 db @ 2115 +5 MHz
          39 db @ 8415 +20 MHz
VSWR: 1.2:1
Polarization: Left hand circular
Bandwidth: 190 MHz and 40 MHz (Dual Band)
Beamwidth: 5.7° (2295 MHz), 6° (2115 MHz), 1.6° (8415 MHz)

Physical Characteristics

Size: 1.47 m (58 inch) diameter
Weight: 4.6 Kg (10.0 lbs)

References

Viking Orbiter 1975 Flight Equipment, S/X-Band Antenna Subsystem,
Des. Req. V075-2017-1, 1 March 1972.

Design Status

This component is scheduled to be flown as part of the planned
1975 Viking Orbiter mission.

6.1.9 APOLLO 17 CSM S-BAND OMNIANTENNAS

The four S-Band omni antennas transmit and receive all S-Band signals during the near-earth operational phase, with a backup capability to support the high-gain S-Band antenna in the lunar sequence. The antennas are flush-mounted, right-hand polarized helical, and in a loaded cavity. They are rated 15 watts cw at 2100 to 2300 MHz.

6.1.9-1   S-BAND OMNI ANTENNA

General Description

Program: Apollo 17 CSM
Vendor: AMECON Division Litton Systems Inc.
Part Number: M45672

Performance Characteristics

VSWR: 1.2   @ 2.1 KMHz
           1.18   @ 2.15 KMHz
           1.10   @ 2.2 KMHz
           1.15   @ 2.23 KMHz
           1.18   @ 2.3 KMHz
Power: 15w
Physical Characteristics

Size:
Weight:

References

Final Report Apollo CSM S-Band Omni Antenna Improvement Program
(Contract No. NAS9-8334, October 1970)

Design Status

This component was flown as part of the 1972 Apollo-17 mission.

General Description

Program: Apollo Command Service Module (CSM)
Vendor: Dalmo Victor
Part Number:

Performance Characteristics

Type: 4-parabolic rejector monopulse tracking antenna system
Frequency Range: Receiver: 2106.4 MHz
                     Transmit: 2272.5 and 2287.5 MHz
Beamwidth: Wide beam 40.0° , 40.0°
              Narrow beam 4.5°,   3.9°
Polarization: Right Hand Circular
Gain: Wide beam 3.8db , 9.2db
         Narrow beam 23db , 26.7db
Power: 15w

Physical Characteristics

Size: 162.6 cm (64 inch) by 162.6 cm (64 inch) by 90.5 cm
          (31.78 inch)
Weight: 31.4 Kg (69 lb) (ant and servo drive only)

References

Technical presentation to MSFC, Huntsville, Ala. Nov. 14, 1969
by Dalmo Victor Company

Design Status

This component was flown as part of the 1972 Apollo-17 mission.

6.1.11   MARINER/MARS 71 S-BAND ANTENNAS SYSTEM

The function of the Antenna Subsystem is to transmit and receive
S-Band signals between the Deep Space Instrumentation facility
and the M71 spacecraft. The Antenna System consists of high,
medium, and low gain antennas. The high gain antenna is a 1.02 m(40
inch) paraboloid having approximately 25 db gain with a right-hand
circularly polarized pattern at 2295 $\pm$5 MHz (transmitter frequency).

The medium-gain element is also a right-hand circularly polarized
radiator with 14 db gain at the operating frequency range of
2115 $\pm$5 (receive) and 2299 $\pm$5 (transmit) MHz.

The low gain element performance is similar except the gain is
reduced to approximately 7 db at the transmit and receive frequency.
All elements are rated at 25 watts continuous wave   input.

Figure 6.1.11-1 illustrates the relationship of the three antennas
to their function.

TRANSMITTING ANTENNA

TRANSMITTING AND RECEIVING ANTENNAS

HIGH GAIN ANTENNA

LOW GAIN ANTENNA

MEDIUM GAIN ANTENNA

UMBILICAL COUPLER PROBE

DIRECTIONAL COUPLER

RF SWITCH ASSEMBLY

DIPLEXER SUBASSEMBLY

RFS
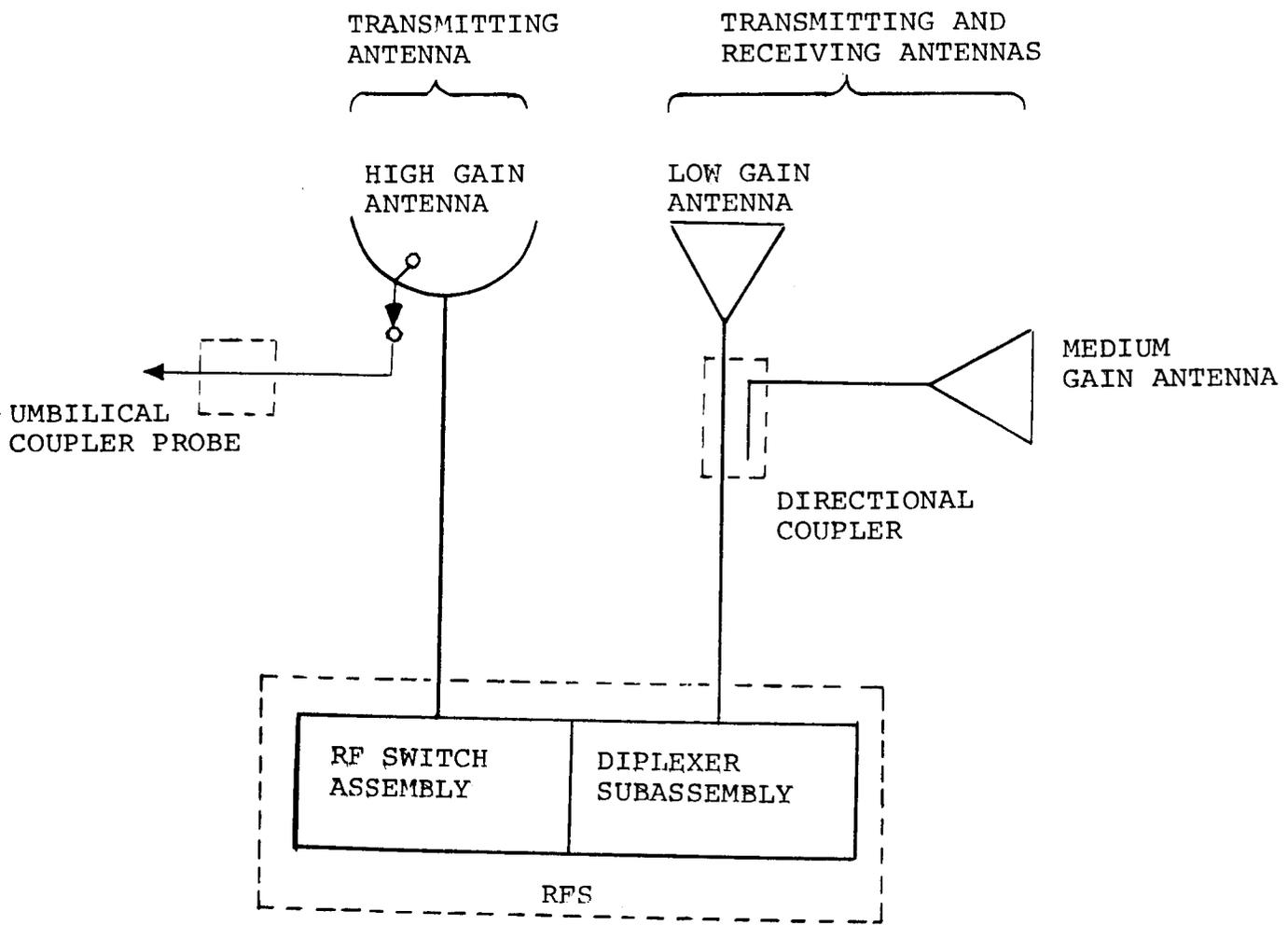
S-BAND ANTENNAS

Figure 6.1.11-1

6.1.11-1   MARINER/MARS MEDIUM GAIN ANTENNA

General Description

Program: Mariner/Mars 71
Vendor: Philco/Ford
Part Number: 17MG1

Performance Characteristics

Type: Horn
Frequency: Transmit 2295 $\pm$5 MHz; Receive 2115 $\pm$5 MHz
Beamwidth: 39 $\pm$2°
VSWR: 1.3:1
Polarization: Right-hand circular
Gain: 14db at 2295 $\pm$5 MHz and 13.5db at 2115 $\pm$5 MHz
Bandwidth: 200 MHz
Power: 25w

Physical Characteristics

Size: Cylindrical section 10.2 cm (4 inch) diameter by 30.5 cm
         (12 inch) long and a truncated cone aperture approximately
         23.5 cm (9.5 inch) diameter by 22.9 cm (9 inch) long
Weight: 0.91 Kg (2.0 lbs)

References

Jet Propulsion Laboratory Document No. M71-4-2017, "Functional
Requirement Mariner Mars 1971 Spacecraft Flight Equipment S-Band
Antenna Subsystem", 17 July 1969.

Design Status

This component was flown as part of the 1971 Mariner Mars mission.

6.1.11-2   MARINER/MARS LOW GAIN ANTENNA

General Description

Program: Mariner/Mars 71
Vendor: Philco/Ford
Part Number: 17LG1

Performance Characteristics

Type: Open-ended circular monoguide
Frequency: Transmit 2295 ±5 MHz; Receive 2115 ±5 MHz
VSWR: 1.3:1
Polarization: Right-hand circular
Gain: 7.0db at 2115 ±5 MHz and 7.25db at 2295 ±5 MHz
Bandwidth: 200 MHz
Power: 25w

Physical Characteristics

Size: 27.9 cm (11 inch) diameter by 15.2 cm (6 inch) long
Weight: 2.085 Kg (2.6 lbs)

References

Jet Propulsion Laboratories Document No. M71-4-2017, "Functional
Requirement Mariner Mars 1971 Spacecraft Flight Equipment
S-Band Antenna Subsystem", 17 July 1969.

Design Status

This component was flown as part of the 1971 Mariner Mars mission.

6.1.11-3 MARINER/MARS HIGH GAIN ANTENNA ASSEMBLY

General Description

Program: Mariner/Mars 71
Vendor: Philco/Ford
Part Number: 17HG1

Performance Characteristics

Type: Parabolic reflector
Frequency: 2295 +5 MHz
Bandwidth: 10 MHz
Beamwidth: 4.5 +0.3 degrees
VSWR: 1.2:1
Polarization: Right-hand circular pattern
Gain: 25.6db
Power Handling: 25 watts of cw power

Physical Characteristics

Size: 1.02 m (40 inches) diameter
Weight: 2.4 Kg (5.2 lbs)

References

Jet Propulsion Laboratories Document No. M71-4-2017, "Functional
Requirement Mariner Mars 1971 Spacecraft Flight Equipment
S-Band Antenna Subsystem", 17 July 1969.

Design Status

This component was flown as part of the 1971 Mariner Mars mission.

6.2.5   VIKING ORBITER UHF ANTENNA

The Relay Antenna Subsystem consists of one low gain conical-log-spiral antenna mounted over a ground plane plus the necessary RF transmission lines and associated connectors. The antenna is used to receive signals from the Viking Lander at a frequency of 380.963 +5% MHz.

The radiation pattern is circularly symmetrical with the relative gain (db down from peak) as a function of antenna cone angle greater than that shown in Figure 6.2.5-1.
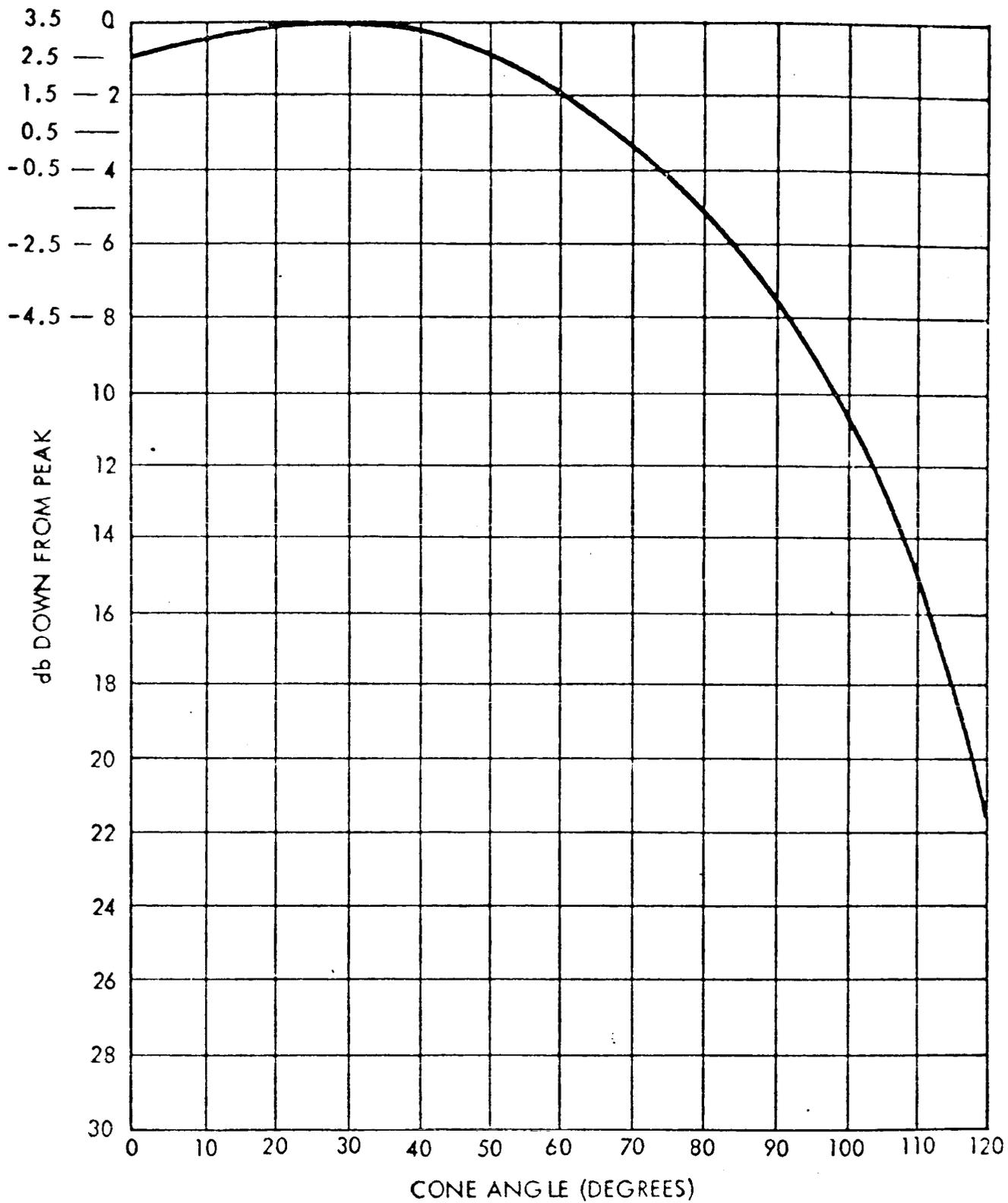
FREE SPACE RELAY ANTENNA RADIATION PATTERN
(FREQUENCY 380.963 ±5% MHz)

Figure 6.2.5-1

6.2.5   CONICAL-LOG-SPIRAL ANTENNA

General Description

Program: Viking Orbiter 75
Vendor:
Part Number: 67LG1

Performance Characteristics

Frequency: 380.963 +5% MHz
VSWR: <1.2:1.0
Axial Ratio: <3.0db @ 0°, 30°, & 60° cone angle
              <7.0db @ 90° cone angle
Gain: >2.5db on boresite axis relative to RHC Isotropic
         Radiator
Power Rating: Up to 60 watts
Radiation Pattern: Circularly symmetrical

Physical Characteristics

Size: 50.8 cm (20 inch) cone on 76.2 cm (30 inch) diameter
         ground plane
Weight: 1.5 Kg (3.3 lbs)

References

"Viking Orbiter 1975 Flight Equipment, Relay Antenna Subsystem",
Des. Req. V075-2067-1, 4 April 1972.

Design Status

This component is scheduled to be flown as part of the planned
1975 Viking Orbiter mission.

6.2.6   OAO-C UHF ANTENNAS

Each UHF antenna is essentially a bent double, folded monopole consisting of three elements formed in the shape of a pitchfork (Figure 6.2.6-1). The antenna is fed from a 50 ohm line through the center element. To obtain the 50 ohm impedance, the pitchfork antenna uses two shorted elements and one driven element and is positioned 5.48 cm (2 5/32 inches) above the ground plane. At resonance, the impedance is 50 ohms. The pitchfork antenna length is approximately 20.3 cm (8 inches). The antenna radiation cordinate system is shown in Figure (6.2.6-2.)

The antenna is fabricated from aluminum and sprayed with a thermal control coating. The antenna's "L" shaped element is mounted on a small aluminum ground plane, bolted to the skin of the spacecraft on Bays A and E. The outer edge of the "L" shaped elements is supported by a fiberglass piece to prevent breakage during launch.
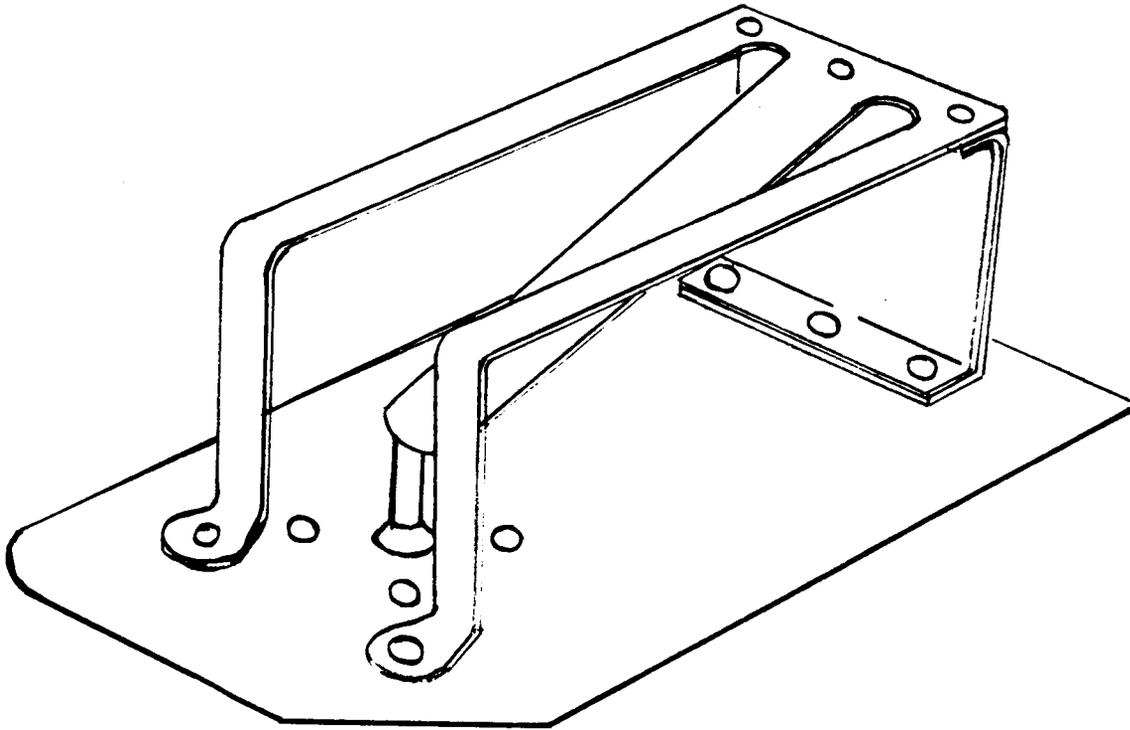
OAO-C UHF PITCHFORK ANTENNA

Figure 6.2.6-1
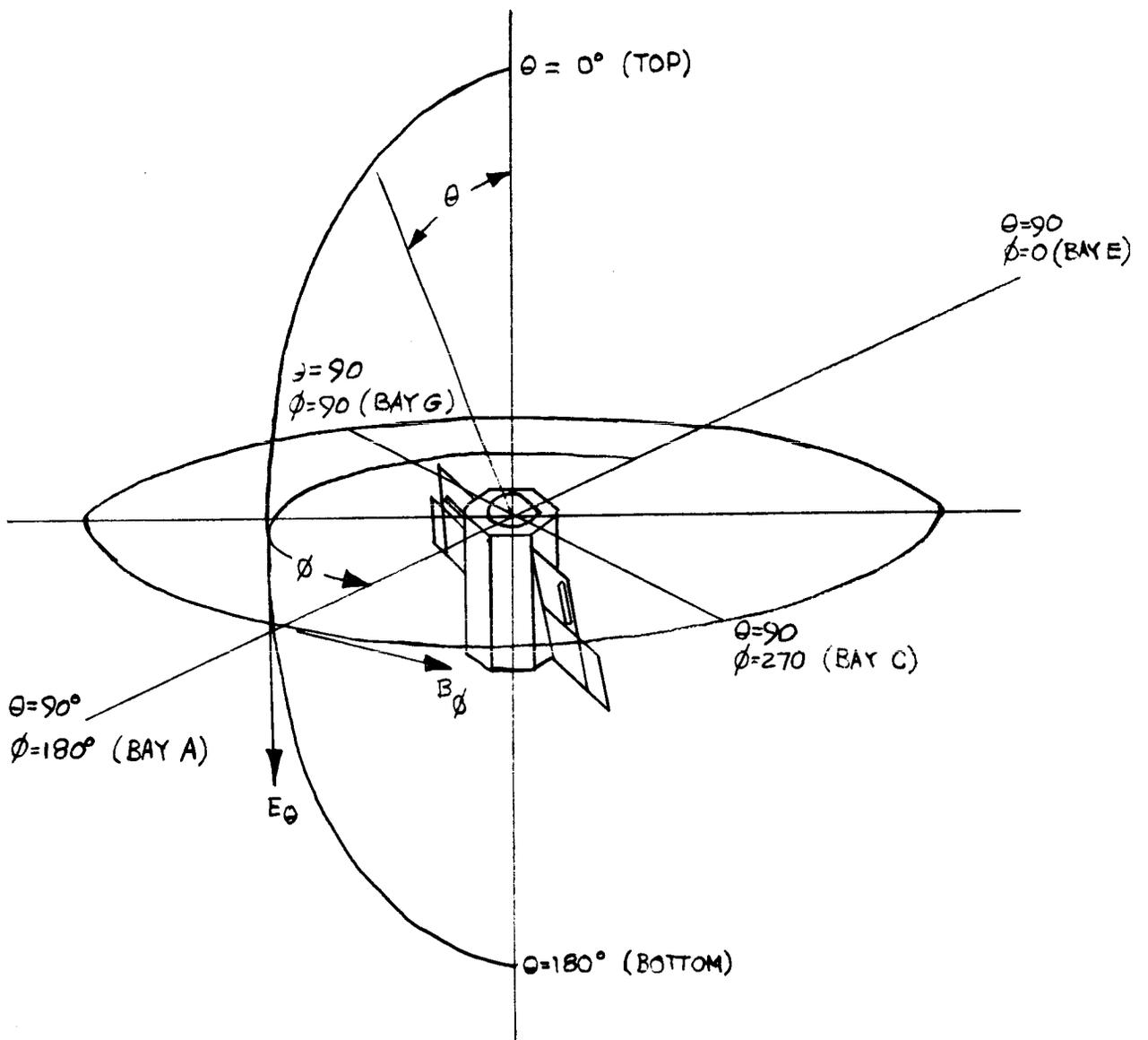
Figure 6.2.6-2   OAO RADIATION COORDINATE SYSTEM

6.2.6-1 UHF ANTENNA

General Description

Program: OAO
Vendor: Grumman
Part Number: 252AR10012

Performance Characteristics

Impedance: 50 ohms nominal
Power Rating: 5 watts average
Frequency: 400.55 MHz
Type: Pitchfork
Radiation Pattern: 2 used to obtain omnidirectional pattern
Gain: 12 db below isotropic for 90% of sphere
Polarization: Linearly polarized in direction of prongs
VSWR: 1.2:1

Physical Characteristics

Size:
Weight: .2Kg (.40 lbs)

References

"OAO Spacecraft System Design Manual", Grumman Aircraft
Engineering Corporation, Revision B, 1968.

"VHF and UHF Antenna Sets Communications Subsystem OAO
Spec No. AV-252CS-85", Grumman Aircraft Engineering Corp
29 Feb. 1968.

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.2.6-2 OAO-C HYBRID JUNCTION (UHF AND VHF)

The hybrid junctions are miniaturized coaxial transmission
line devices. The design and construction is such that a
99.97% probability of operation within the performance require-
ments is achieved during the launch and one year orbital lifetime.

Both hybrid junctions (UHF and VHF) perform the same functions.
Signals fed into each of the two input ports are equally
divided to provide two outputs. Isolation between the two input
signals is also provided by this component.

6.2.6-2 HYBRID JUNCTION (UHF)

General Description

Program: OAO
Vendor:
Part Number:

Performance Characteristics

Power Rating:
a)   Port 1 to Port 3 & Port 1 to Port 4
     15 watts cw power at 400.55 MHz +12.0 KHz
b)   Port 2 to Port 3 & Port 2 to Port 4
     15 watts cw power at 400.55 MHz +12.0 KHz
RF Impedance: 50 ohms (all terminals)
VSWR: Measured with all other ports terminated in 50 ohm load.
a)   Port 1, 1.15:1 at 400.55 MHz
b)   Port 2, 1.15:1 at 400.55 MHz
c)   Port 3, 1.15:1 at 400.55 MHz
d)   Port 4, 1.15:1 at 400.55 MHz
RF Insertion Loss: All other ports terminated in matched
                      50 ohm load.
a)   Port 1 to Port 3 average of the two insertion losses
     Port 1 to Port 4 shall be 3.2 db* maximum at 400.55 MHz
b)   Port 2 to Port 3 average of the two insertion losses
     Port 2 to Port 4 shall be 3.2 db* maximum at 400.55 MHz

*NOTE: This limit, 3.2 db, includes the inherent power
        split required in providing two outputs.
RF Isolation: The r-f isolation requirements, with all other
                 ports terminated in a matched 50 ohm load,
                 shall be 30 db minimum at 400.55 MHz between
                 the following ports:
a)   Port 1 to Port 2
b)   Port 3 to Port 4

Physical Characteristics

Size:
Weight: Less than 1.3 pounds

References

Hybrid Junction (UHF and VHF) Communications and Antennas
Subsystem Orbiting Astronomical Observatory, Specification
for, AV-252CS-36B, 22 August 1965 (Amendment 1 dated 10 Nov 1967)

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.2.7-1   AM COMMAND ANTENNA

General Description

Program: Airlock Module
Vendor: McDonald-Douglas
Part Number: 61A84003 (2 each)

Performance Characteristics

Type: Discone
Frequency: 440 to 460 MHz
Bandwidth: 20 MHz
Beamwidth: Omnidirectional
VSWR: 2.0:1
Polarization: Linear
Gain: -14dbi over 90% of 4 Pi steradians (individual antenna
         coverage)
         -14dbi over 97% of 4 Pi steradians (2 antennas coverage)

Physical Characteristics

Size: 46.8 cm (18.4 inch) by 38.1 cm (15.0 inch) diameter
Weight: 0.680 Kg (24 oz)

References

"Engineering Data and Analysis, Skylab Antenna Coverage Handbook",
ED-2002-1120, Rev. D, Contract NAS8-24000, November 1972.

Comments

The discone antenna system is a pair of boom mounted antennas each
on a 10.3 m (33 ft. 9 in.) boom (orthogonally mounted) it has
coverage as specified under the "gain" parameter above when the
antennas are deployed.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.2.7-2   UHF STUB ANTENNA

General Description

Program: Airlock Module
Vendor:
Part Number: 52-85121

Performance Characteristics

Power Rating: 10 watt maximum (launch) 50 watt maximum (in orbit)
Frequency: 230.4 to 246.3 MHz (3:1 VSWR), 450 MHz (5:1 VSWR)
Gain: 2db
Polarization: Linear
Beamwidth: 78 degrees

Physical Characteristics

Size: 2.54 cm (1 inch) by 31.5 cm (12.4 inch)
Weight: 0.906 Kg (2.0 lbs)

References

"Airlock Critical Design Review", Skylab Program Operational
Data Book (MSC-01549)

Design Status

This component was flown as part of the 1973 Skylab mission.

6.2.7-3   AM COMMAND ANTENNA

General Description

Program: Airlock Module
Vendor: McDonald-Douglas
Part Number: 61A840092 (2 each)

Performance Characteristics

Type: Stub
Frequency: 440 to 460 MHz
Bandwidth: 20 MHz
Beamwidth: Omnidirectional
VSWR: 1.5:1
Polarization: Linear
Gain: -14dbi over 80% of 4 Pi steradians (orbit configuration)
           -14dbi over 75% of 4 Pi steradians (launch configuration)

Physical Characteristics

Size: 36.3 cm (14.27 inch) by 3.18 cm (1.25 inch) diameter stub
Weight: 0.227 Kg (8 oz)

References

"Engineering Data and Analysis, Skylab Antenna Coverage Handbook",
ED-2002-112, Rev. D, Contract NAS8-24000, November 1972.

Comments

The stub antenna system consists of a launch configuration stub
(used during launch) and an orbit configuration stub (used during
orbit in conjunction with the discone antennas).

The combined discone/stub antenna gain is -14dbi over 98% of 4 Pi
steradians.

These same boom mounted discone antennas are used for telemetry.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.2.8-1   COMMAND ANTENNA

General Description

Program: ATM
Vendor:
Part Number: 50M73458

Performance Characteristics

Type: Dipole
Frequency: 440 to 460 MHz
Bandwidth: 20 MHz
Beamwidth: omni
VSWR: 1.25:1
Polarization: Linear
Gain (System):   -6dbi, 82% 4 Pi Steradian

Physical Characteristics

Size: 23.2 cm (9.3 inch) by 25 cm (10.3 inch) by 2.5 cm (1 inch)
Weight: 11.4   Kg (25 lbs) with antenna panel

Environment: MSFC spec 50M04664 A13

References

"Engineering Data and Analysis, Skylab Coverage Handbook",
ED-2002-1120, Rev. D, Contract NAS8-24066, November 1972.

"ATM Hardware Integrity Review", Delivery of ATM Antenna
System Components by S&E-ASTR-IRD for S&E-ASTR-BA, 29 March 1973.

Comments

Antennas arranged such that their electric vectors are orthogonal.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.2.8-2   COMMAND ANTENNA

General Description

Program: ATM
Vendor:
Part Number: 50M16490

Performance Characteristics

Type: Dipole
Frequency Range: 440 to 460 MHz
Bandwidth: 20 MHz
Beamwidth: omni
VSWR: 1.3:1
Polarization: Linear
Gain: -6dbi over 82% of 4 Pi steradian (subsystem coverage)

Physical Characteristics

Size: 3.81 cm (1.5 inch) by 40.7 cm (16 inch) by 2.54 cm (1 inch)
Weight: 0.425 Kg (15 oz)

Environment: Test spec 50M16785A A/B

References

"Engineering Data and Analysis, Skylab Antenna Coverage Handbook",
ED-2002-1120, Rev. D, Contract NAS8-24000, November 1972.

"ATM Hardware Integrity Review", Delivery of ATM Antenna System
Components by S&E-ASTR-IRA for S&E-ASTR-BA, 29 March 1973.

Comments

Antennas are arranged such that their electric vectors are
orthogonal.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.2.8-3   ATM COMMAND ANTENNA (MODEL 316)

General Description

Program: ATM
Vendor:
Part Number: 50M73458

Performance Characteristics

Type: Half-wave dipole, edge mounted
Frequency Range: 440 to 460 MHz
Bandwidth: 20 MHz
Beamwidth: Omnidirectional
VSWR: 1.25:1
Polarization: Linear
Gain: -6 dbi over 77% of 4 Pi steradians

Physical Characteristics

Dimension: 28.6 cm (9.3inch) by 25.9 cm (10.24 inch) by
               2.54 cm (1.0 inch)
Weight: 0.425 Kg (15 ounces)

References

Skylab Program Operational Data Book, MSC-01549
Volume IV Rev A (Amended 04/17/73)

Design Status

This component was flown as part of the 1973 Skylab mission.

6.2.8-4   ATM COMMAND ANTENNA (MODEL 356)

General Description

Program: ATM
Vendor:
Part Number: 50M16490

Performance Characteristics

Type: Half-wave dipole
Frequency Range: 440 to 460 MHz
Bandwidth: 20 MHz
Beamwidth: Omnidirectional
VSWR: 1.25:1
Polarization: Linear
Gain: -6 dbi over 80% of 4 Pi steradians

Physical Characteristics

Dimension: 29.2 cm (11.5 inch) by 40.6 cm (16.0 inch)
             by 2.54 cm (1.0 inch)
Weight: 0.425 Kg (15 ounces)

References

Skylab Program Operational Data Book, MSC-01549
Volume IV Rev A (Amended 04/17/73)

Design Status

This component was flown as part of the 1973 Skylab mission.

6.3.1   ATS OMNI ANTENNA SYSTEM

The antenna system consists of two (7921784) antennas mounted
180° apart on the ATS. Each antenna (Figure 6.3.1-1) consists
of two orthogonal metallic radiating elements mounted at right
angles to each other on a potted assembly containing the
matching and phasing network. The operating frequency range
of the antenna system is from 136 to 155 MHz. The antenna
system coverage is based on the use of best antenna look angle
and best of the four polarizations.
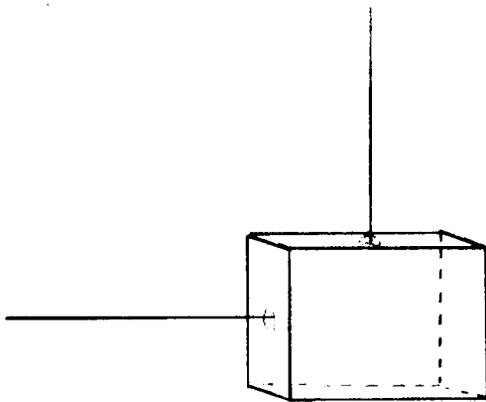
Figure 6.3.1-1.   OMNI ANTENNA

6.3.1   ATS T&C OMNIDIRECTIONAL ANTENNA SYSTEM

General Description

Program: ATS
Vendor: IBM
Part Number: 7921777

Performance Characteristics

Type: Crossed monopole
Frequency: 136 to 154 MHz
Bandwidth: 18 MHz
Beamwidth: Omnidirectional
VSWR: 2.0:1
Polarization: Right hand circular
Gain: -6dbi over 90% of 4 pi steradians (2 antenna coverage, launch configuration)
           -6dbi over 99% of 4 pi steradians (2 antenna coverage, orbit configuration)

Physical Characteristics

Size: 56.34 cm (22.34 inch) by 42.52 cm (16.74 inch) by 2.54 cm (1.0 inch)
Weight: 0.215 Kg (7.6 oz)

References

ATS VHF Omni Antenna Pattern Test Report, ATS-71-7-24, 12 July 1971.

Comments

This is a 2 antenna system and coverage is based on use of best antenna and the best of four polarizations - Horizontal, Vertical, RHC and LHC polarizations.

Design Status

This component is scheduled to be flown as part of the planned mid-1974 ATS-F mission.

6.3.1   ATS T&C OMNI ANTENNA SYSTEM

General Description

Program: ATS
Vendor: IBM
Part Number: 7921784

Performance Characteristics

Type: Crossed monopole
Frequency Range: 136 to 155 MHz
Bandwidth: 19 MHz
Beamwidth: Omni Directional
VSWR: 1.5:1 from 136.23 to 137.11 MHz; 2.0:1 from
         148.26 to 154.2 MHz
Polarization: Right hand circular
Gain: -6 dbi over 90% of 4 Pi steradians (2 antenna coverage,
         launch configuration)
         -6 dbi over 99% of 4 Pi steradians (2 antenna coverage,
         orbit configuration)

Physical Characteristics

Size: 56.34 cm (22.34 inch) by 42.52 cm (16.74 inch) by
         2.54 cm (1.0 inch)
Weight: 28 kg (10 ozs max)
Input Power: Up to 10 watts average

References

ATS VHF Omni Antenna Pattern Test Report
ATS-71-7-24
July 12, 1971

Design Status

This component is scheduled to be flown as part of the planned
mid-1974 ATS-F mission.

6.3.4-1 OSO-I VHF ANTENNA

General Description

Program: OSO-I
Vendor: Hughes
Part Number: 3280661-100

Performance Characteristics

Type: Array (8 whips)
Frequency: Command 149.520 MHz, telemetry 136.290 MHz
              to 136.920 MHz
Bandwidth: 13.23 MHz
Beamwidth: Omnidirectional
VSWR: 1.4:1
Polarization: Right hand circular or left hand circular
Gain: (Command) -13dbi over 97% of 4 Pi steradians
         (Telemetry) -6dbi over 95% of 4 Pi steradians

Physical Characteristics

Size: Length (each whip) 50.8 cm (20 inch)
         Diameter (each whip) 0.3175 cm (0.125 inch)
Weight: 0.794 Kg (1.75 lbs)

Environment: Hughes spec SS31331-003

References

Development Specification (Hughes), DS-31331-166

Comments

The VHF antenna consists of an array of 8 whips fed by a dual
hybrid balun so as to provide two elliptically polarized signals.
At any given time one output is predominantly left hand circularly
polarized and the other is predominantly right hand circularly
polarized.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

6.3.4-2 OSO-I DIPLEXER

The OSO-I diplexer is a 50 ohm impedance passive device containing
a transmitter-to-antenna filter and a receiver-to-antenna filter.
The transmitter-to-antenna filter is tuned to reject the received
frequency and pass the transmit frequency with minimum attenua-
tion. The receiver-to-antenna filter is tuned to reject the
transient frequency and pass the received frequency with minimum
attenuation.

6.3.4-2 OSO-I DIPLEXER

General Description

Program: OSO-I
Vendor: Hughes
Part Number: 3280635-100

Performance Characteristics

Receive-Transmit operating frequencies:

Observatory	Receiver Carrier Frequency, MHz	Transmitter Carrier Frequency, MHz
OSO-I	149.520	136.920

Insertion Loss (± 50 KHz bandwidth)

Direction	Carrier Frequency	Max. Insertion Loss, db
Antenna port to receiver port	Receiver	1.0
Transmitter port to antenna port	Transmitter	1.5

Isolation (± 50 KHz bandwidth)

Direction	Frequency Carrier	Minimum Required Isolation, dB
Transmitter port to receiver port	Receiver	50
Transmitter port to receiver port	Transmitter	60
Antenna port to transmitter port	Transmitter	15
Antenna port to receiver port	Transmitter	60

Input/Output Impedance: 50 ohm with max. VSWR 1.5:1.0, all ports.
Maximum Power: Transmit: 33dbm (2 watts) at transmit frequency
                   Receive: 6dbm (4 min) at receive frequency
Magnetic Interference: 0.5 gauss emanating at surface enclosure

Physical Characteristics

Size: 15 cm (5.9 in) by 8.1 cm (3.2 in) by 2.5 cm (1 in)
Weight: 0.3 kg (0.55 lbs)

Environment: Hughes Spec SS31331-003

Reference

Development Specification for Diplexer HAC PN 3280635-100,
DS31331-198, 11 December 1972, Rev A.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

6.3.6 -1 VHF ANTENNAS (OAO-C)

The VHF antennas consist of two half-wave length, thin rectangular slots cut in the OAO solar paddle arrays as shown in Figure 6.3.6-1. Each slot is fed at a point off center and has a series capacitive matching stub at the feed point resulting in a nominal 50 ohm radiation impedance.

The slots are 95.25 cm (37.5 inches) long to accommodate the Command Receiver Equipment (CRE) frequency of 148.26 MHz, the Radio Tracking Beacon (RTB) frequency of 136.44 MHz and the Narrow-Band Transmitter (NBT) frequency of 136.26 MHz. One of the VHF antennas has been matched with a 50.8 cm (20 inch) series shorted stub, and the other antenna has been matched with a 91.4 cm (36 inches) series open stub. Since both stubs are capacitive in nature, the use of series open versus series shorted to match the antenna depended on the impedances of the slots at 136 and 148 MHz. The stub that best provided impedance of 1.2 to 1 or better was used. The slot fed location is adjustable +1.27 cm (+1/2 inch) so that the antennas may be trimmed up after installation on the spacecraft.

Antenna gain shall be greater than 12db below isotropic for at least 90% of the total solid angle about the antenna (4 pi steradians) when polarization diversity is used.
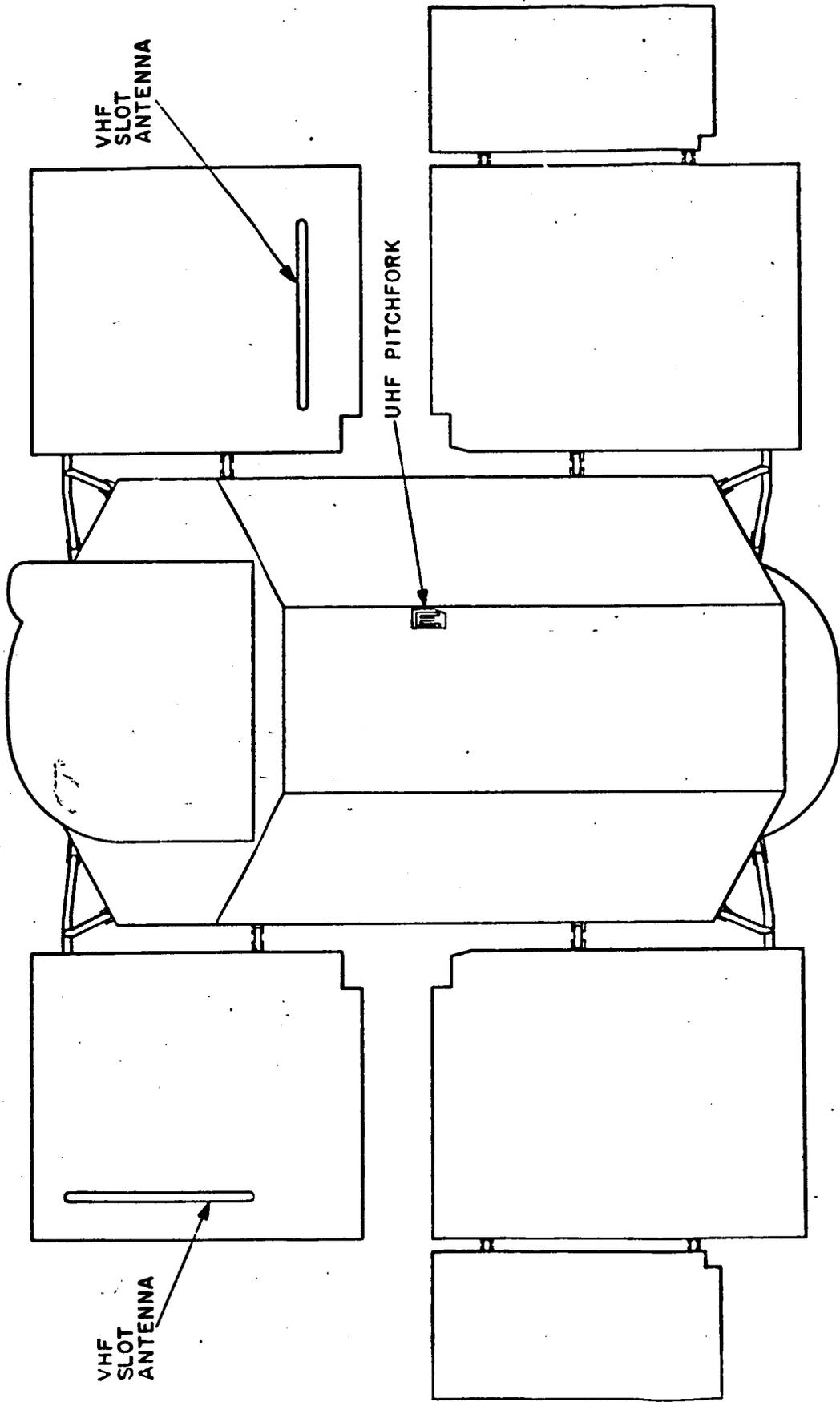
OAO-C ANTENNA LOCATION

Figure 6.3.6-1

6.3.6-1   VHF ANTENNA

General Description

Program: OAO-C
Vendor:
Part Number:

Performance Characteristics

Power Rating: 1.6 watts
Frequency: 136.26, 136.44, 148.26 MHz (Max VSWR of 1.5:1)
Type: Half wave length slots
Radiation Pattern: Omnidirectional
Gain: 12db below isotropic for 90% of sphere
Polarization: Linearly polarized in direction perpendicular
                 to direction of slot
Impedance: 50 ohms

Physical Characteristics

Size: 92.25 cm (37.5 inch) long slot
Weight:

References

"OAO Spacecraft System Design Manual", Grumman Aircraft
Engineering Corporation, Revision B, 1968.

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.3.6-2   OAO-C DIPLEXER

The OAO-C diplexer is a unit of the communication and antennas subsystem. It is a miniaturized, coaxial transmission line device which provides isolation between the received VHF command signal and the transmitted VHF telemetry and radio tracking beacon signals.

The diplexer design and construction is such that a 99.9% probability of operation within the specified performance requirements should be achieved during the launch and one year orbital lifetime of the OAO.

6.3.6-2   OAO-C DIPLEXER

General Description

Program: OAO-C
Vendor:
Part Number:

Performance Characteristics

Frequency pass bands & input power:

   a) Port 1 to port 3:   149.520 MHz $\pm$20 KHz, 0.001 watts cw power.

   b) Port 2 to port 3:   136.260 MHz $\pm$4.1 KHz, 1.6 watts cw power;
      and 136.440 MHz $\pm$4.1 KHz, 0.3 watts cw power

R-F Impedances: The nominal impedances at all terminals (ports)
shall be 50 ohms.

VSWR: The following maximum r-f input VSWR's shall be measured
with the unused ports terminated in a matched 50 ohm load:

   a) Port 1 shall be 1.10:1 at 149.520 MHz $\pm$20 KHz

   b) Port 2 shall be 1.10:1 at 136.260 MHz $\pm$20 KHz
      and 136.440 Mhz $\pm$20 KHz

   c) Port 3 shall be 1.25:1 at 136.260 MHz $\pm$20 KHz,
      136.440 MHz $\pm$20 KHz and 149.520 MHz $\pm$20 KHz

R-F Insertion Loss and Isolation: The r-f insertion losses and
isolation shall be as follows (with the unused port terminated
in a matched 50 ohm load)

   a) Port 1 to port 2:   60 db minimum at 149.520 MHz
      $\pm$20 KHz and 60 db minimum at any frequency within
      the range from 136 - 137 MHz.

   b) Port 1 to port 3:   0.6 db maximum at 149.520 MHz
      $\pm$20 KHz and 60 db minimum at any frequency within
      the range of 136 -137 MHz and 163-401 MHz

   c) Port 2 to port 3:   60 db minimum at 149.520 MHz
      $\pm$20 KHz and 0.6 db maximum at frequencies 136.260 MHz
      $\pm$20 KHz and 136.440 MHz $\pm$20 KHz

Physical Characteristics

Size: NA
Weight: 2 kg (4.5 lbs)
Cooling Method: Passive

References

Diplexer, Communications and Antennas Subsystem, OAO Specifi-
cation for, AV-252CS-35C, 18 August 1965 (Amendment No. 2
20 February 1968)

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.3.6-3 HYBRID JUNCTION (VHF)

General Description

Program: OAO-C
Vendor:
Part Number:

Performance Characteristics

Power Rating:
  a) Port 1 to Port 3 & Port 1 to Port 4
      3.2 watts cw power @ 136.260 MHz +4.1 KHz
  b) Port 2 to Port 3 & Port 2 to Port 4
      0.3 watts cw power @ 136.440 MHz +4.1 KHz
RF Impedance: 50 ohms (All Terminals)
VSWR: Measured with all other ports terminated in 50 ohm load.
  a) Port 1, 1.15;L at 136.260 MHz
  b) Port 2, 1.15:1 at 136.440 MHz
  c) Port 3, 1.15:1 at 136.260 + 136.440 MHz
  d) Port 4, 1.15:1 at 136.260 + 136.440 MHz
RF Insertion Loss: All other ports terminated in matched
                      50 ohm load.
  a) Port 1 to Port 3 average of the two insertion losses
      Port 1 to Port 4 shall be 3.2 db* maximum at 136.260
                       and 136.440 MHz
  b) Port 2 to Port 3 average of the two insertion losses
      Port 2 to Port 4 shall be 3.2 db* maximum at 136.260
                       and 136.440 MHz

  *NOTE: This limit, 3.2 db, includes the inherent power
          split required in providing two outputs.
RF Isolation: The r-f isolation requirements, with all
                 other ports terminated in a matched 50 ohm
                 load, shall be 30 db minimum at 136.260 and 136.440
                 MHz between the following ports:
  a) Port 1 to Port 2
  b) Port 3 to Port 4

Physical Characteristics

Size:
Weight: Less than .6 Kg (1.3 pounds)

References

Hybrid Junction (UHF and VHF) Communications and Antenna Subsystem
Orbiting Astronomical Observatory, Specification for AV-252CS-36B,
22 August 1965 (Amendment 1 dated 10 Nov 1967)

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.3.7   AM VHF RANGING ANTENNA

General Description

Program: AM
Vendor: MacDonald Douglas
Part Number: 61A840083 (1 ea)

Performance Characteristics

Type: 5-turn helix
Frequency Range: 250 to 300 Mhz
Bandwidth: 50 MHz
Beamwidth: 50 degrees
VSWR: 2:1
Polarization: Right-hand circular
Gain: 8 dbi (259.7 MHz), 9 dbi (296.8 MHz)

Physical Characteristics

Size: 81.3 cm (32.0 inch) diameter ground plane 34.5 cm
         (13.6 inch) diameter by 139.7 cm (active element)
         (55.5 inch) long helix
Weight: 6.8 Kg (15 lb.)

References

Engineering Data and Analysis, Skylab Antenna Coverage
Handbook ED2002-1120 Rev D, Contract NAS8-14000

Design Status

This component was flown as part of the 1973 Skylab mission.

6.3.8   ATM VHF TELEMETRY ANTENNAS

The telemetry antennas are half-wave balanced dipoles. They are center fed through a 1/4-wavelength balun transformer. Figure 6.3.8-1 shows the ATM antennas.
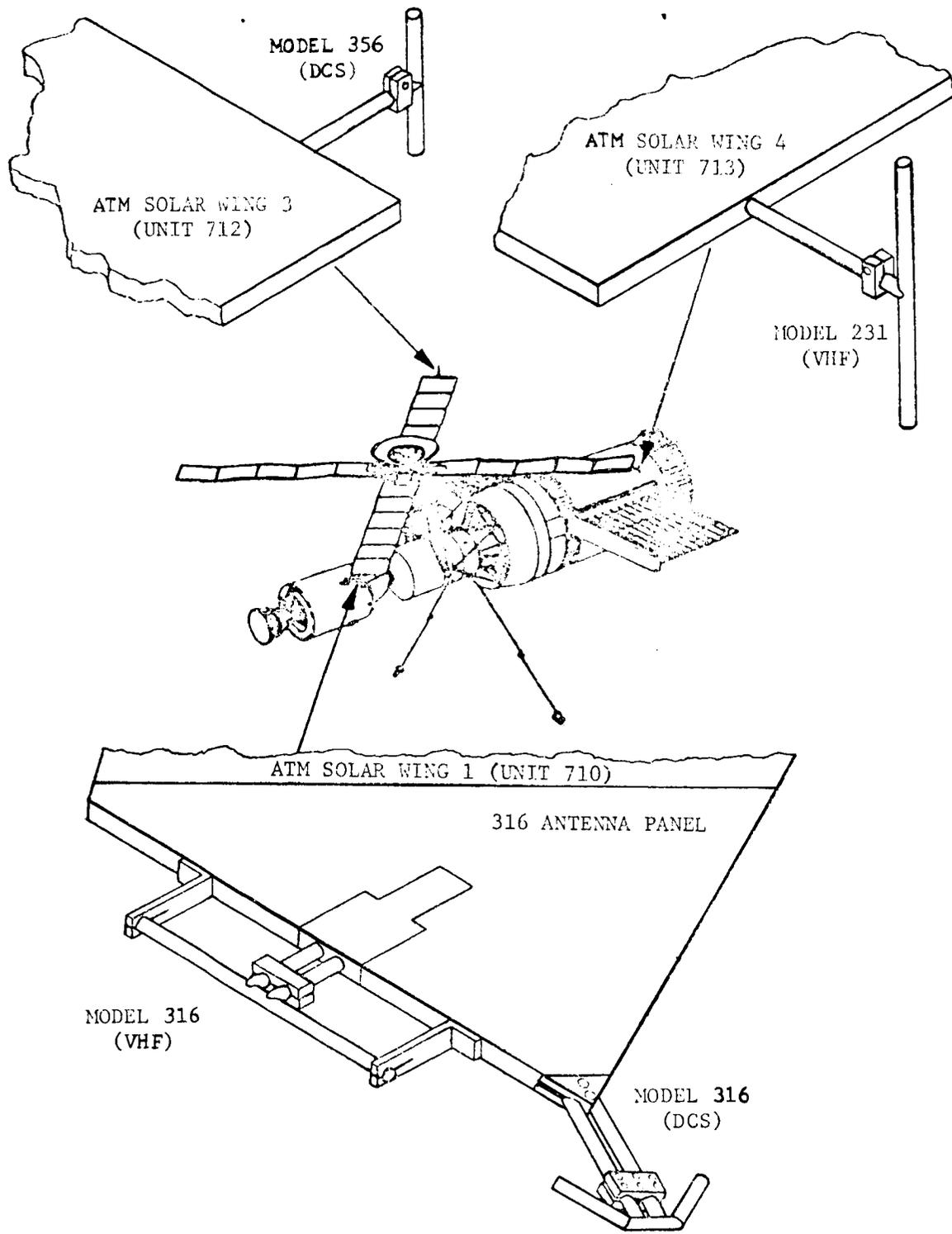
Figure 6.3.8-1   ATM Antennas

6.3.8-1   ATM TELEMETRY ANTENNA

General Description

Program: ATM
Vendor:
Part Number: 50M73507 (1 ea)

Performance Characteristics

Type: Half-wave dipole, edge mounted
Frequency Range: 220 to 245 MHz
Bandwidth: 25 MHz
Beamwidth: Omnidirectional
VSWR: 1.25:1
Polarization: Linear
Gain: -6dbi over 97% of 4 Pi steradians (2 ant system coverage)
Power Rating: 30 w

Physical Characteristics

Size: 53.4 cm (21.0 inch) by 38.1 cm (15.0 inch)
         by 2.54 cm (1.0 inch)
Weight: 11.34 Kg (25 lb) (with 316 antenna panel)

References

Engineering Data and Analysis, Skylab Antenna Coverage Handbook
ED2002-1120 Rev D, Contract NAS8-24000

Design Status

This component was flown as part of the 1973 Skylab mission.

6.3.8-2   ATM TELEMETRY ANTENNA

General Description

Program: ATM
Vendor:
Part Number: 50M12733 (1 ea)

Performance Characteristics

Type: Dipole
Frequency Range: 225 to 245 MHz
Bandwidth: 20 MHz
Beamwidth: Omni
VSWR: 1.25:1
Polarization: Linear
Gain: -6 dbi over 97% of $4 Pi$ steradians (2 ant system
         coverage)
Power Rating: 30 w

Physical Characteristics

Size: 55.6 cm (22.1 inch) by 40.7 cm (16.0 inch)
         by 2.54 cm (1.0 inch)
Weight: 0.544 Kg (1.2 lb)

References

Engineering Data and Analysis, Skylab Antenna Coverage Handbook
ED2002-1120 Rev. D, Contract NAS8-24000.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.3.9   CSM VHF RECOVERY ANTENNA EQUIPMENT

Two VHF recovery antennas, No. 1 and No. 2, are stowed in the forward compartment of the Apollo Spacecraft. Each antenna consists of a quarterwave stub, 28 cm long, and a ground plane. Each is automatically deployed 8 seconds after main parachute deployment, during the descent phase of the mission.

VHF recovery antenna No. 1 is connected to the VHF recovery beacon equipment. VHF recovery antenna No. 2 is used with the VHF/AM transmitter-receiver equipment and is connected to the VHF antenna switch with a coaxial cable. An access hatch is provided to allow either of the VHF recovery antennas to be used with the GFE survival transceiver. This requires that the coaxial cable from one of the antennas be manually disconnected at the triplexer and reconnected to the survival transceiver.

6.4.2 ERTS TELEMETRY TRANSPONDERS

The Unified S-Band Equipment (USBE) (Figure 6.4.2-1) receives and acquires phase lock to an S-Band ground transmission and generates a coherent spacecraft S-Band transmission link. It extracts any command information from the received signal and transfers the information to the command equipment. It also extracts and retransmits any ranging code present in the received signal. In the absence of phase-lock loop acquisition, an S-Band carrier is generated from an auxiliary oscillator.

The USBE consists of two S-Band transmitter/receiver pairs (transponders), the transmit and receive frequencies being 2287.5 MHz and 2106.4 MHz respectively. Each transmitter/ receiver pair normally operates as a separate transponder unit, only one of the two being powered at any given time, but it is possible to cross-strap them by ground command. When cross-strapped, the receiver of one transponder and the transmitter of the other are powered.

The Premodulation Processor (PMP) performs two primary functions. The command subcarrier from either USB receiver is demodulated and sent to the Command Integration Unit. Various combinations of real-time and stored data (telemetry and some payload data) are selected to modulate specified subcarriers or are used directly. All subcarriers and raw data are linearly summed and applied to one of the USB transmitters.

The PMP has two 70 kHz discriminators for demodulation of the command subcarrier. Only one discriminator is powered at all times. (The discriminator powered corresponds to whichever USB receiver is powered.)

The modulation section of the PMP contains two redundant oscillator/ modulator sections. Each oscillator/modulator section will produce a modulating signal consisting of a combination of the following:

1. 1024 kHz from the Data Collection Subsystem receiver.

2. 768 kHz subcarrier oscillator (SCO) phase-shift keyed by PCM output of the telemetry processor.

3. 597 kHz SCO phase-shift keyed by playback of stored telemetry data from any one of either Narrowband Tape Recorder or the auxiliary track of either Wideband Tape Recorder.
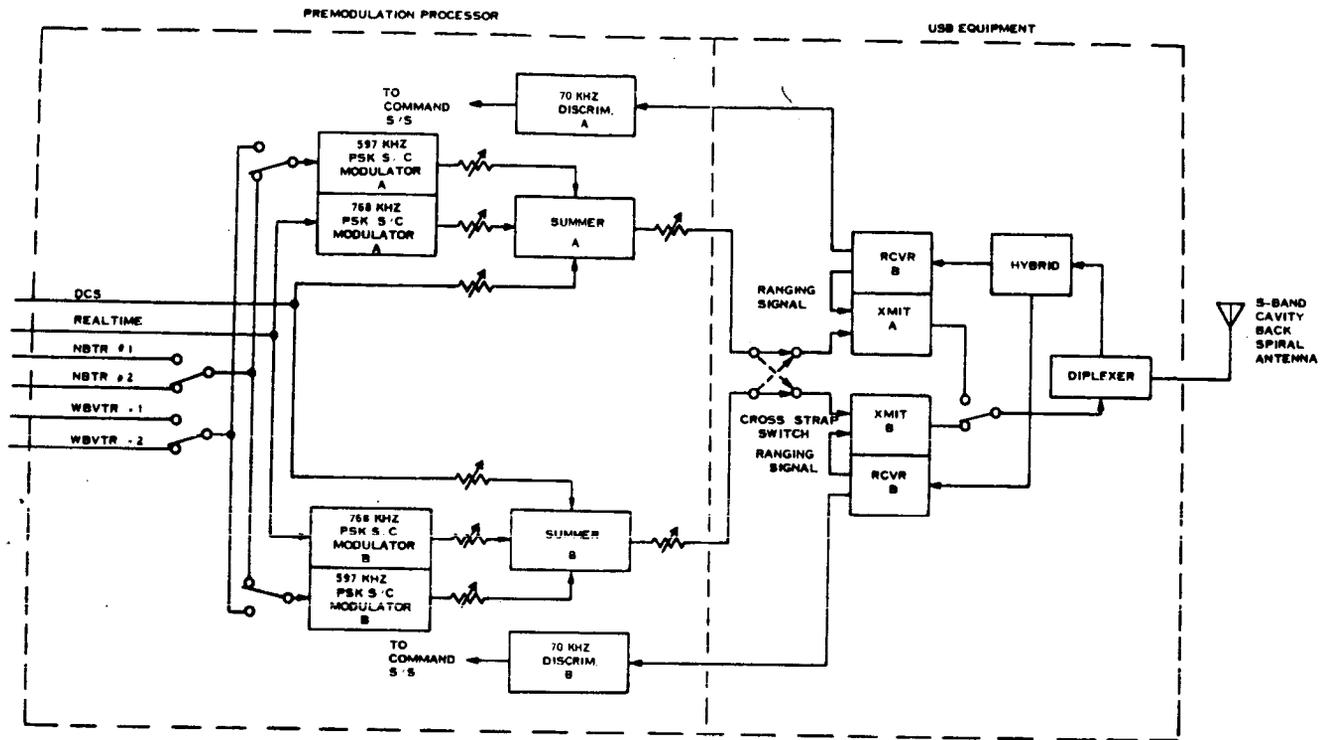
UNIFIED S-BAND BLOCK DIAGRAM

Figure 6.4.2-1

6.4.3   HEAO-A TELEMETRY TRANSPONDERS

Two transponders in the HEAO-A communication subsystem (Figure 6.4.3-1) contain four S-Band coherent communication transmitters. Each transponder contains two redundant transmitters which operate on the same frequency, but not simultaneously. Dual frequency operation from the two transponders over its respective antenna is permitted on assigned downlink frequencies of 2275.0 MHz and 2269.0 MHz.

Each Baseband Assembly Unit receives PRN signals from transponders No. 1 and No. 2 for cross strapping purposes. Commands select the desired Baseband Assembly and configuration for data transmission to the ground. Each Baseband Assembly also receives cross strapped 25.6 KBPS (recorded) tape data, and a 1.024 MHz telemetry subcarrier clock from the Data Handling Subsystem. The Baseband Assembly Unit contains the 1.024 MHz biphase modulation, switches, and scaling circuits for presenting the proper modulation indices. A block diagram of the Baseband Assembly is shown in Figure 6.4.3-2.

A detailed block diagram of the HEAO-A (ERTS type) S-Band transponder is shown in Figure 6.4.3-3. Each transponder transmitter is capable of operating in a non-coherent or coherent mode. In the non-coherent mode, an auxillary crystal oscillator serves as the transmitter local oscillator. In the coherent mode the phase locked VCO (multiplied by 4) in the receiver acts as the transmitter local oscillator. The signal from either of the oscillators is phase modulated by either the turn around PRN range code (from the transponder receiver) or the 512 KBPS tape data and/or the 1.024 MHz telemetry subcarrier (with in 25.6 KBPS PCM/biphase real time telemetry data.)

Amplifiers and multipliers multiply the oscillator frequency (and phase modulator indices) by a factor of 30 (x2, x5 and x3) and a final power amplifier produces a minimum of 0.5 watts (in the low power mode) or 1.5 watts (in the high power mode) at the transponder RF power connector.
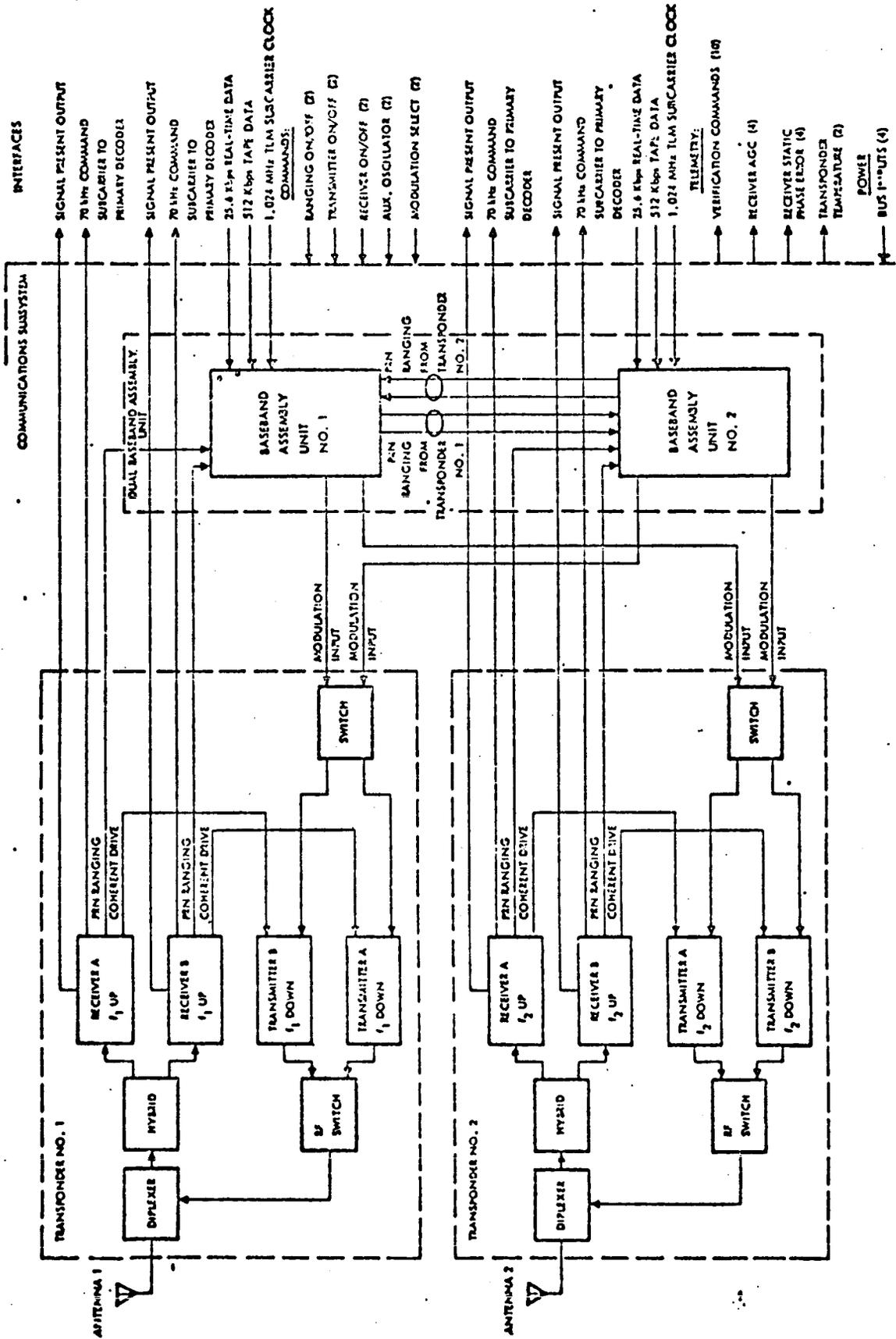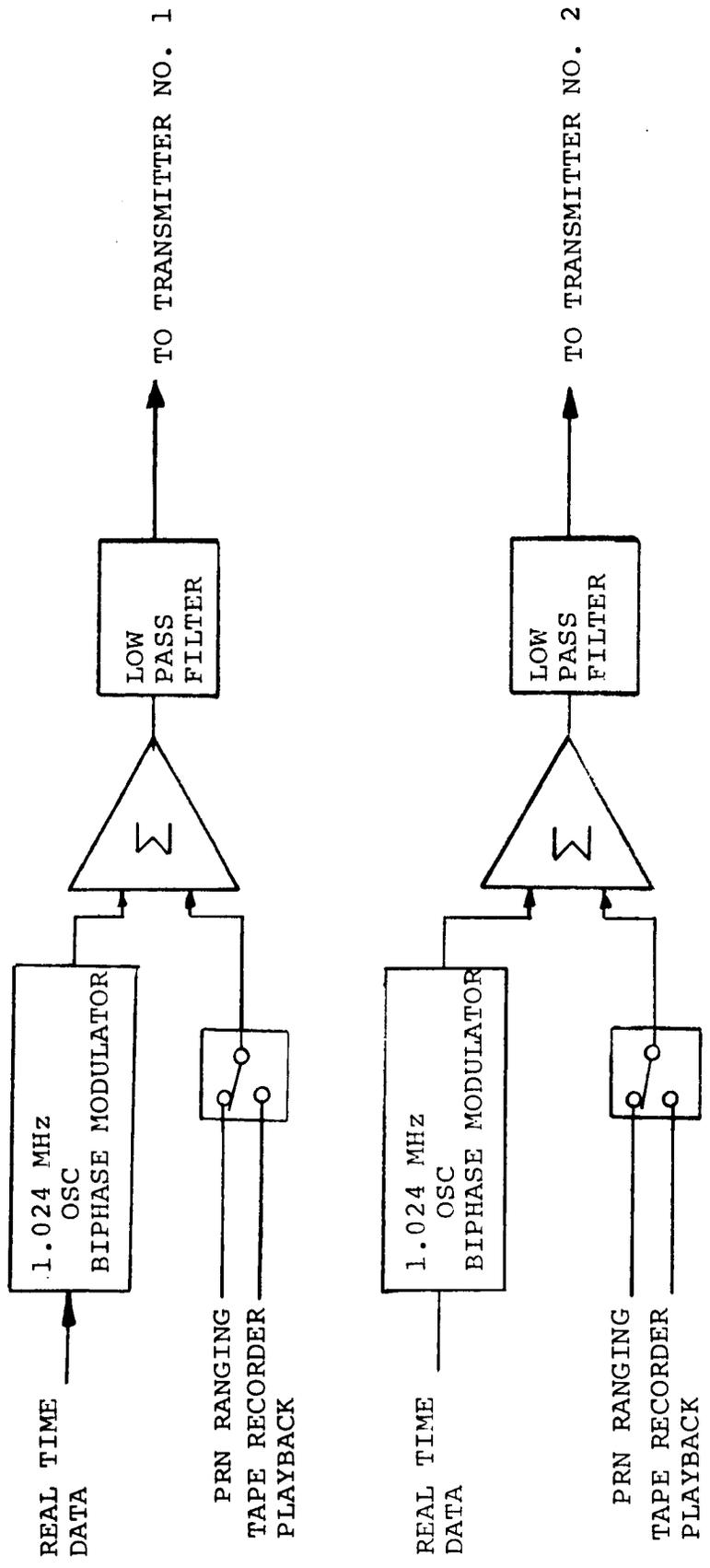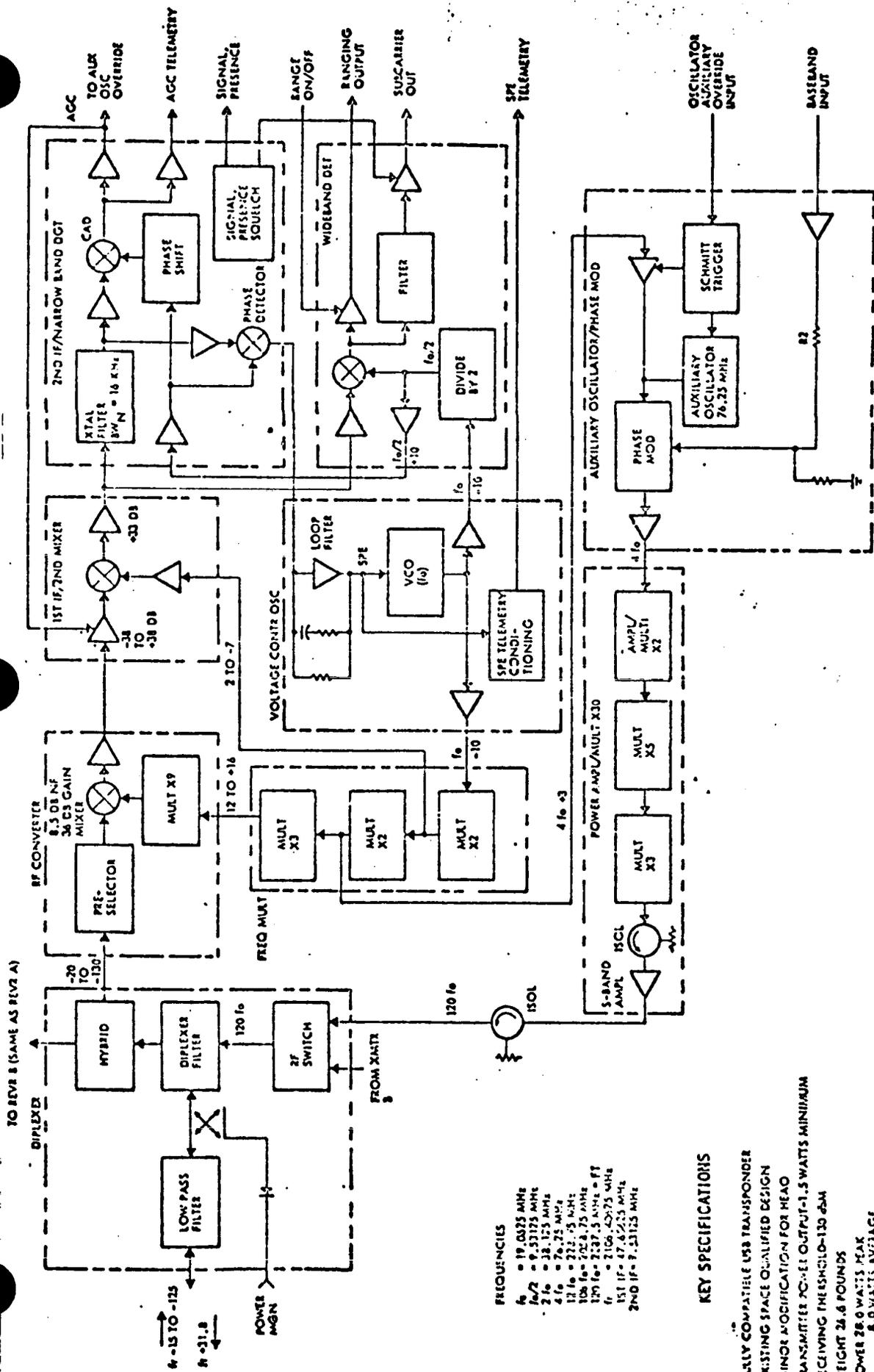
Figure 6.4.3-1. Communications Subsystem Block Diagram (HEAO-A)

DUAL BASEBAND UNIT BLOCK DIAGRAM

Figure 6.4.3-2

Figure 6.4.3-3. HEAO Transponder Block Diagram

6.4.3-1 DUAL S-BAND TRANSPONDER

General Description

Program: HEAO-A
Vendor: Motorola
Part Number:

Performance Characteristics

Input Characteristics
    Noise Figure: 15 db
    Dynamic Range/Threshold: -15 to -125 dbm/-125 dbm
    Frequency: 2089.371 or 2094.894 MHz
    Bandwidth: 16 KHz IF BW
    Modulation: 70 KHz Command FM Subcarrier and PRN ranging
                   code phase modulates carrier
Output Characteristics: Frequency phaselocked to uplink
                           (240/221 turn-around ratio) or generated
                           from auxiliary oscillator in absence of
                           uplink
    Power: 1 watt minimum
    Frequency: 2269 or 2275 MHz
    Modulation: Carrier phase modulated with 1.024 MHz
                   subcarrier and either 512 Kbps wideband
                   data or PRN ranging code.
    Subcarrier Modulation: 25.6 Kbps biphase modulates
                              1.024 MHz subcarrier

Physical Characteristics

Size: 21.8 cm (8.6 in) by 15.2 cm (6 in) by 33.0 cm (13 in)
Weight: 12.0 kg (26.5 lbs) each
Input Power: 23 to 33 Vdc (28.0 watts peak, 8.0 watts aver.)
Cooling Method: Baseplate conduction & radiation

References

"Preliminary Requirements Review Volume III-B Subsystem Require-
ments and Data Communications Subsystem", TRW No. 17622-301-001-001,
TRW Systems Group, Redondo Beach, Cal., 24 July 1972; "HEAO
Phase B Final Report", Volume II, TRW Systems Group, Redondo
Beach, Cal., 23 April 1971.

Comments

The above described Motorola transponder is one of the two
candidate transponder designs being considered for HEAO. The
Atmospheric Explorer/Skylab II (Philco-Ford) transponder is also
being considered.

Design Status

The HEAO-A program is currently in a state of redefinition. This
component is a viable candidate for application in the 1977
HEAO-A mission.

6.4.3-2   BASEBAND ASSEMBLY UNIT

General Description

Program: HEAO-A
Vendor: Dynatronics
Part Number: Spec. No. EQ4-1084

Performance Characteristics

Inputs: 27.5 KHz NRZ-L PCM, 500 Kbps split phase PCM,
            PRN ranging code
Outputs:
    Composition: Composite 27.5 KHz PCM data modulated on
                  1.024 MHz subcarrier and either 500 Kbps
                  wideband tape recorded data or PRN ranging.
    Composite Bandwidth: 1.5 MHz (3 db)

Physical Characteristics

Size: 12.7cm (5 in) by 18.4 cm (7.25 in) by 2.9 cm (1.125 in)
Weight: 0.91 Kg (2 lb)

References

1) "High Energy Astronomy Observatory Phase B Final Report",
    Volume II, TRW Systems Group, April 23, 1973.

2) "High Energy Astronomy Observatory Preliminary Requirements
    Review", Volume III-B, TRW Systems Group, No. 17622-301-001-
    001, July 24, 1972.

Comments

The above described baseband unit is the Phase B selection.
Candidates included in the Phase C study include the SGLS
(Motorola) and the Skynet II (Philco-Ford) baseband units.

Design Status

The HEAO-A program is currently in a state of redefinition. This
component is a viable candidate for application in the 1977
HEAO-A mission.

6.4.4-1   OSO VHF TRANSMITTER

The OSO VHF transmitter performs three major functions: stable carrier generation; phase modulation of the carrier with a split phase PCM (Manchester coded telemetry data) bit stream at a bit rate of 6.4 kilobits/sec; and amplification of the carrier to a 1 watt minimum power level. The unit is capable of being commanded on/off.

The unit accepts PCM bit streams from two separate sources. Only one of these sources will be active at any time. These two sources are logically "ORed" in the unit before the modulator. The phase modulator modulates the VHF RF carrier output with a modulation index over the range of $\beta = 0.8$ to $\beta = 1.5$ while accepting the active PCM signal at the phase modulator input. This phase modulator can be adjusted for a modulation index of 1.44 +10 percent. Modulation components at 50 +5 Hz, 100 +10 and 200 +5 Hz are at least 35 db below the average power output, within a 10 kHz band centered on the carrier.

The power output is 1 to 2 watts while working into a 50 ohm load having a VSWR of 1.5:1 or less. Transmitter frequency is 136,920 MHz.

The transmitter operates with a bandwidth of 30 kHz, transmits with a bit error rate of less than 10^{-6}, and is designed to maintain a frequency stability of +.0015 percent for one year life.

6.4.4-2   S-BAND TRANSMITTER

General Description

Program: OSO-I
Vendor:
Part Number: 3280650-100

Performance Characteristics

Power Output: 1 watt minimum, 2 watts maximum
Carrier Frequency: 2212.5 MHz
Modulation: Split-phase PCM/PSK (Manchester code, 128 Kbps max)
Bandwidth: 1 MHz at 10 db points

Physical Characteristics

Size: 24.4 cm (9.6 inch) by 14.6 cm (5.8 inch) by 7.24 cm (2.85 inch)
Weight: 1.5 Kg (3.3 lbs)
Input Power: 8.0 watt @23 V and 11.5 watt @ 33 V

Environment: Hughes Spec SS31331-003

References

"Data Handling and Telemetry Subsystem Spec" (SS31331-160).

"Development Specification for S-Band Transmitter", (DS31331-194) Hughes Aircraft Co., 7 December 1972.

Design Status

This component is scheduled to be flown as part of the planned 1974 OSO-I mission.

6.4.6-1   OAO WIDE-BAND TELEMETRY TRANSMITTER (WBT)

Two wide-band telemetry transmitters capable of transmitting either digital or analog data are provided in the spacecraft. Figure 6.4.6-1 is a block diagram of the WBT. The digital data can be transmitted in real-time or from storage. Command memory data, data from storage, and experiment digital data are transmitted at a 50 kbs rate as NRZ data. Tape recorder data are transmitted at a 66.6888 kbs rate as split phase data. Digital data from the experimenters' data handling equipment (EDHE) can also be transmitted at a rate of 1.042 kbs NRZ. As back-up, data from either experiment package may be transmitted in real-time as analog data.

Each WBT is a solid-state transmitter, frequency-modulated by the signals above. Nominal power output is 8 watts over the expected temperature range. The transmitter consists of a pre-modulator, which causes frequency variations in the output of the crystal-controlled oscillator. The oscillator operates at approximately 25 MHz. Its signal is amplified and increased by four frequency doublers to provide 10 watts of power at a frequency of 400.550 Mhz. This RF power is reduced to 8 watts by a harmonic filter and applied to the UHF hybrid junction. The purpose of the junction is to split the RF power equally between the two UHF antennas. Each antenna is a bent double-folded monopole consisting of three elements formed in the shape of a pitchfork. Each antenna is mounted on a ground plate bolted to the skin of the spacecraft.
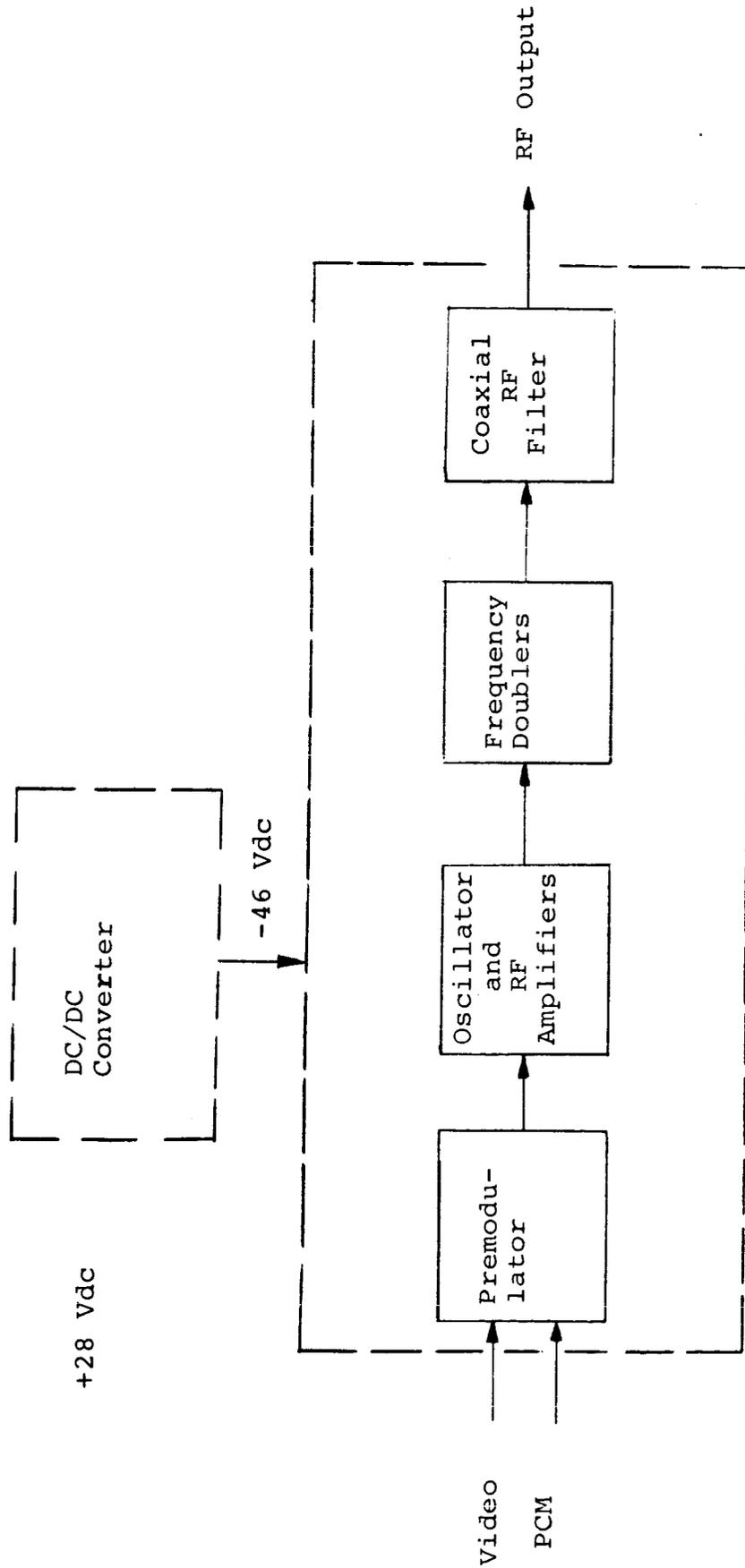
Figure 6.4.6-1   Wide-Band Transmitter Block Diagram

6.4.6-1 OAO WIDEBAND TELEMETRY TRANSMITTER

General Description

Program: OAO-C
Vendor:
Part Number:

Performance Characteristics

Power Output: 8 watts
Carrier Frequency: 400.550 MHz $\pm 0.006\%$
Modulation: FM
Bandwidth: 62.5 kHz

Physical Characteristics

Size: 26 cm (10.25 inch) by 10.1 cm (4 inch) by 5.5 cm
         (2.2 inch)
Weight: 1.59 Kg (3.5 lbs) for transmitter,
           0.91 Kg (2 lbs) for DC-DC converter
Cooling Method: Radiation

References

"OAO Spacecraft System Design Manual", Grumman Aircraft
Engineering Corporation, Revision B, 1968.

"Wideband Transmitter Performance and Interface Spec (SYS-252PI-1A)",
Revision A, 13 January 1969, Grumman Aircraft Engineering Corporation.

"Wideband Telemetry Transmitter - Solid State Communications and
Antennas Subsystem Orbiting Astronomical Observatory (Spec No.
AV-252CS-34C)", Revision C, 10 July 1967, Grumman Aircraft Engineering
Corporation.

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.4.6-2   NARROW-BAND TELEMETRY TRANSMITTER (NBT)

Two redundant narrow-band telemetry transmitters are provided
in the spacecraft to transmit spacecraft status and command
verification data. In addition, the NBT may be utilized to
transmit data from the experimenters' data-handling equipment,
data storage, or command storage (Figure 6.4.6-2).

All data to the NBT are channeled through the spacecraft data-
handling equipment (SDHE). The inputs to the NBT are PCM
split-phase, which have been modified from PCM/NRZ. The output
from the NBT is PCM (split-phase) phase shift keyed (PSK) and
transmitted at a rate of 1042 bits per second. The split-phase
PCM/PSK transmission is utilized to obtain an improved signal-
to-noise ratio with available minimum power output of 1.6 watts
from the NBT.

The two NBTs and RF switch are packaged in the main package
with the output harmonic filter installed in a separate sealed
package adjacent to the output connector.
The filter package is connected to the main package by a short
length of coaxial cable. Each NBT consists of a crystal-controlled
oscillator, a phase modulator, amplifier and driver stages, and
a doubler stage. When power is applied to one of the NBTs, the
oscillator operates at a frequency of 68.130 MHz. A buffer stage
isolates the oscillator from the modulator. Modulation input
pulses are applied to the modulator as zeros (0 v) or ones
(8.5 V). Changes in the voltage level cause phase shifts in the
oscillator output. The transmitter is phase-modulated by the
sudden changes in voltage level when zero or one transitions are
received. The circuit is designed to allow a total phase shift
of 140° +10°. The output of the modulator is amplified in the
amplifier stages and is doubled to 136.260 MHz +0.003% in the
doubler stage.

The output of the NBT is applied (via the VHF hybrid junction
and diplexer) to the VHF slot antennas.
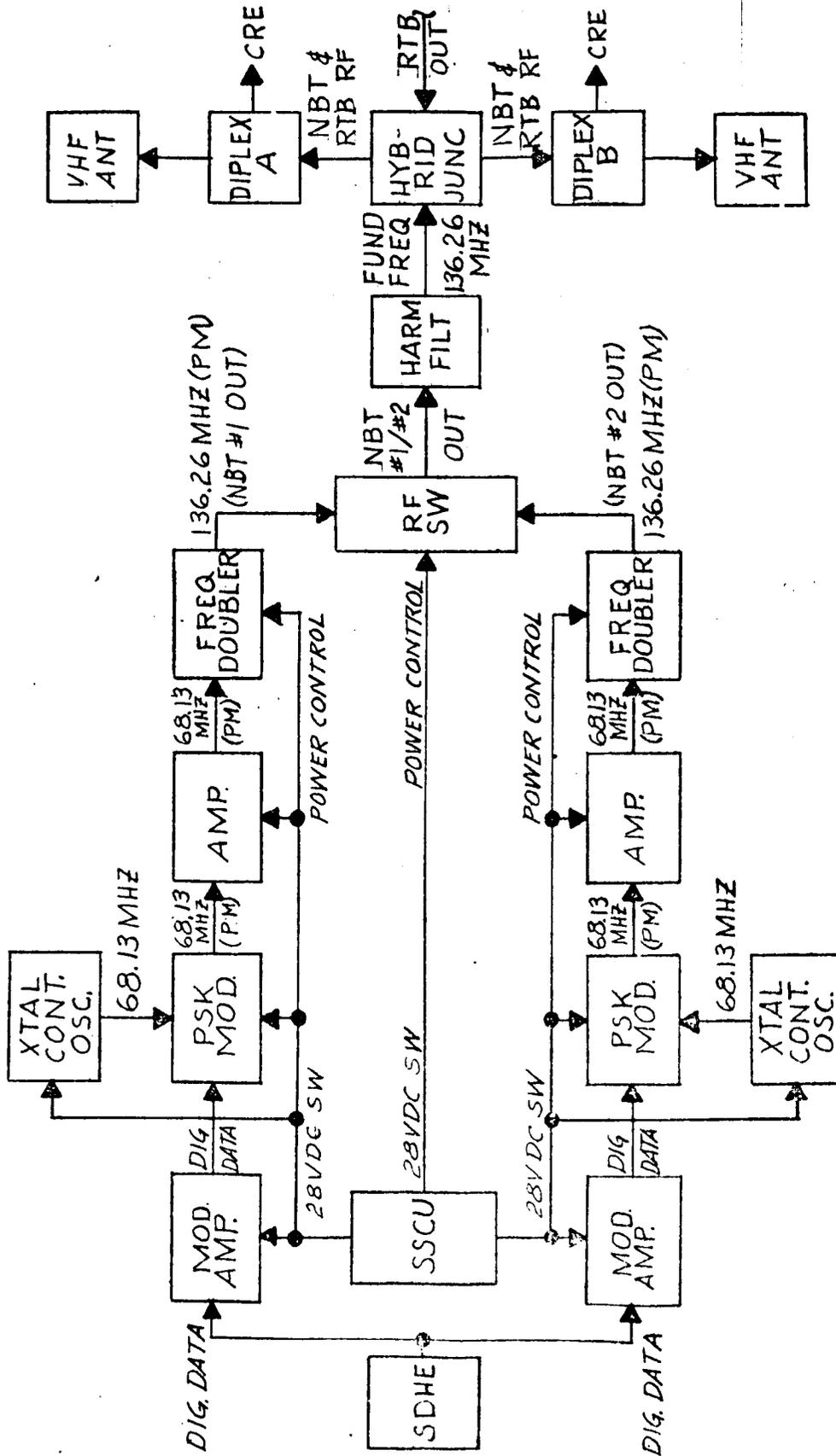
NARROWBAND TRANSMITTER BLOCK DIAGRAM

Figure 6.4.6-2

6.4.6-2   OAO NARROWBAND TELEMETRY TRANSMITTER

General Description

Program: OAO-C
Vendor:
Part Number:

Performance Characteristics

Power Output: 1.6 watts
Carrier Frequency: 136.260 MHz $\pm 0.003\%$
Modulation: Split-phase PCM/PSK

Physical Characteristics

Size:
Weight: 1.59 Kg (3.5 lbs) total including output filter
Input Power: 28 V (9 watts)
Cooling Method: Radiation

Reference

"OAO Spacecraft System Design Manual", Grumman Aircraft
Engineering Corporation, Revision B, 1968.

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.4.6-3   OAO-C RADIO TRACKING BEACON

Radio Tracking Beacon (RTB) equipment is provided in the space-
craft to permit ground tracking of the spacecraft at any point
in its orbit when it is within line-of-sight of a ground station.

The RTB equipment consists of two redundant radio tracking
transmitters and an RF switch in one package. An output harmonic
filter, connected to the main package by a short length of coaxial
cable (Figure 6.4.6-3) is in a separate package. Each radio track-
ing beacon transmitter is composed of three LC-coupled transistor
stages (oscillator, doubler, and power output). The crystal
oscillator operates as a third overtone oscillator with an out-
put frequency of 68.220 MHz. The doubler stage converts this
frequency to 136.440 MHz +0.003%. The final amplifier stage
provides a minimum output power of 160 mw.

Either of the two transmitters may be selected by ground command.
Beacon transmitter selection is accomplished by application of
an external pulse (via ground command) to actuate an RF switching
relay. Simultaneously, dc power to the transmitters is switched
in the data-processing subsystem. Only one beacon operates at
a time; the other remains inoperative until selected by ground
command.

The beacons utilize the same VHF slot antennas as the narrow-
band telemetry transmitter.
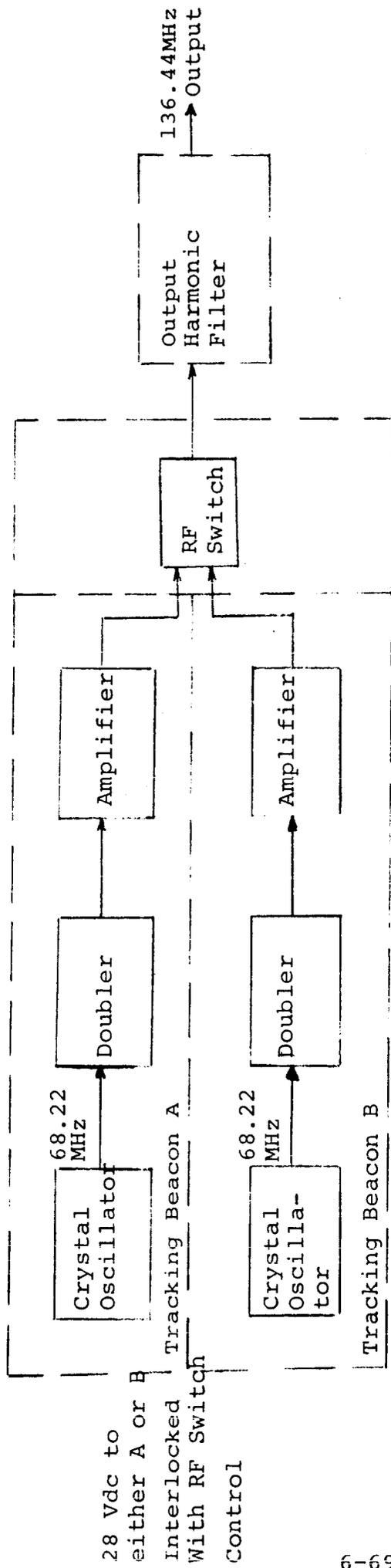
Figure 6.4.6-3. Radio Tracking Beacon Equipment Block Diagram

6.4.6-3 RADIO TRACKING BEACON

General Description

Program: OAO-C
Vendor:
Part Number:

Performance Characteristics

Power Output: 160 mw minimum
Frequency: 136.440 MHz

Physical Characteristics

Size:
Weight: 0.91 Kg (2 lbs)
Input Power: 28 V (1.2 watts)
Cooling Method: Radiation

References

"OAO Spacecraft System Design Manual", Grumman Aircraft
Engineering Corporation, Revision B, 1968

Radio Tracking Beacon Equipment - Communication and Antennas
Sub-system Orbiting Astronomical Observatory Specification for,
No. AV-252CS-240, Grumman Aircraft Engineering Corporation,
6 Aug 1965.

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.4.7-1   AM/MDA TM TRANSMITTER

Each transmitter contains a modulation amplifier that amplifies
the input modulation from the instrumentation system (Figure
6.4.7-1). A VCO varies the carrier frequency such that there
is a 0.1 MHz peak deviation for a 1.0 volt peak signal input to
the transmitter. The frequency modulated carrier is amplified
and sent to a band pass filter that attenuates those frequencies
not in the modulation frequency bands.
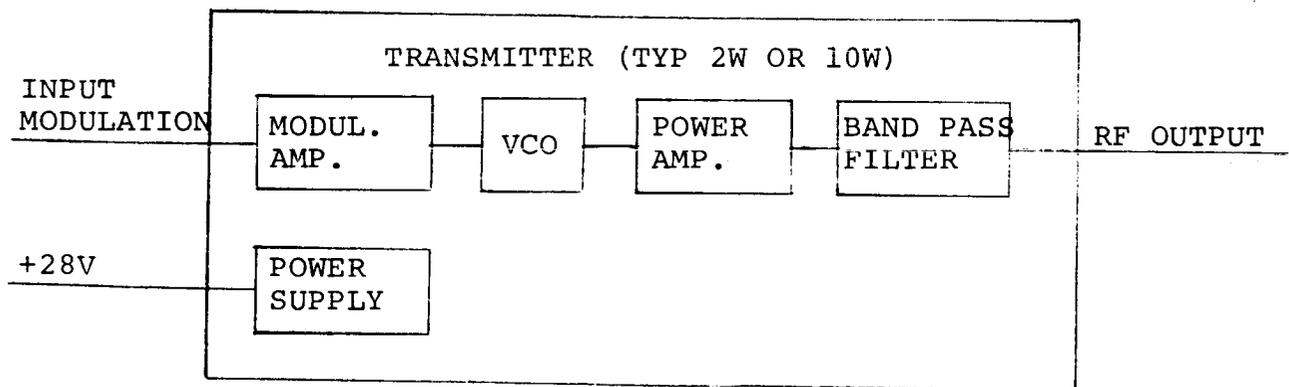
Figure 6.4.7-1. AM/MDA TRANSMITTER BLOCK DIAGRAM

6.4.7-1 AM/MDA TM TRANSMITTER

General Description

Program: Airlock Module
Vendor:
Part Number: 52-85713-367

Performance Characteristics

Power Output: 2.0 watts minimum (3.0 watts max)
Frequency: 230.4 MHz
Modulation: PCM/FM - 51.2, 112.64, 126.72 KBPS NRZ
            voice - 6600 Hz to 66 KHz

Physical Characteristics

Size: 5.7 cm (2.3 in) by 17.0 cm (6.5 in) by 7.0 cm
        (2.75 in)
Weight: 1.16 Kg (2.56 lbs)
Input Power: 18.9 watts @ 27 Vdc
Cooling Method: Coldplate

References

"Airlock Critical Design Review", ICD 50M13126,
Skylab Operations Handbook OWS/AM/MDA.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.4.7-2   AM/MDA TM TRANSMITTER

Each transmitter contains a modulation amplifier that amplifies
the input modulation from the instrumentation system (Figure
6.4.7-2). A VCO varies the carrier frequency such that there
is a 0.1 MHz peak deviation for a 1.0 volt peak signal input
to the transmitter. The frequency modulated carrier is ampli-
fied and sent to a band pass filter that attenuates those
frequencies not in the modulation frequency bands.
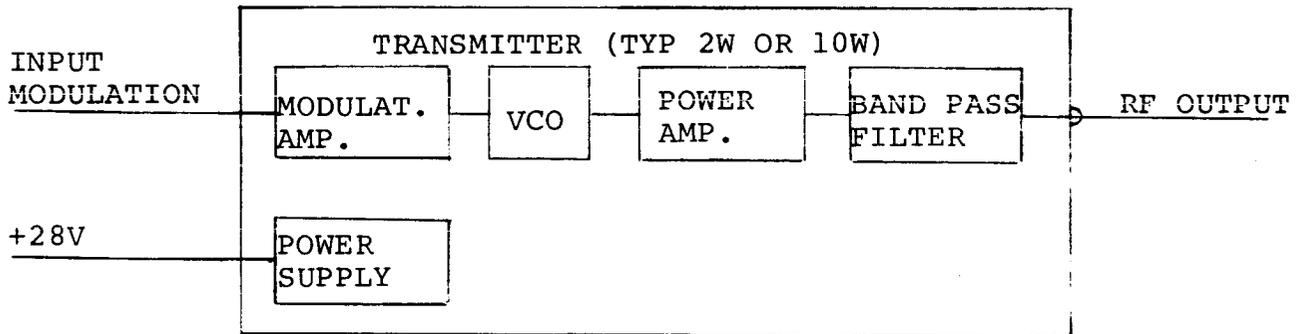
Figure 6.4.7-2. AM/MDA Transmitter Block Diagram

6.4.7-2 AM/MDA TM TRANSMITTER

General Description

Program: Airlock Module
Vendor:
Part Number: 61C850001-1, -3, -5

Performance Characteristics

Power Output: 10 watts minimum (13w maximum)
Frequency: 235.0 Mhz, 230.4 MHz, 246.3 MHz
Modulation: PCM/FM-51.2, 112.64, 126.72 KBPS NRZ
              Voice - 6600 Hz to 66 KHz

Physical Characteristics

Size: 11.7 cm (4.6 in) by 11.7 cm (4.6 in) by 3.4 cm
          (1.34 in)
Weight: 0.735 Kg (1.62 lbs)
Input Power: 81 watts @ 27 Vdc
Cooling Method: Coldplate

References

"Airlock Critical Design Review", ICD 50M13126,
Skylab Operations Handbook OWS/AM/MDA.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.4.8   ATM VHF TRANSMITTER

General Description

Program: ATM
Vendor:
Part Number:

Performance Characteristics

Power Output: 10 watts minimum
Frequency: 231.9 MHz, 237.0 MHz
Modulation: 72 Kbps PCM/FM NRZ-L or bi-phase level

Physical Characteristics

Size:
Weight:

References

Skylab Program Operational Data Book, (MSC-01549).

Design Status

This component was flown as part of the 1973 Skylab mission.

6.5.2   ERTS-B VHF RECEIVER

The Command and Clock Subsystem (Figure 6.5.2-1) consists of three modules: VHF Receiver, Command Integration Unit, and Command Clock. Parts of two other modules (Unified S-Band Receiver and Premodulation Processor) provide one of the two primary inputs to the subsystem but are not considered to be part of it.

The Command and Clock Subsystem performs the following functions:

1. Receives, processes, and executes real-time commands from the STDN ground station.

2. Receives, processes, and stores command information from the STDN ground station and executes these commands at the predetermined time.

3. Receives and transfers serial data to the VIP for reprogramming its memory.

4. Provides an accurate time base upon which all spacecraft activities can be planned, referenced, and measured.

5. Generates NASA Minitrack time-code data which are stored and transmitted with VIP, RBV, and MSS data so that the time reference may be used to process data in the ground station.

6. Generates standard frequencies and motor-drive signals used by other subsystems within the spacecraft.

The VHF receiver receives and demodulates command data transmitted from STDN ground stations and provides three bi-level signals (data, strobe, and enable) to the Command Clock. The VHF Receiver operates from a VHF monopole antenna at 154.2 MHz and uses an in-line notch filter to protect against the spacecraft VHF trans-mitter output. It is a completely redundant unit (excepting an input matching network) consisting of two RF receivers and two demodulators. Each RF receiver feeds its own demodulator; no internal cross-strapping exists. Only one RF receiver/demodulator is powered at a time.

Each RF superheterodyne receiver accepts a PCM/FSK-AM/AM signal conforming to the STDN PCM Command Data Standards. This signal consists of a 154.2 MHz carrier amplitude modulated (80%) by FSK data at 8.6 kHz (data "1") and 8.0 kHz (data "0"). The FSK signal is amplitude modulated (50%) by a 128 Hz sine wave corresponding to bit sync.
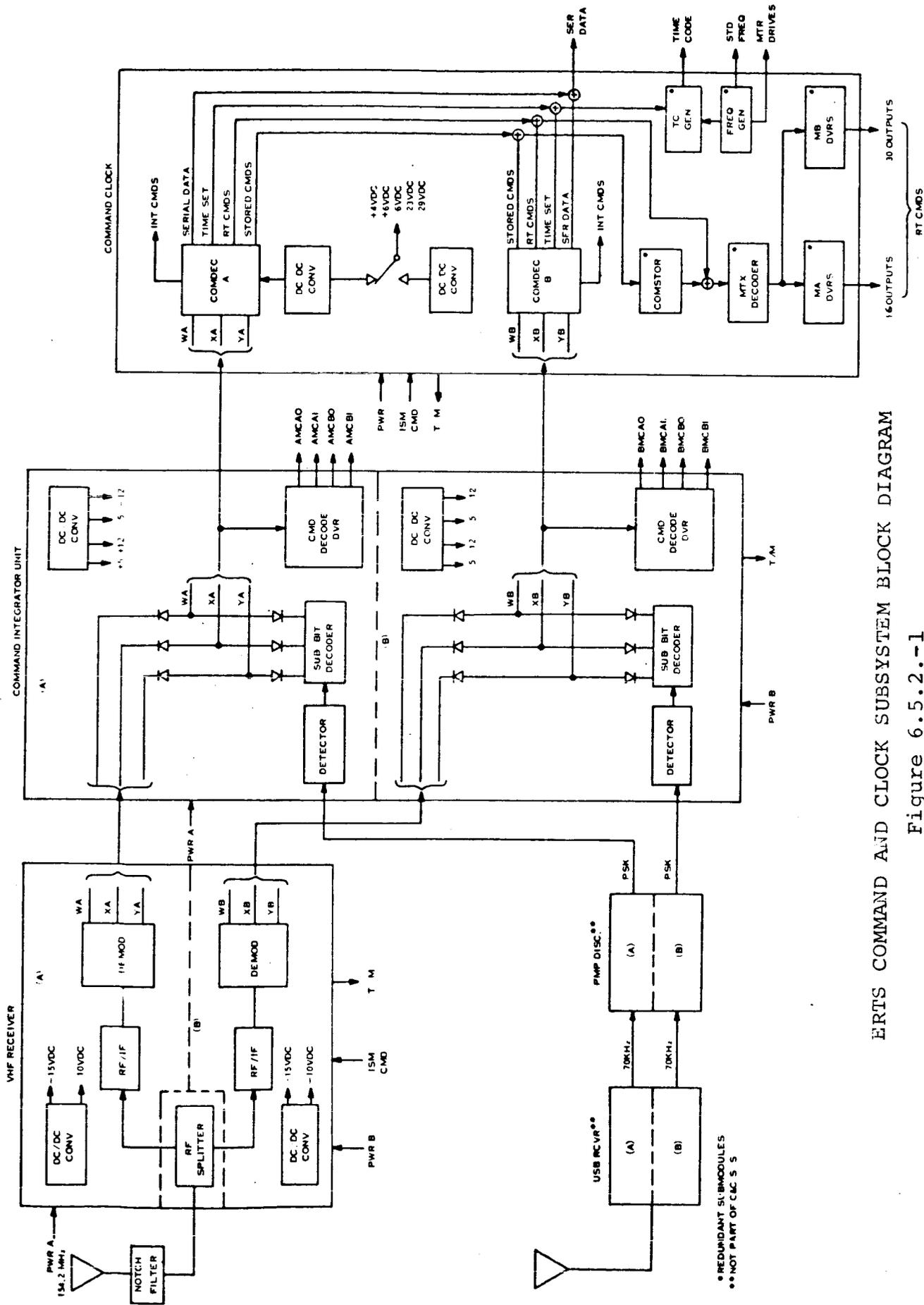
ERTS COMMAND AND CLOCK SUBSYSTEM BLOCK DIAGRAM

Figure 6.5.2.-1

The demodulator accepts the FSK audio signal from the RF receiver and provides data (W), strobe (X), and enable (Y) signals compatible with the Command Clock. The FSK data are converted to an NRZ digital output on the W line as command data.

Only one receiver/demodulator is powered at a time, with selection controlled in conjunction with selection of STDN receiving equipment (USB and PMP).

6.5.3   HEAO-A COMMUNICATIONS RECEIVER

Four S-Band coherent communication receivers (Figure 6.5.3-1) are in the HEAO-A Communication Subsystem and are located within two transponders. Each transponder contains two redundant receivers, operating simultaneously on the same S-Band frequency. Each transponder is comprised of an RF switch, a diplexer, redundant receivers, redundant transmitters, and power supplies. Assigned uplink frequencies are 2094.894 MHz and 2089.371 MHz. The S-Band RF signal contains PSK uplink command data (2 KBPS data with 1 KHz sync) modulating a 70 KHz subcarrier and/or a 1 MBPS pseudo-random noise (PRN) range code.

The receiver section of the Transponder is a double conversion, phase locked receiver with a loop noise bandwidth of 800 Hz at design threshold (unity signal-to-noise ratio in the receiver predetection bandwidth). The receiver is designed to lock-on and hold-in a received signal through a frequency range of 2094.896 MHz $\pm$90 kHz and at sweep rates up to 65 KHz over a power level of -115 dbm to -15 dbm. The unlocked or center frequency of the receiver is within 0.001 percent of its specified input frequency.

The signal received from the ground station may be phase modulated by a PRN ranging code that has a modulation index of 0.6 and/or a 70 kHz command subcarrier that has a modulation index of 1.22.

Coherent Automatic Gain Control (AGC) provides in excess of 100 db of dynamic range control. The receiver also contains a wideband modulation phase detector for detecting the PRN range code and the 70 KHz subcarrier. The PRN ranging code, when present, is recovered at baseband in the wideband detector, routed through the Baseband Assembly and subsequently phase modulated onto the transmitter transponder downlink carrier.

When the receiver is locked to an input signal, the transmitted signal is derived from a Voltage Controlled Oscillator (VCO) in the receiver loop. Thus, the down-link signal is a continuous-wave signal that is coherent in both frequency and phase with the up-link signal. The down-link frequency is offset from the up-link frequency by the ratio of 240/221.

When the receiver is not locked to the up-link signal, the down-link signal is derived from an auxiliary oscillator in the trans-mitter section. Transfer of the transmitter signal source from the VCO to the auxiliary oscillator is automatic and is initiated by a command signal from a coherent amplitude detector in the receiver AGC loop. During the time the auxiliary oscillator is
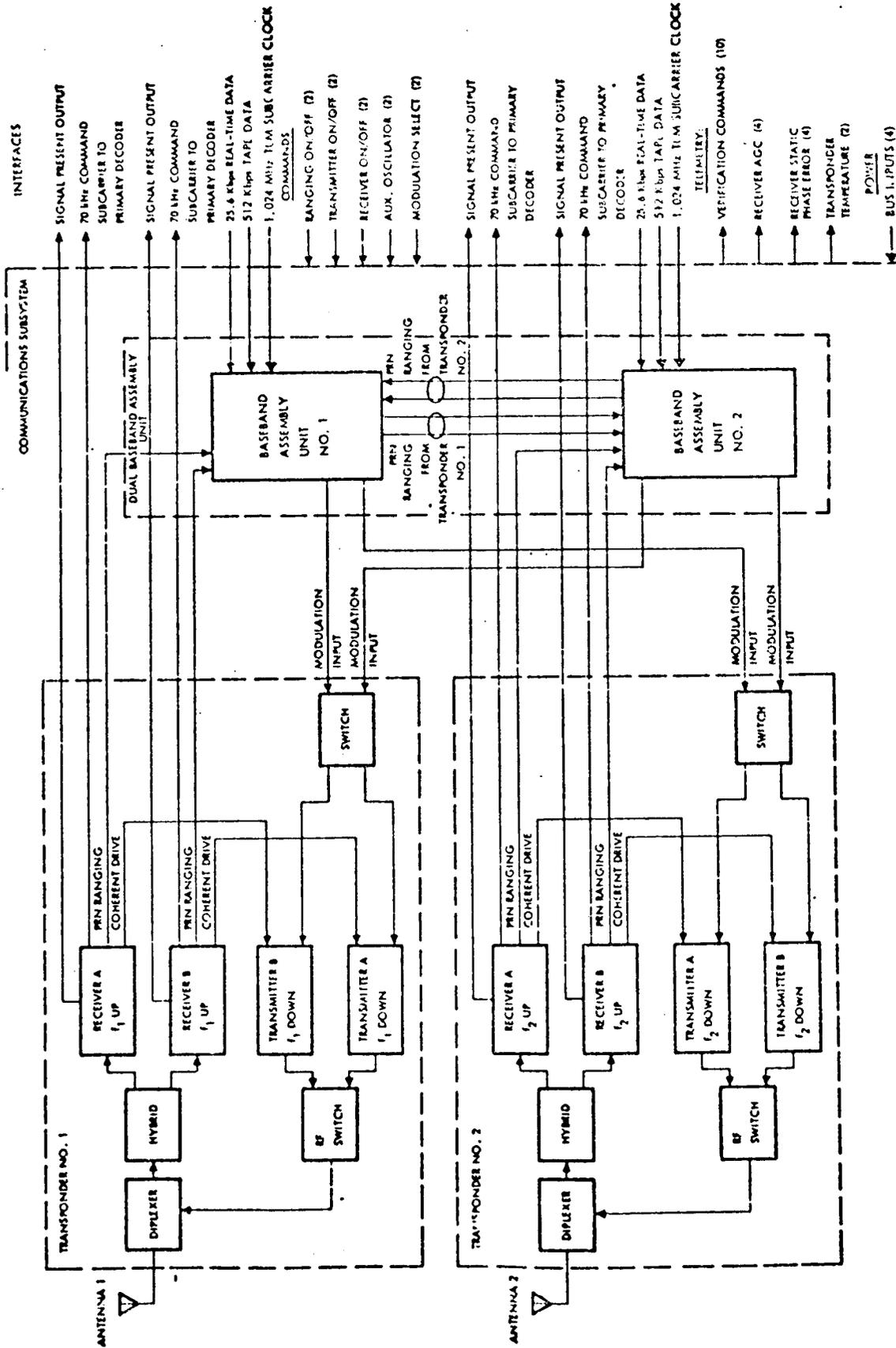
Figure 6.5.3-1   Communications Subsystem Block Diagram

functioning, the receiver modulation detector is disabled to prevent unwanted noise modulation of the transmitted signal. The signal derived from the auxiliary oscillator, however, may be modulated with the 25.6 KBPS Pulse Code Modulation (PCM) telemetry input or the 512 KBPS tape recorder data.

6.5.3   DUAL S-BAND RECEIVER (TRANSPONDER)

General Description

Program: HEAO-A
Vendor: Motorola
Part Number:

Performance Characteristics

Input Characteristics

    Noise Figure: 15 db
    Dynamic Range/Threshold: -15 to -125 dbm/-125 dbm
    Carrier Frequency: 2089.371 or 2094.894 MHz
    Bandwidth: 16 KHz
    Modulation: 70 KHz Command FM Subcarrier and PRN
                   Ranging Code Phase Modulates Carrier
Output Characteristics: Frequency phase locked to uplink

    (240/221 turn-around ratio) or generated from auxiliary
    oscillator in absence of uplink
    Power: 1 watt minimum
    Carrier Frequency: 2269 or 2275 MHz
    Modulation: Carrier phase modulated with 1.024 MHz
                   subcarrier and either 512 Kbps wideband
                   data or PRN ranging code
    Subcarrier Modulation: 25.6 Kbps biphase modulates
                              1.024 MHz subcarrier

Physical Characteristics

Size: 21.8 cm (8.6 in) by 15.2 cm (6 in) by 33.0 cm (13 in)
Weight: 12.0 Kg (26.5 lbs) each
Input Power: 23 to 33 Vdc (28.0 watts peak, 8.0 watts aver.)
Cooling Method: Conduction

References

"Preliminary Requirements Review Volume III-B Subsystem
Requirements and Data Communications Subsystem", TRW No.
17622-301-001-001, TRW Systems Group, Redondo Beach, Cal.,
24 July 1972; "HEAO Phase B Final Report", Volume II, TRW
Systems Group, Redondo Beach, Cal., 23 April 1971.

Comments:

The above described Motorola transponder is one of the two
candidate transponder designs being considered for HEAO. The
Atmospheric Explorer/Skylab II (Philco-Ford) transponder is
also being considered.

Design Status

The HEAO-A program is currently in a state of redefinition. This
component is a viable candidate for application in the 1977 HEAO-A
mission.

6.5.4   OSO VHF COMMAND RECEIVER

The two receivers onboard OSO-I are solid state and are compatible with STDN ground equipment. Each is capable of receiving an amplitude modulated signal at a frequency of 149.520 MHz. The receiver amplifies and demodulates the carrier and provides a baseband subcarrier (PCM/FSK-AM) signal to two demodulator/ central decoder units. 40ma at 18 volts DC regulated power is supplied to the receiver by the demodulator power supply.

The receiver is designed to operate properly with a signal input range of -40 dbm to -115 dbm and with a noise level not to exceed 5db. The input impedance is nominally 50 ohms. The receiver has a long term frequency stability of +0.002 percent The receiver selectivity is 25db down at frequencies greater than +200 KHz from the assigned center frequency. The output level is adjustable from 0.5 to 3.0 volts RMS with a -110 dbm input signal.

6.5.4   VHF COMMAND RECEIVER

General Description

Program: OSO-I
Vendor:
Part Number: 3280520-100

Performance Characteristics

Noise Figure: 5db
Dynamic Range/Threshold: -40 to -115 dbm
Carrier Frequency: 149.520 MHz
Type Modulation: PCM/FSK-AM/AM

Physical Characteristics

Size: 15.73 cm (6.2 in) by 12.2 cm (4.8 in) by 4.0 cm (1.58 in.)
Weight: 0.566 kg (1.25 lb.)

Environment: Hughes Spec SS31331-003

References

Command Subsystem Specification (SS31331-180)

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

6.5.5   V075 COMMAND DETECTOR UNIT (CDU)

The CDU shown in Figure 6.5.5-1 provides the following functions:

a. Acquires and maintains phase synchronization

b. Demodulates the Orbiter composite command signal

c. Detects the command information

d. Generates a pair of two-level signals indicating establishment of required demodulation references.

e. Detected data, bit timing, and signal derived from the detector status indications.

f. Signals indicating the operational status of the CDU.
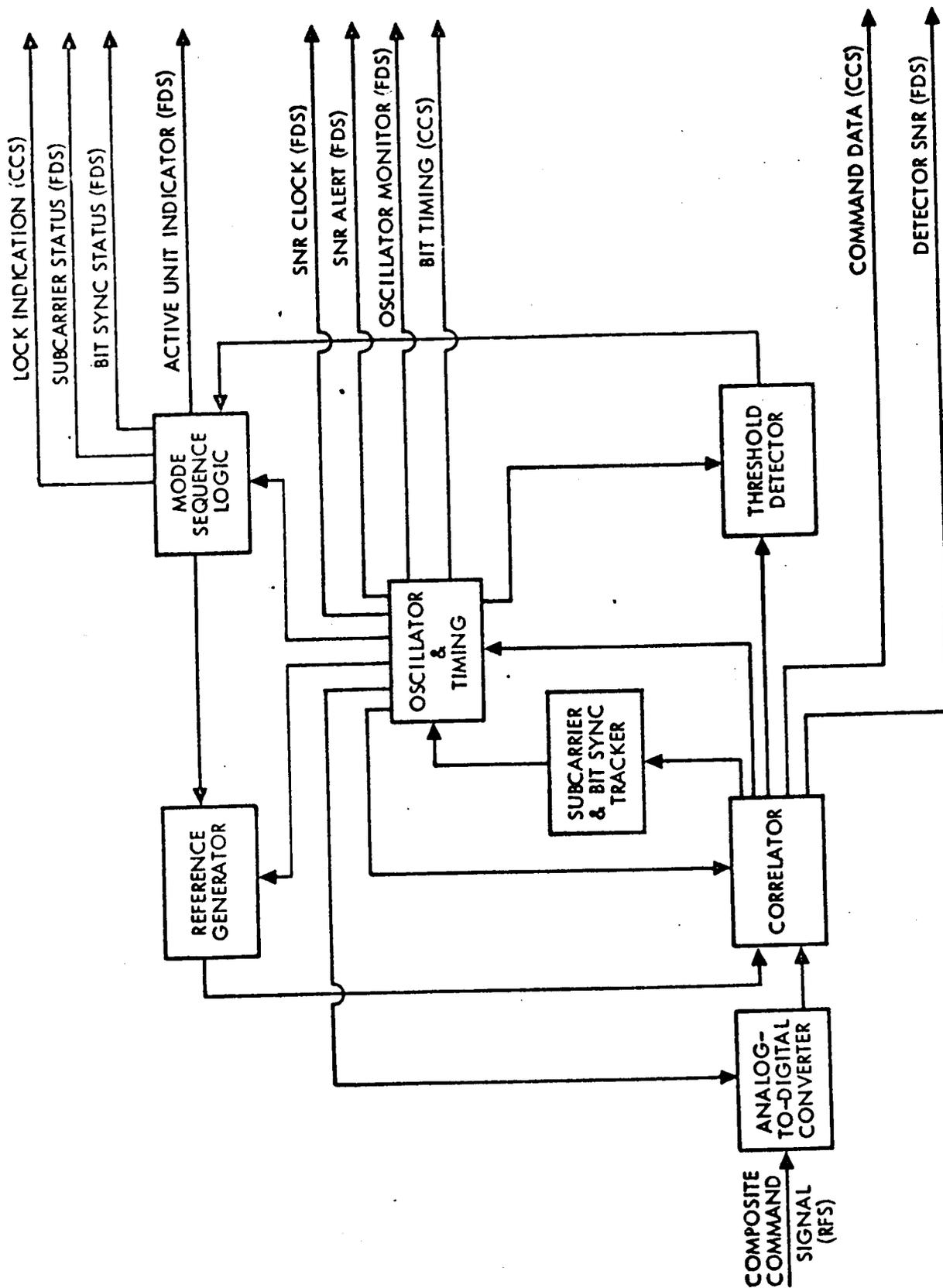
Figure 6.5.5-1. COMMAND DETECTOR UNIT FUNCTIONAL BLOCK DIAGRAM

6-86

6.5.5   COMMAND DETECTOR UNIT

General Description

Program: Viking Orbiter 1975
Vendor:
Part Number:

Performance Characteristics

CMD data bit rate: 4 bits/sec
CMD subcarrier frequency: 512 Hz (square wave)
CMD input signal: 50 to 800 millivolts

Physical Characteristics

Size:
Weight:
Input Power: To CDU pwr supply: 5.0 watts from 2.4 KHz
source ,+12.0 Vdc +10%, -12.0 Vdc +10%, +5.0 Vdc +10%

References

Viking Orbiter 1975 Flight Equipment Modulation Demodulation
Subsystem, Des. Req V075-2003-1 Rev A, 6-25-72.

Design Status

This component is scheduled to be flown as part of the planned
1975 Viking Orbiter mission.

6.5.6   OAO COMMAND RECEIVER

Four command receivers are contained in one package and are utilized in redundant pairs as shown in Figure 6.5.6-1.   All four receivers are always on, and at least one must be operational in order to command the spacecraft.

Each of the four command receivers is fix-tuned to 148.260 MHz and converts the received signal to a 10 MHz IF. The IF circuitry incorporates a crystal filter (for bandpass accuracy), four stages of amplification, and two AGC bridges. Two detectors are operated from the IF output. The detected output is applied to audio amplifiers and logic circuits. Three digital outputs are provided by the command receiver: carrier presence, message rate clock, and command message. These command signals are applied to the data processing subsystem where the commands are executed or stored for delayed execution.

Command messages are generated by frequency shift keying (FSK) two tones (7294 Hz for a ONE and 10420 Hz for a ZERO) with PCM NRZ data. The FSK data is amplitude modulated with a 1042 Hz clock signal before being amplitude modulated onto the carrier.
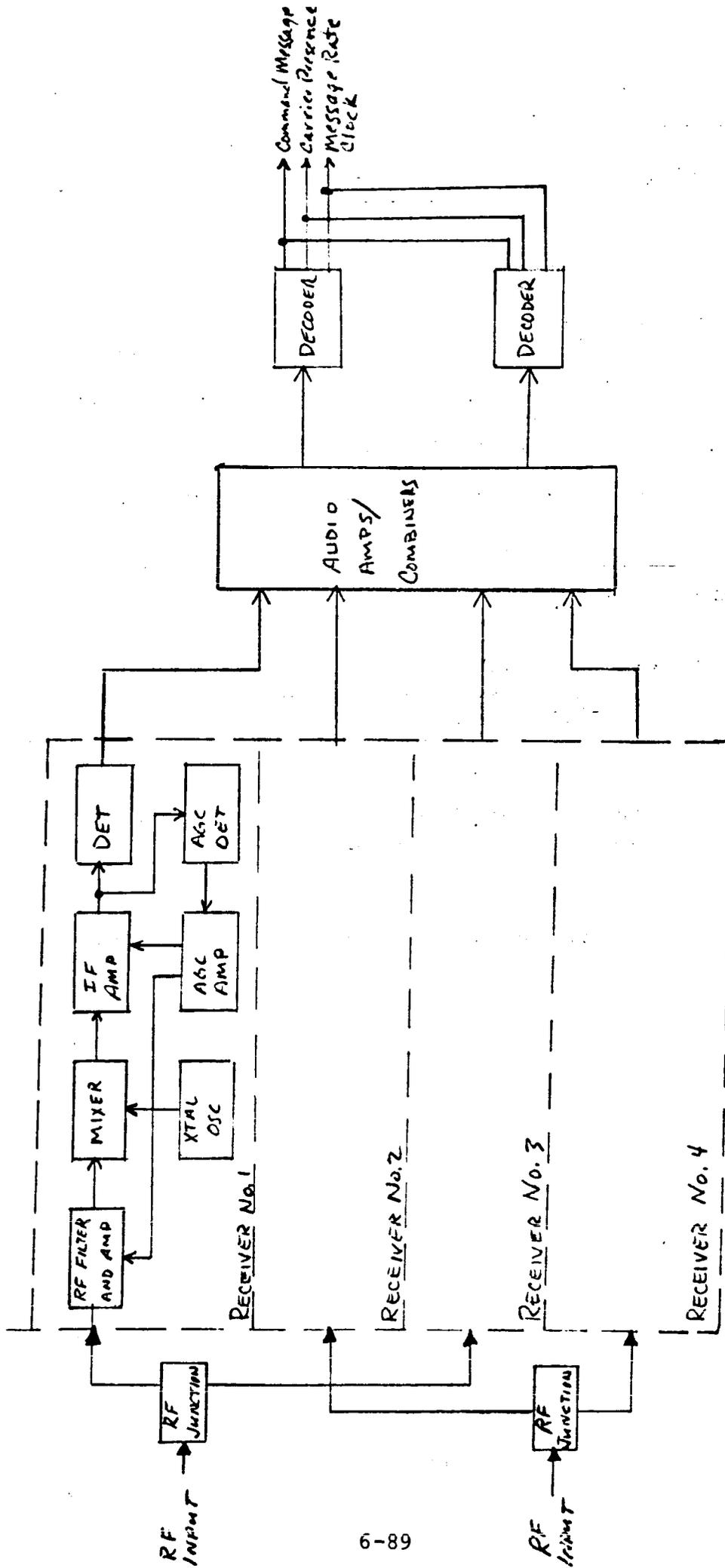
Figure 6.5.6-1. COMMAND RECEIVER EQUIPMENT BLOCK DIAGRAM

6.5.6 COMMAND RECEIVER

General Description

Program: OAO
Vendor:
Part Number:

Performance Characteristics

Noise Figure: 8 db
Dynamic Range/Threshold: Between -17 and -100 dbm/-100 dbm
Carrier Frequency: 148.260 MHz
Type Modulation: PCM (NRZ)/FSK/AM/AM
IF Frequency: 10 MHz
Outputs: 3 digital outputs (command message, carrier presence,
            message rate clock)
Bandwidth: 6 db IF bandwidth = 34 kHz

Physical Characteristics

Size:
Weight: 4.42 Kg (9.75 lbs)
Input Power: +18 vdc (2 watts @ 100% duty cycle)
Cooling Method: Radiation

References

"OAO Spacecraft System Design Manual", Grumman Aircraft
Engineering Corporation, Revision B, 1968.

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.5.7   SKYLAB AM/MDA COMMAND RECEIVER/DECODER

Each receiver/decoder (Figure 6.5.7-1) contains two receivers (each connected to a separate antenna) for command reception. The receiver outputs are first routed to a sub-bit detector, then to a sub-bit decoder where groups of five sub-bits are decoded into data bits. The data bits are shifted to the input register and the teleprinting subsystem. The first three data bits are sent to the vehicle and system address decoder. These initiate a vehicle address sub-bit coding control signal and a vehicle address recognition signal in the receiver/decoder whose vehicle address is recognized. The vehicle address sub-bit coding control signal causes the sub-bit decoder to change state and establish a different sub-bit decoding technique for the data bits. The different sub-bit decoding technique precludes a wrong vehicle address being generated by random message bits. The next three data bits are decoded by the vehicle and system address decoder to determine the Digital Command System (DCS) component for which the message is intended. For instance, if the message is intended for DCS relay modules, a system address signal enables the relay module decoder to accept the data.

A verification pulse from the timing and interface logic is downlinked to STDN. The verification pulse is generated when the timing and interface logic receives the TRS or CRDU clock pulses in response to the corresponding ready pulse, or when the common set or reset signal is sent to the relay modules from the relay module decoder (no verification pulse exists for a teleprinter message).
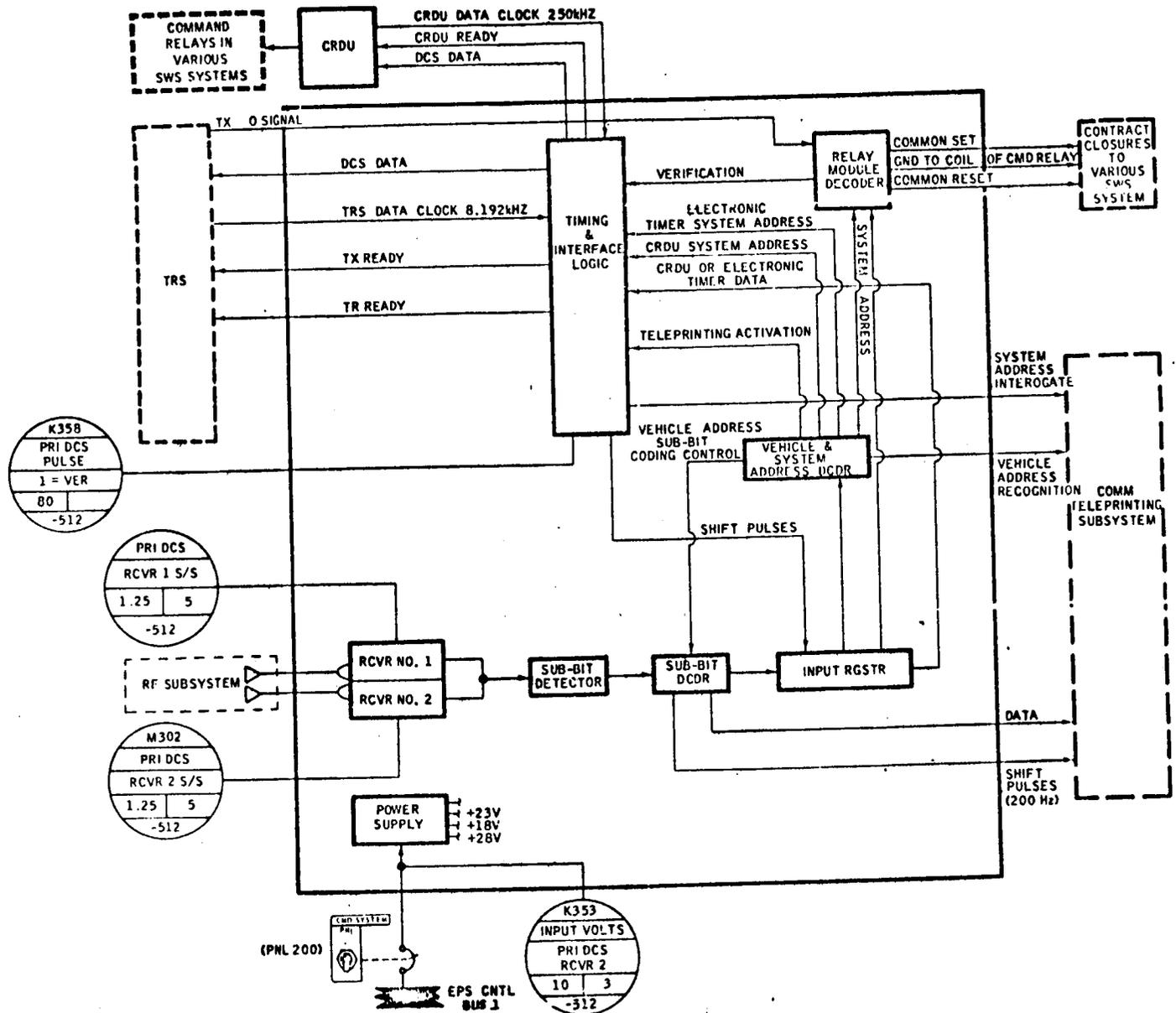
Figure 6.5.7-1   Receiver/Decoder Block Diagram

6.5.7   COMMAND RECEIVER/DECODER

General Description

Program: Airlock Module
Vendor:
Part Number: 52-85714-27

Performance Characteristics

Noise Figure: 11db
Threshold: -93 dbm
Frequency: 450 MHz
Bandwidth: 255 KHz
Type Modulation: PSK/FM (1 KHz and 2 KHz PSK)
Bit Rate: 200 BPS (1 KBPS sub bit data rate)
Word Length: Variable 12 bit minimum 30 bit maximum
Max CMD Spacing: Relay: 20 ms, CRDU: 255 ms, elect-timer:
                    16 ms, teleprinter: 5 ms

Physical Characteristics

Size: 23.5 cm (9.25 in) by 31.75 cm (12.5 in) by 21 cm (8.25 in.)
Weight: 9.0 kg (19.9 lbs.)
Input Power: 12.5 watts @ 27 Vdc

References

Skylab Operations Handbook OWS/AM/MDA, ICD 50M13126

Design Status

This component was flown as part of the 1973 Skylab mission.

6.5.8   ATM COMMAND RECEIVER

The model MCR-503D command receiver (Figure 6.5.8-1) is a
crystal-controlled, transistorized, dual conversion, super-
heterodyne. It consists of eight functional modules of similar
configuration, individually constructed, and assembled into a
pressurized container.

Input signals are coupled into a preselector assembly con-
sisting of a low-pass filter, bandpass filter, and an RF
amplifier. The -3db bandwidth of this assembly is approximately
4 MHz, the gain approximately 5db. Signal mixing in the first
IF amplifier assembly produces a 10.7 MHz IF output to the IF
bandpass filter.

The IF bandpass filter is a passive L-C type filter, which
determines the overall RF bandwidth of the receiver. The
filter insertion loss is approximately 10db and the 3db bandwidth
340 KHz. The filtered 10.7 MHz output signal goes to a second IF
amplifier assembly containing two feedback amplifier pairs,
each pair tuned to 10.7 MHz and having a gain of approximately
30db. From the second amplifier pair the output goes to the
limiter-discriminator assembly, where the audio bandwidth of
the receiver is established, then to the audio amplifier assembly.
Dual isolated PSK audio outputs from the audio amplifier assembly
are sent to the ATM command decoder for decoding. If one of the
isolated outputs is shorted, the other output signal will not
be reduced by more than 3db.
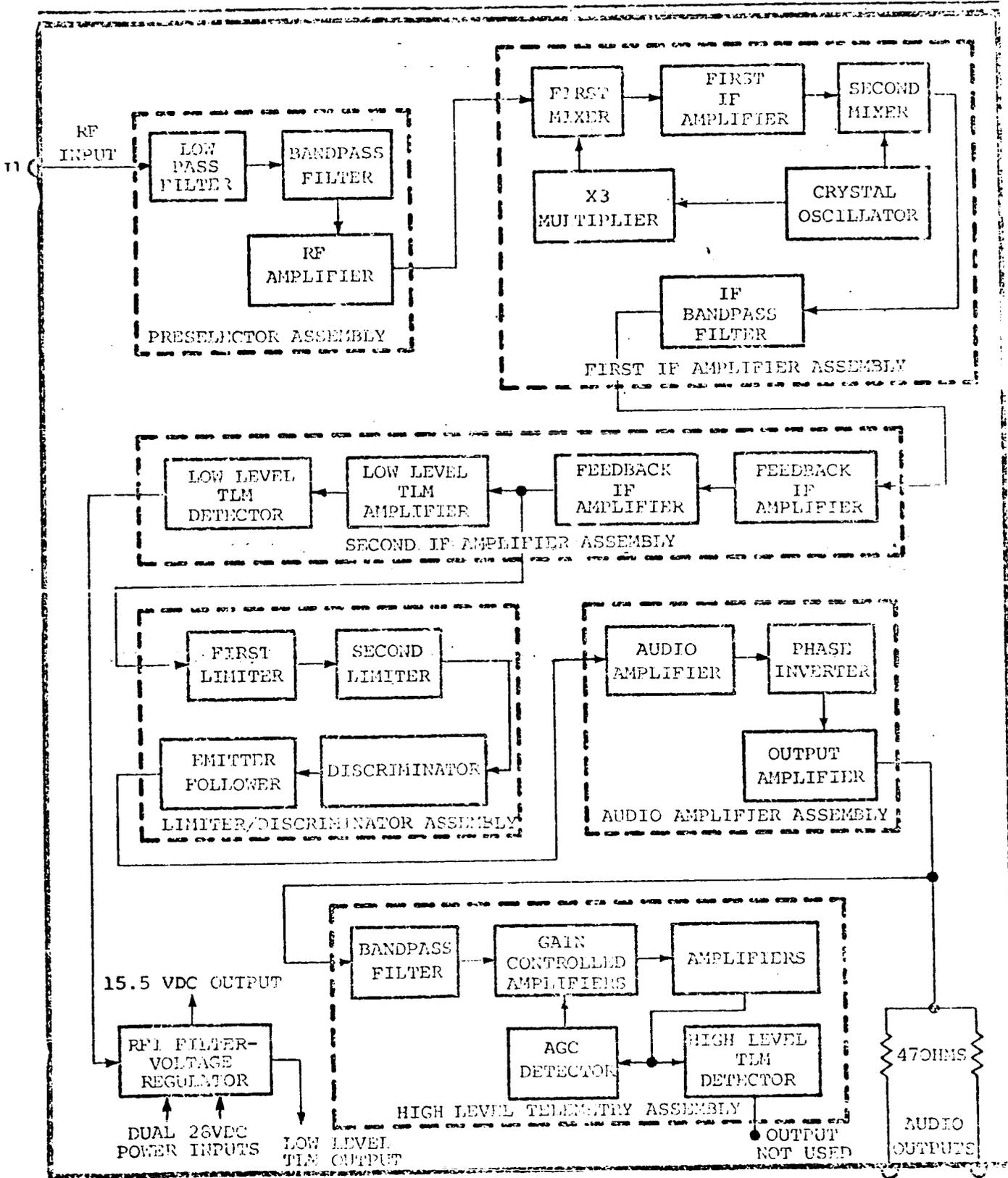
Figure 6.5.8. Command Receiver Block Diagram

6.5.8   UHF COMMAND RECEIVER

General Description

Program: Skylab ATM
Vendor:
Part Number:

Performance Characteristics

Dynamic Range: 1-93 dbm
Frequency: 450 MHz
Bandwidth: 340 +30 kHz
Type Modulation: PSK/FM (1 kHz and 2 kHz PSK)
Phase Development (1 kHz and 2 kHz):   4 microseconds maximum

Physical Characteristics

Size:
Weight:

References

ICD 50M13126, "Skylab Program Operational Data Book",
(MSC-01549).

Design Status

This component was flown as part of the 1973 Skylab mission.

6.6.2   ERTS-B COMMAND DECODERS

The Command Integrator Unit (CIU) (Figure 6.5.2-1) accepts
data from both the VHF Receiver and the Unified S-Band Receiver/
Premodulation Processor discriminator. It contains two completely
independent channels. Only one type of data is fed to each channel
at any one time; each channel is capable of handling either type
of data.

No processing of STDN Command Clock data takes place in the CIU.
The three outputs of the VHF Receiver are simply diode OR-gated
with the CIU processed USB data prior to being sent to the
Command Clock.

The OR-gated outputs of channel A feed the primary command decoder
(COMDEC) in the Command Clock. The OR-gated outputs of channel B
feed the redundant COMDEC in the Command Clock. Both channels of
the CIU will be powered, permitting processing of VHF data in one
channel and processing of USB data in the other channel.

Each CIU channel contains a command decoder which is in parallel
with the three output lines to the Command Clock. Each decoder
is capable of decoding four commands.

6.6.3   HEAO-A COMMAND DECODERS

Command decoders provide the ground controlled functional inter-
face to the HEAO-A spacecraft for housekeeping and experiment
commands. The decoders consist of primary command decoders (PCD)
and secondary command decoders (SCD). Figure 6.6.3-1 shows the
uplink command word structure and Figure 6.6.3-2 the command sub-
system functional block diagram. Uplink commands are sent to
the spacecraft using a 2 KHz PSK signal with 1 KHz sync super-
imposed. The 1 KHz sync and 2 KHz PSK signals modulate a 70 KHz
subcarrier which in turn modulates the uplink S-Band carrier.
Cross strapped 70 KHz subcarrier input signals are sent to the
primary command decoders (PCD) (Figure 6.3.3-3) from receivers
in the two transponders. Each PCD may be selected separately
by a decoder address or both may be addressed simultaneously by
a decoder address .

A 70 KHz subcarrier demodulator within the PCD demodulates sync
and data at a 1K bit data rate. The 1 KHz sync is used as timing
for the command subsystem.

The primary command decoder detects and rejects errors in the
following:
  °   HEAO spacecraft address
  °   Demodulator address
  °   Sub-bit pattern
  °   User address
  °   Missing bit

The probability of an undetected data bit error is equal to
or less than 10^{-9}. After each successful decoding of a vehicle
address and user address, a message acceptance pulse output is
provided to telemetry. Enable, 1 KHz clock, and data signals
are sent to the Secondary Command Decoder for subsequent decoding
and routing. Secondary command decoders (SCD) (Figure 6.3.3-4)
are physically located as near as possible to the command function
to be performed and each is interchangeable with every other
secondary command decoder. Each decoder (when addressed) performs
the necessary decoding and parity checking, and provides standard
logic outputs to all experiments and spacecraft subsystems. These
commands may be (a) 10 bit serial commands and (b) discrete or
state pulse outputs. Based upon the command bit word length and
steering address, each secondary command decoder has a theoretical
capacity for 1024 discrete 100 msec pulse commands and 31 ten
bit serial commands. The NRZ-L serial data rate and command
data transfer rate is 200 bps.

29 bits x 5 subbits/bit at 1 K subbits/sec

40 bit "0"
Preamble

Vehicle Address

PR1 DCDR Add.

Remote DCDR Add.

Remote DCDR Steering

Data

Odd Parity

Intercommand

| 3 | 3 | 4 | 5 | 10 | 3 | Finish |

Start
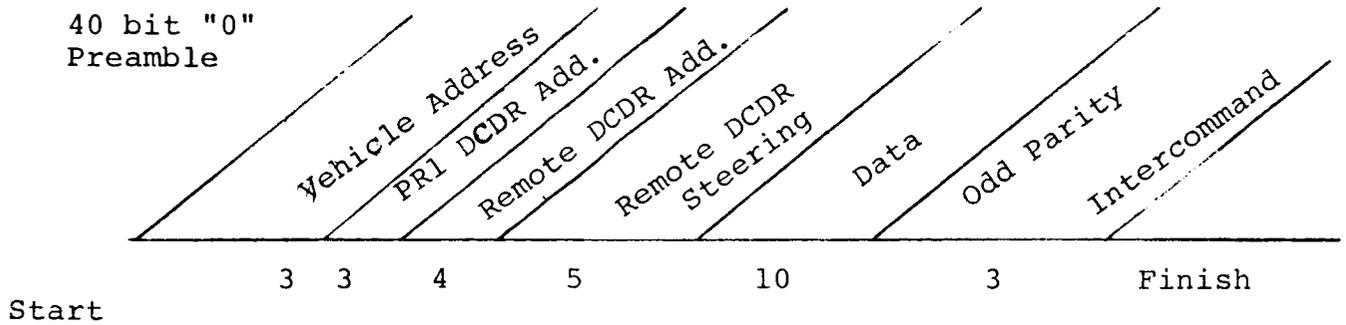
Figure 6.6.3-1.   Command Word Structure
(Single Real Time CMD)
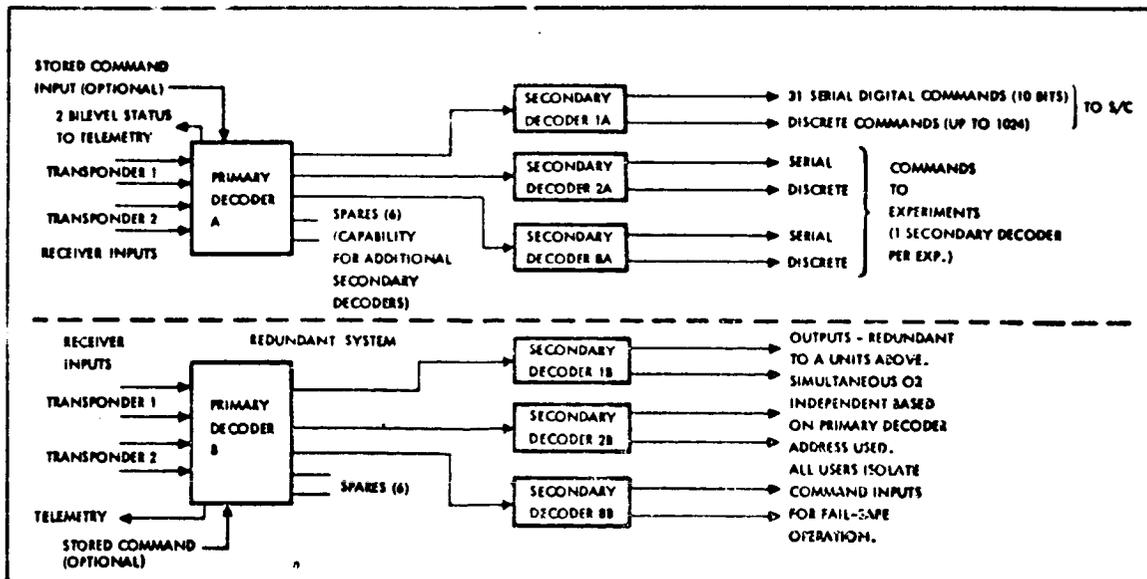
Figure 6.6.3-2.   Command Subsystem

Figure 6.6.3-3   HEAO-A Primary Command Decoder
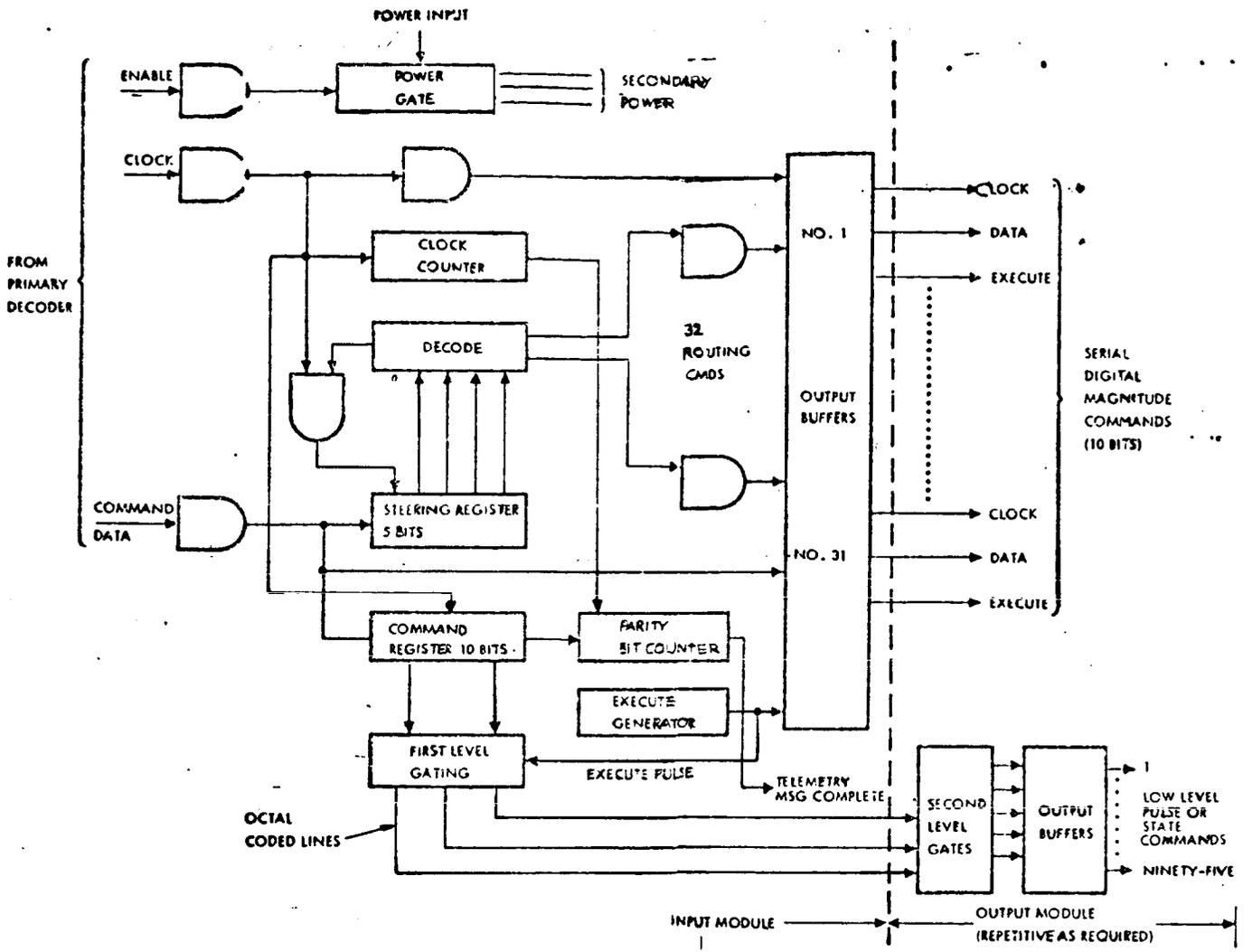
Figure 6.6.3-4   Secondary Command Decoder

6.6.3-1   HEAO-A PRIMARY COMMAND DECODER

General Description

Program: HEAO-A
Vendor: TRW
Part Number:

Performance Characteristics

Number of Output Commands: Theoretical capacity for 8192
                               discrete and 248 serial 10-bit
                               commands using 8 secondary decoders
Type Modulation: PCM/PSK/FM/PM
Input Signal: 70 KHz subcarrier FM modulated by 1 and 2 KHz
                  PSK signals
Message Length: 145 msec
Subbit Rate: 1000 bits per second (bps)
Encoded Scheme: 5 subbits per data bit
Effective Data Bit Rate: 200 bps
Effective Command Message Length: 29 bits
Error Detection: Invalid spacecraft address, subbit pattern,
                     secondary decoder address, or command word
                     length
Command Output: To secondary decoders (16 secondary decoders
                    possible)
Format: Serial NRZ command data, clock, and enable pulse
Signal Level: "One" + 2.4 to +5.4 volts, "Zero" -0.4 to +0.4 volts
Signal Duration: 20 usec $\pm$10%

Physical Characteristics

Size: 15.2 cm (6 in) by 20.3 cm (8 in) by 4.1 cm (1.6 in)
Weight: 0.9 kg (2.0 lbs)
Input Power: 0.5 watts (+15 v and +5.3 Vdc)

References

HEAO Design Approach, TRW Systems Group, Aug. 27, 1971

Design Status

The HEAO-A program is currently in a state of redefinition. This
component is a viable candidate for application in the 1977 HEAO-A
mission.

6.6.3-2 HEAO-A SECONDARY COMMAND DECODER

General Description

Program: HEAO-A
Vendor: TRW
Part Number:

Performance Characteristics

Number of Output Commands: Theoretical capability for 31
                               serial 10-bit digital and 1024
                               discretes
Type Modulation: NRZ PCM
Bit Rate: 200 bps
Input Signal: Serial command data, enable pulse, and clock
Bit Duration: 200 usec
Bit Spacing: 5 msec
Signal Level: "One" + 2.4 to 5.4 V, "Zero" -0.4 to +0.4 V
Command Length: 16 bits

Format: Discretes or NRZ-L serial digital 10-bit words
            with execute pulse and clock
Signal Level: 5 V
Signal Duration: 100 msec discretes, 5 msec serial digital

Physical Characteristics

Size: 15.2 cm (6 in) by 20.3 cm (8 in) by 2.8 cm (1.1 in)
          per slice (input or output)
Weight: 0.45 kg (1.0 lb) per slice (input or output)
Input Power: Input slice: 0.3 W continuous, 0.7 W processing;
Output Slice: 0 W continuous, 0.3 W processing

References

HEAO Design Approach, TRW Systems Group, Aug. 27, 1971

Design Status

The HEAO-A program is currently in a state of redefinition. This
component is a viable candidate for application in the 1977 HEAO-A
mission.

6.6.4-1   OSO-I DEMODULATOR/CENTRAL DECODER

The OSO-I Demodulator/Central Decoder performs the following functions:

° Process real time (RT) commands and provide the appropriate NRZ or manchester encoded output commands.

° Process either stored command processor (SCP) or onboard processor inputs (OBP) and provide the appropriate encoded output commands.

° Provide unit status outputs

° Provide power outputs

° Operate in accordance with unit specifications from two unregulated +28 Vdc power sources.

° Provide timing functions from an internal clock.

Functional block diagrams of the Demodulator and the Central Decoder are shown in Figures 6.6.4-1 and 6.6.4-2 respectively. Figure 6.6.4-3 illustrates the input word format and associated NRZ data.

When processing real time commands, the FSK subcarrier is received from the receiver, demodulated, and processed through the demodulator if the S/N (signal-noise ratio) is adequate as determined by the squelch circuitry. In the normal mode, the decoder then selects for processing either the output of the demodulator or the output of a cross-strapped demodulator depending on which has the highest S/N ratio. If the abnormal mode is selected, the decoder simply processes the demodulator output. Real time command processing shall be inhibited if the S/N ratio at both demodulator inputs falls below the level required for reliable communications. The selected PCM data bit stream shall then be decoded and checked for the proper central decoder address. Failure of this, the loss of a good or fair S/N signal, or the polynomial code check shall cause the unit to inhibit further processing and reject the message. The verified message shall either be sent to the command memory in NRZ format (data, clock, envelope) via the stored command processor for delayed execution, or be Manchester encoded and transferred across a single wire interface to a remote decoder for real time execution. Stored commands shall be processed by the stored command processor and sent to a selected remote decoder via the central decoder in the same manner as real time commands.
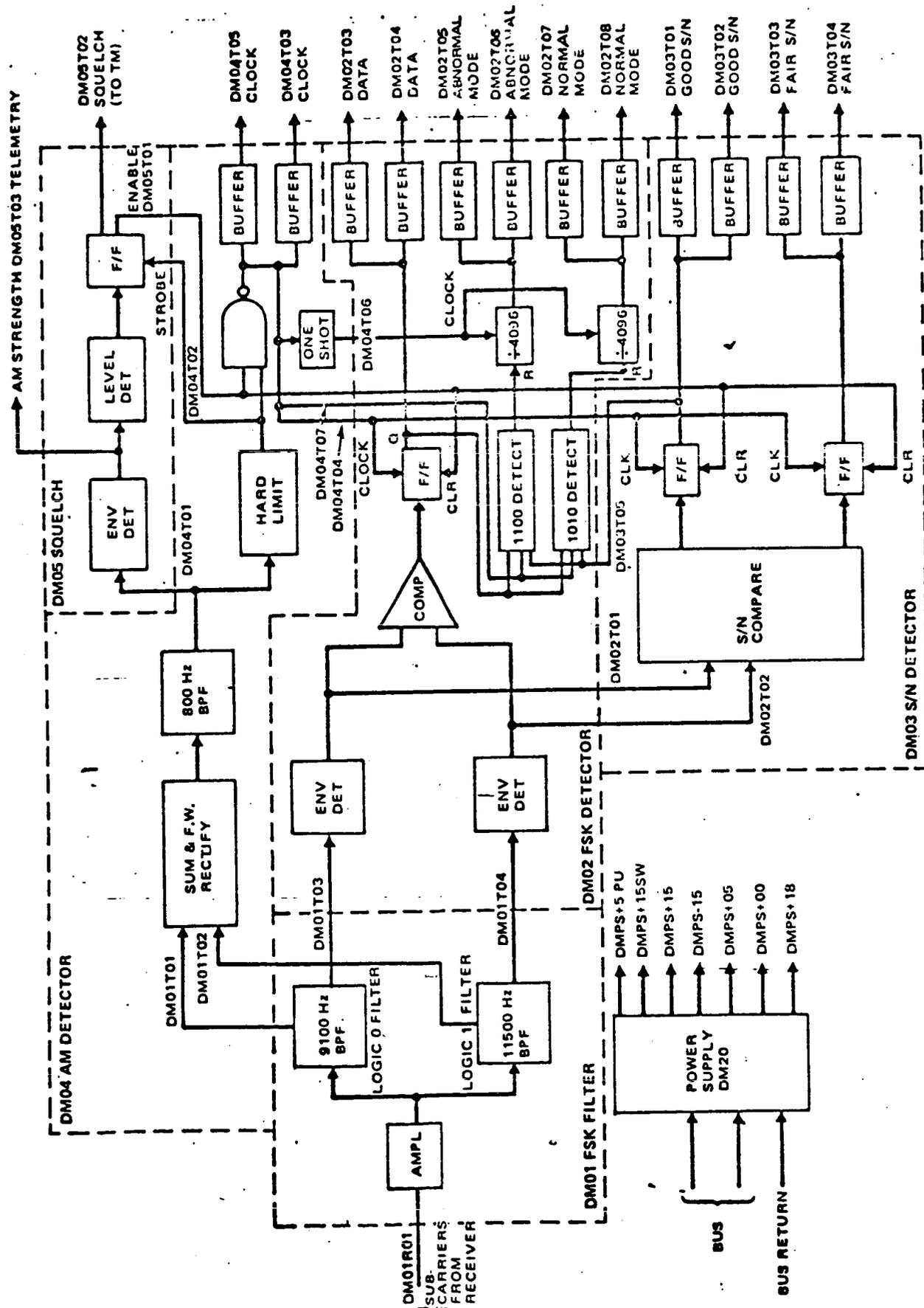
Figure 6.6.4-1   Demodulator Functional Block Diagram
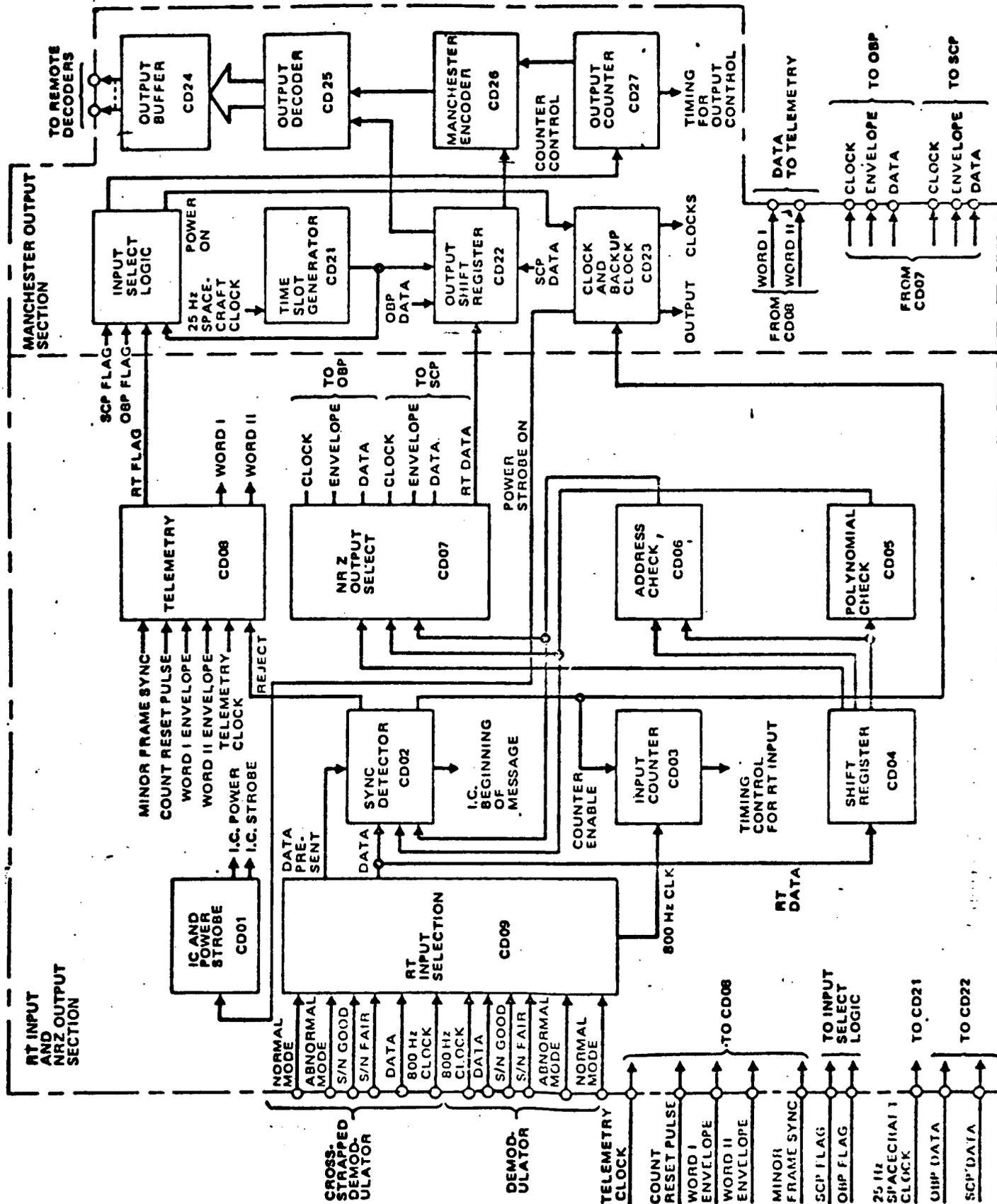
Figure 6.6.4-2 Central Decoder Functional Block Diagram

COMMAND: DATA

NORMAL INTRODUCTION 42 BITS
41 ZEROS, BIT 42 IS A ONE

42 BITS WORD 1 | 42 BITS WORD 2 | 42 BITS WORD N-1 | 42 BITS WORD N
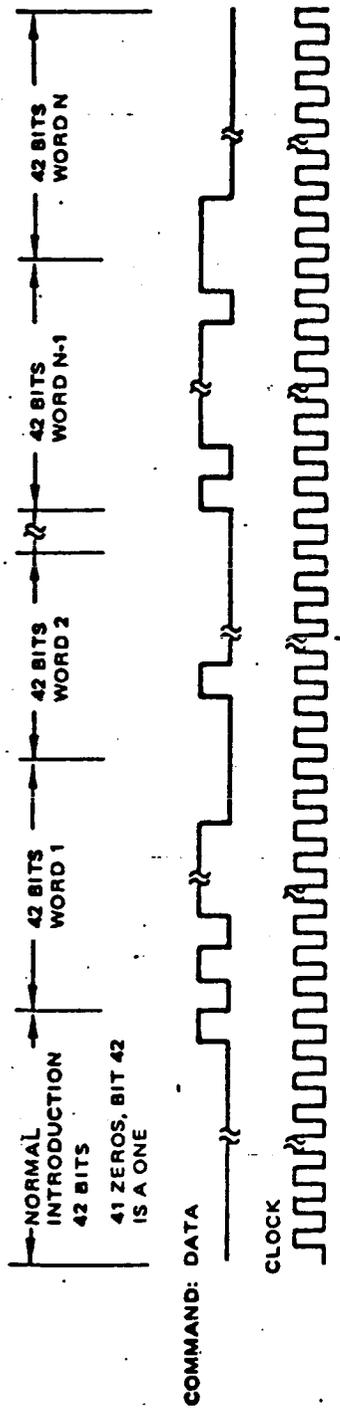
CLOCK

a) INPUT DATA AND CLOCK FROM DEMODULATOR(S)

OPERATION CODE

SERIAL MAGNITUDE OR PULSE COMMAND BIT

| SPACECRAFT DECODER ADDRESS | REMOTE DECODER ADDRESS | NRZ LINE | PULSE COMMAND SELECT OR DATA TO BE NRZ TRANSFERED | FILL | POLYNOMINAL CHECK |

ADDRESS $A_1 - A_7$ | SELECT $S_1 - S_3$ | CMD $C_1 - C_{24}$ | FILL F_1 | PARITY $P_1 - P_7$

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42

b) INPUT WORD FORMAT FROM DEMODULATOR(S)

| OP CODE | 24 BITS DATA |

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

c) OUTPUT TO SCP OR OBP

CHECK BIT

| FILL | 24 BITS DATA |

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

d) TO MANCHESTER OUTPUT SECTION (SEE FIGURE 5)

Figure 6.6.4-3   Input Word Format and Associated NRZ Data

6.6.4-1   DEMODULATOR/CENTRAL DECODER

General Description

Program: OSO-I
Vendor:
Part Number: 3280530-100

Performance Characteristics

Input Modulation: PCM/FSK-AM
Input Bit Rate: 800 bps
Input Signal Discrimination: Checks input for proper central decoder address, good signal level, and polynominal code check. Failure of any of these inhibits further processing.

Command Output:

  a. No. of output commands: 24
  b. Format: Manchester to remote decoder, NRZ to command memory
  c. Signal Level: Manchester-logic 1 +10.3 to 13.7 V @ 4 ma, logic zero 0 to 1.5 V; Hyperpulse +18.9 to 22.9 V @ 6 ma; NRZ - logic 1 +14.2 +2.3 V @ 4 ma, logic zero 0 to +1.0 V
  d. Output Bit Rate: 16 Kbps

Physical Characteristics

Size: 30.7 cm (12.1 in) by 14.7 cm (5.8 in) by 6.85 cm (2.7 in)
Weight: 2.63 kg (5.8 lb)

Environment: Hughes Spec SS31331-003

References

Command Subsystem Specification (SS31331-180).

Design Status

This component is scheduled to be flown as part of the planned 1974 OSO-I mission.

6.6.4-2   OSO-I   REMOTE DECODER

The remote decoder shown functionally in Figure 6.6.4-4 interfaces
the command subsystem to the using subsystems and experiments.
The remote decoder receives a Manchester coded command input
(Figure 6.6.4-5) from the central decoder and converts it into
either a NRZ serial magnitude command (Figure 6.6.4-6) to one of
four user destinations or into one of 64 discrete pulse commands.
Each NRZ serial command contains a data, a clock, and an
envelope line, thus forming a three wire interface. NRZ serial
commands are automatically executed; however, an optional verifica-
tion pulse is available, which indicates whether the data trans-
fer was valid. Pulse commands are stored, parity checked, and
executed in accordance with the subsequent receipt of an execute
signal generated within the central decoder. The remote decoder
is on only when processing commands.

Figure 6.6.4-4 Remote Decoder Functional Block Diagram

6-110
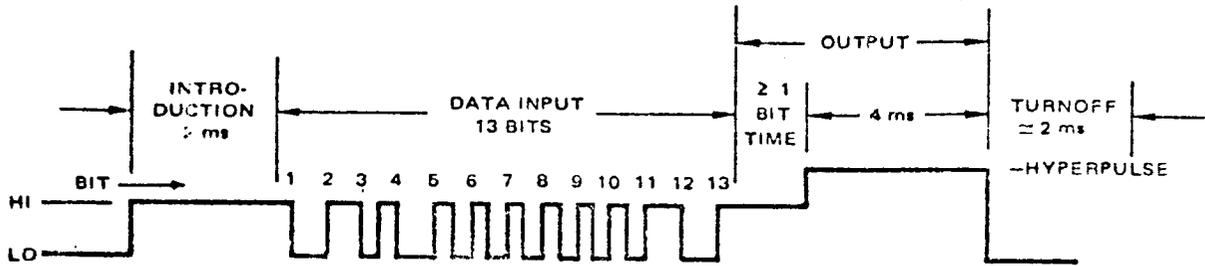
A. PULSE COMMAND
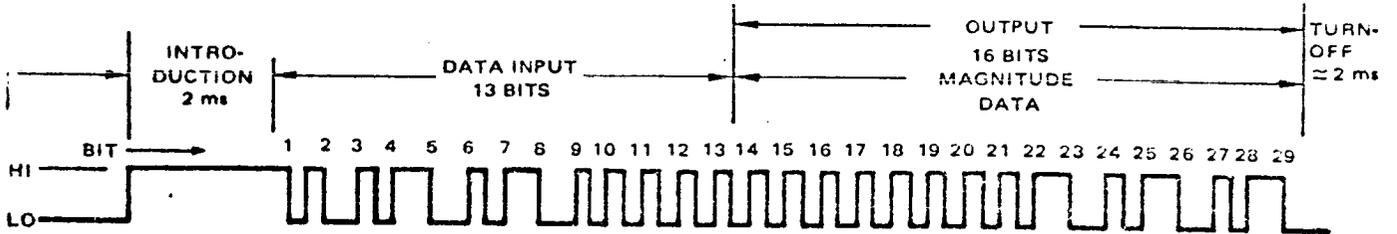
B. MAGNITUDE COMMAND

Figure 6.6.4-5   Input Command Word Formats
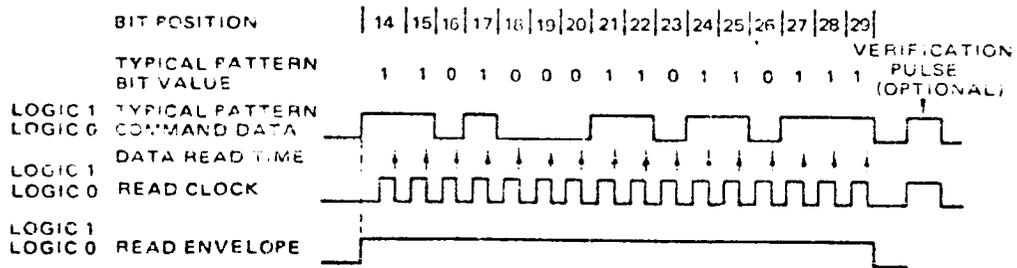
Figure 6.6.4-6   Serial Magnitude Command Output
Overall Timing Diagram

6-111

6.6.4-2   REMOTE DECODER

General Description

Program: OSO-I
Vendor:
Part Number: 3280540-100

Performance Characteristics

Input Format: A sync bit with 13 manchester coded control
                 bits followed by either a hyperpulse (pulse
                 command) or 16 manchester coded bits (magnitude
                 command)
Input Bit Rate: 16 KBPS +1%
No. of Output Commands: 64 discrete pulses, 4 16-bit serial NRZ
Output Signal: Pulse
    Pulse Signal: Logic 1   12 V @ 4 ma, logic zero 0 V,
                     duration of 4 msec +5%
    Serial NRZ: Logic 1 +12 to +17 V @ 4 ma, logic zero 0 V,
                   16 KBPS +1%
Command Rate: Max 44/sec

Physical Characteristics

Size: 10.0 cm (3.95 in) by 8.88 cm (**3.5** in) by 3.17 cm (1.25 in)
Weight: 0.227 kg (0.5 lb)

Environment: Hughes Spec SS31331-003

References

Command Subsystem Specification (SS31331-180).

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

6.6.4-3   OSO-I STORED COMMAND PROCESSOR

The Stored Command Processor (SCP) (Figure 6.6.4-7) is an input-output control center for the external random addressable 4096 x 16 NDRO core memory. The SCP generates the required timing, buffering, formatting, distribution, and comparison functions for all stored command processing.

The SCP is partitioned into four distinct functions in addition to the memory input/output interface logic. One is the Memory Load Control Logic (ML) which receives real time data from the Central Decoder, reorganizes the data, and writes the data into memory for processing at a later time. Secondly, the Memory Data Verification Formatter (MV) controls and formats complete memory readouts for ground terminal verification of the memory contents either by S-Band or real time VHF telemetry. The real time telemetry verification utilizes both the dwell mode and normal telemetry readout.

A third function is the Event Flag Processor (EP). The EP is capable of processing and generating the associated hardwired address for 12 event flags from the respective users. The fourth involves the processing of time initiated (T) and delta-time (ΔT) commands by the T and ΔT Command Processor (TP). Stored command processing in this case is initiated either by coincidence with the spacecraft clock time code (time initiated) or detection of the zero state of a presettable down counter (delta time). Con-current processing of real time ground station commands, time-initiated commands, and delta-time subroutines on a noninterference basis is accomplished by time sharing the distribution of the commands at the Central Decoder and assignment of time slots and priorities within the SCP. A total of 1348 commands are available for T and ΔT commands, 12 commands are dedicated to the event flags, and 5 commands are not used for any purpose (these are fill words associated with the event commands and memory locations 4095 and 0).
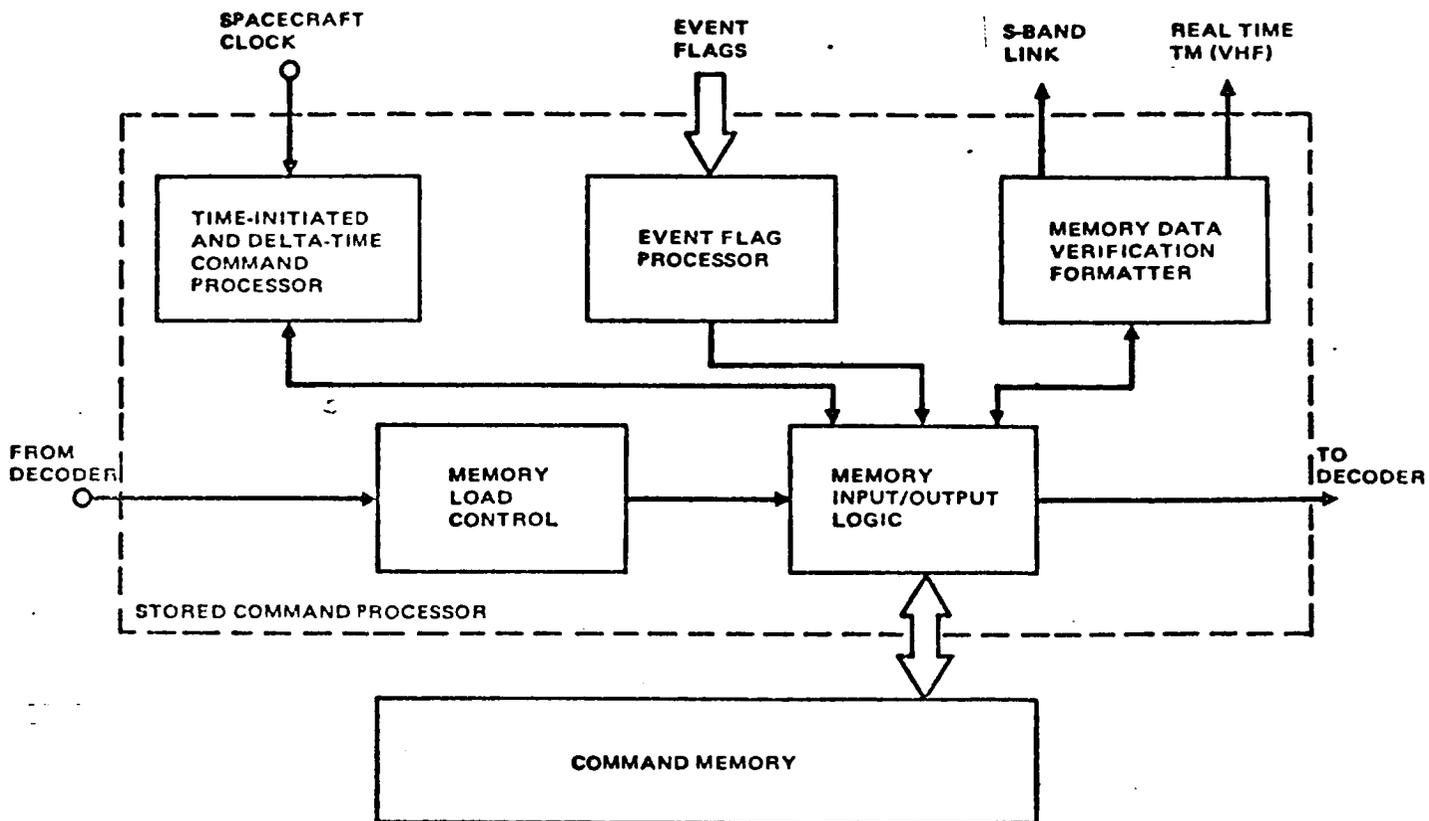
Figure 6.6.4-7.   Stored Command Processor Simplified Block Diagram

6.6.4-3   STORED COMMAND PROCESSOR

General Description

Program: OSO-I
Vendor:
Part Number: HAC 3280550-100

Performance Characteristics

Stored Command Format: Figure 6.6.4-4
Capacity: 1360 commands
    °   1348 time (Spacecraft clock) related commands-up to
    46.6 hrs after memory load

    °   12 event related commands

       Note-relative time execution capability exists for
       all commands (i.e., command processing may be referenced
       to a previously executed command or event up to a maximum
       delay of 2.9 hrs)

VHF TM Output
    °   Memory dump, address monitor data, event file data,
    and transfer command status data.

    °   NRZ-L, 8 bits/word, 32K bps

Physical Characteristics

Size: 32.3 cm (12.7 in) by 14.9 cm (5.9 in) by 7.2 cm
     (2.84 inches)
Weight: 2.4 kg (5.3 lbs)
Input Power: 5.70 watts +30 percent @ 28 Vdc
Cooling Method: Conduction

Environment: Hughes Spec SS31331-003

References

"Development Specification For Stored Command Processor," P/N
DS31331-183, Rev. A, Hughes Aircraft Company, Sep 5, 1972

"Subsystem Specification Command Subsystem," P/N SS31331-180,
Rev A, Hughes Aircraft Company, Jun 5, 1972.

Comments

Unit part of the OSO Command Subsystem and provides input/
output functions for the command memory.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

6.6.6 OAO-C PRIMARY PROCESSOR AND DATA STORAGE (PPDS)

Commands are transmitted to the spacecraft to control orientation; conduct the experiments; and transmit experiment, spacecraft status, and operational data to the ground stations. The PPDS (Figure 6.6.6-1) is a digital processing and memory element which performs the following functions with respect to these commands and space-craft operation:

o   Verifies the accuracy of commands transmitted from ground stations.

o   Stores commands in a nondestructive memory for subsequent use when the spacecraft is no longer in contact with the ground.

o   Executes commands either in real-time while in contact with a ground station or in delayed mode after transmission ceases.

o   Supplies the basic timing signals for the entire OAO-C spacecraft.

o   Provides nondestructive storage for data from the astronomical experiments as well as status data pertaining to spacecraft performance.

The PPDS receives the 1042 BPS NRZ, 4 word command shown in Figure 6.6.6-2 from the command receivers. Verification is performed by comparing the command word with the corresponding verification word which is the complement of the command word. If the command is valid, the command is processed. The first command information word is used by the PPDS to determine the command type, destination, real time or stored command for later execution, etc. Operational instructions for user subsystems is contained in the second command information word. The second information word is also used to determine the channel address for the discrete control commands issued by the PPDS.
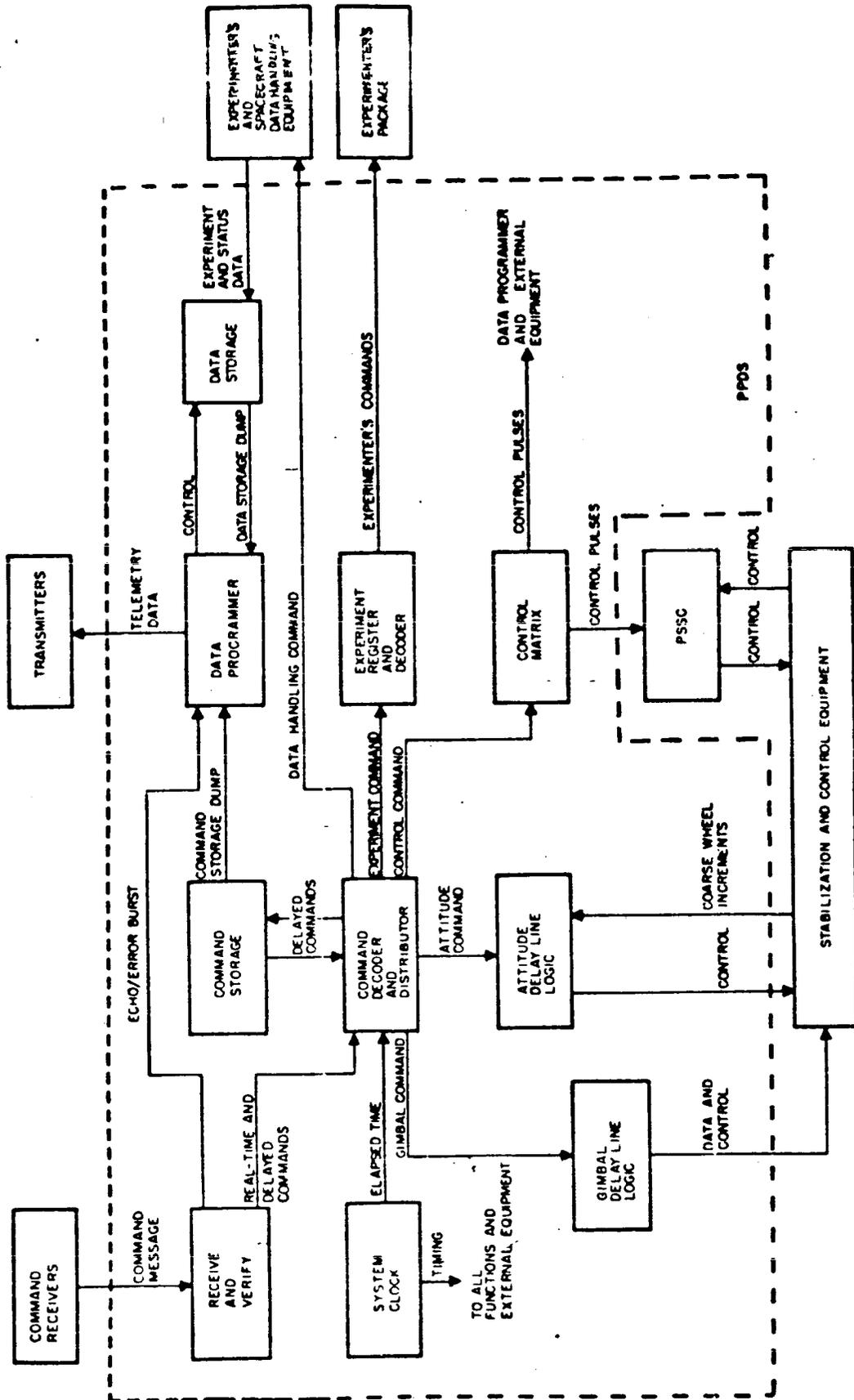
Figure 6.6.6-1. SIMPLIFIED PPDS BLOCK DIAGRAM

FIRST COMMAND WORD	FIRST VERIFICATION WORD	SECOND COMMAND WORD	SECOND VERIFICATION WORD
COMMAND INFORMATION (30 BITS SEE FIGURE 3)	1st WORD COMMAND INFORMATION COMPLEMENT	COMMAND INFORMATION (30 BITS SEE FIGURE 3)	2nd WORD COMMAND INFORMATION COMPLEMENT
*	*	*	*

REGISTRATION BITS
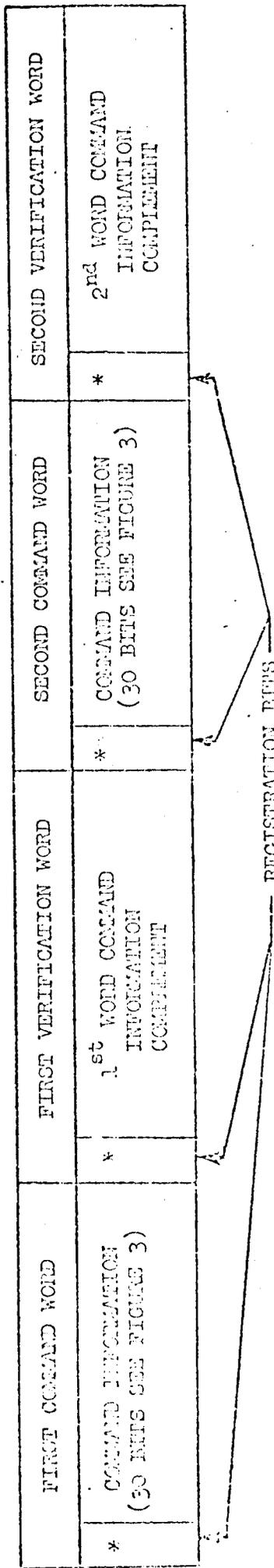
* BITS MAY BE ONES OR ZEROS

Figure 6.6.6-2. OAO COMMAND WORD STRUCTURE

6.6.6   PRIMARY PROCESSOR AND DATA STORAGE (PPDS)

General Description

Program: OAO-C
Vendor:
Part Number:

Performance Characteristics

Input from Receivers: 1042 BPS NRZ
Command Structure: 4 32 bit words (2 command words and 2
                      verification words)
Command Rate: 50 per min
Command Storage Capability: Redundantly stores 128 commands
System Clock: Provides elapsed time from zero to 1023 minutes
                 recycling to zero after 1023 minutes.
                 Synchronization of all data words and command
                 words are derived from the system clock.
Output Commands: 35 30 bit word commands @ 1042 BPS, 187
                    discretes (bit length variable), clock
                    outputs of 1.6 MHz, 50 kHz, 25 kHz, and 1.042
                    kHz

Physical Characteristics

Size:
Weight:
Input Power: $\leq$86 watts average @ 28 vdc and 18 vdc
Cooling Method:

Environment: AV-252CS-150   (See Reference)

References

"Primary Processor and Data Storage (PPDS) and Programmer and
Star Tracker Signal Controller (PSSC) Data Processing Subsystem
Orbiting Astronomical Observatory Specification For", No.
AV-252CS-150, Grumman Aircraft Engineering Corporation, 2 April 1963.

Design Status

This component was flown as part of the 1972 OAO-C mission.

6.6.8 ATM COMMAND DECODER

The ATM command decoder (Figure 6.6.8-1) receives PSK audio
signals from the command receiver and applies them to the PSK
detector. The PSK detector separates the 1 kHz and 2 kHz signals,
and makes a comparison to determine if the 2 kHz signal is in-
phase (sub-bit=1) or out-of-phase (sub-bit=0) with the 1 kHz
reference signal. The sub-bits are decoded in groups of 5 and
tested in a sub-bits shift register. If the sub-bit pattern
is a valid "0" or "1", it is shifted into the main shift register.
If the 35 bit word has a valid vehicle address, a 90 msec Address
Verification Pulse (AVP) is issued to the telemetry for transmission
to the STDN station, the command word data is gated to the output
device and the command decoder is reset.

Figure 6.6.8-1. COMMAND DECODER BLOCK DIAGRAM

6.6.8 COMMAND DECODER

General Description

Program: Skylab ATM
Vendor: SCI
Part Number: MSFC No. 50M12746-1, SCI No. 1825000-1

Performance Characteristics

Number of Output Commands: Limited only by output device (i.e.,
                                computer and   selector)
Type Input Modulation: 1 kHz and 2 kHz PSK/FM
Command Bit Rate: 1000 sub-bits/sec (200 bps)
Command Word Rate: 265 ms/CMD word
Address Verification Pulse: 90 milliseconds pulse
Output Enable Pulse: 50 milliseconds pulse
Reset Output Pulse: 20 msec pulse delayed 50 msec from start of AVP
Execute Output Pulse: 25 msec pulse delayed 20 msec

Physical Characteristics

Size: 10.79 cm (4.24 inch) by   22.6 cm (8.9 inch) by
         18.39 cm (7.24 in)
Weight: 4.08 Kg (9.0 lbs)
Input Power: 5.5 W (nominal), 26 W (maximum) at +28 vdc (-6, +10 vdc)

Environment: MIL-E-5272

References

ICD 50M13126, "Skylab Program Operational Data Book", MSC-01549.

"Skylab Operations Handbook", ATM, Volume 1, 27 Marcy 1972, MSFC-205.

"ATM Command Decoder Operations Handbook", Space Craft Inc., No date.

Design Status

This component was flown as part of the 1973 Skylab mission.

6.6.11   MARINER MARS COMMAND DECODER

The Mariner Mars 71 command decoder (Figure 6.6.11-1) is
comprised of a shift register, program control counter, matrix
drivers, isolation switches, pulse synchronizer and associated
control logic. The shift register is used as a means of storing
detected bits and recognizing the command word subaddresses and
direct command addresses. An integrated circuit matrix driver
interfaces the decoder shift register with the universal isolation
switches' decode matrix. The command decoder is interrogated
with a synchronizer circuit to assure that the 100 msec pulse
to the command word user, the detector bit sync, and the command
events begin concurrently with a transition edge of the spacecraft
2.4 kHz power. This synchronization prevents a universal isolation
switch from conducting momentarily, shutting off, and then conducting
for the remainder of the 100 msec. The universal isolation switch
is used in all command word interfaces with spacecraft user sub-
systems and in the command event and detector status interfaces
between the command decoder and the flight telemetry subsystem.
Universal isolation switches (UIS) provide dc voltage isolation
between the flight command subsystem and other spacecraft sub-
systems. Each UIS circuit contains its own decoding matrix.
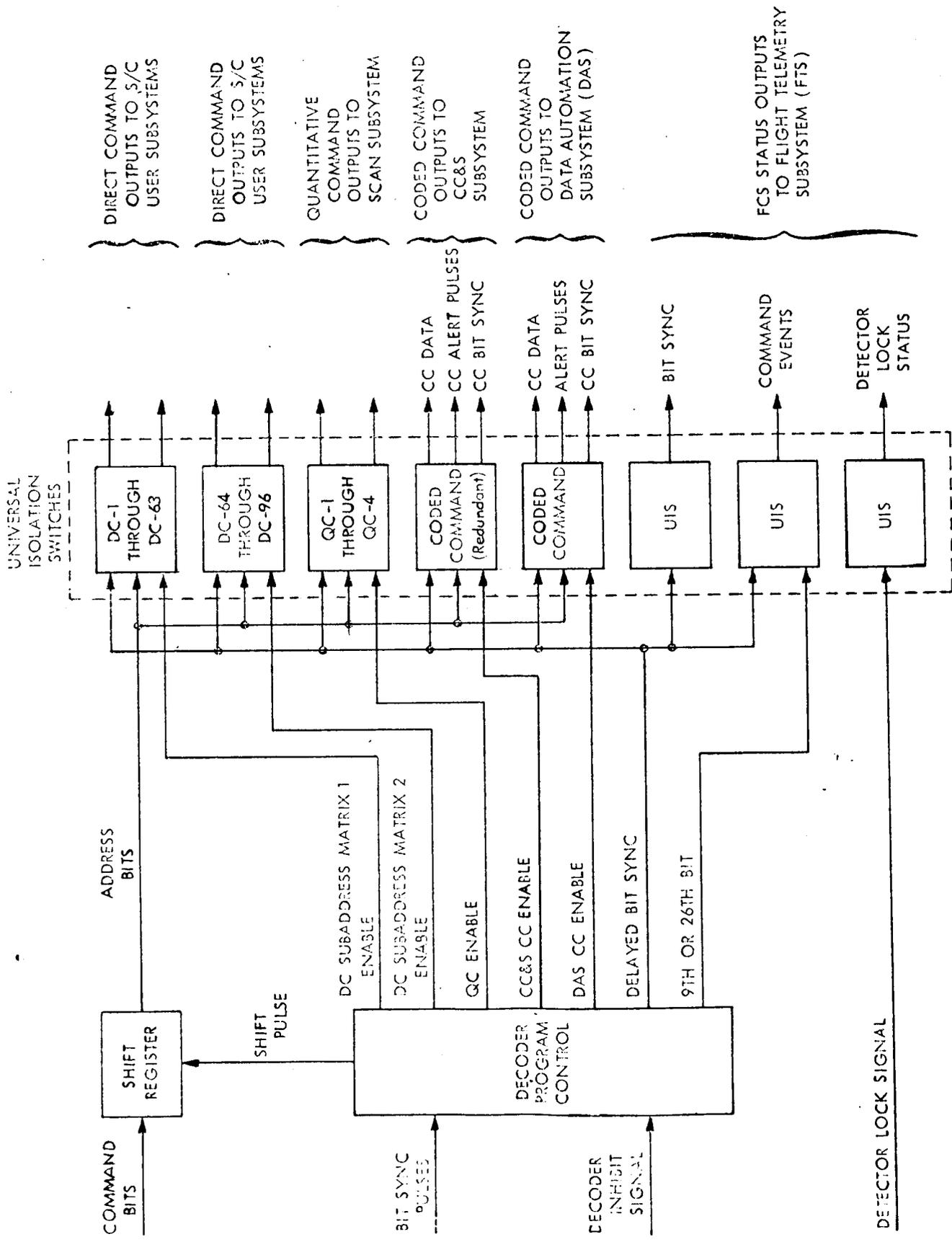Integrated circuits are used in decoder logic.

Figure 6.6.11-1. MARINER MARS 71 COMMAND DECODER

7.1.3   HEAO-A REMOTE MULTIPLEXING UNIT (RMU)

Remote multiplexing units consist of a control unit and expander units located throughout the spacecraft to accommodate experiment and housekeeping data. Housekeeping submultiplexers are located within the experiments (non-redundant). Redundant remote multiplexer control units are provided to service each experiment. The RMUs can accept four types of data: analog, bilevel, parallel digital, and serial digital words (the mix is under CPU control). Input capacity is 256 data channels (32 in redundant RMU and 224 in submultiplexer).

A block diagram of the RMU is shown in Figure 7.1.3-1. This basic RMU contains the transmitting and receiving circuits for communication with CPU, control logic, A/D converter, the basic 32-data channel multiplexer, and designated submultiplexers. Operationally the RMU receives from the CPU a clock signal and an instruction word containing a channel address, a word type, and a message type. Upon proper address recognition the selected RMU turns on its standby circuits and the channel address selects the data input channel to be sampled. The word type programs the RMU to process one of the four types of data. If the data is analog it is converted to an 8-bit digital word. If bilevel, eight inputs are sequentially sampled to form a 8-bit word. If parallel digital, the multiplexer operates sequentially.

In addition, the RMU may control and sample submultiplexers located in the experiments. The submultiplexer is incremented by the frame rate signal if it is to be sampled in a minor frame word slot or incremented by the sub-frame rate signal if it is to be sampled in a subcommutator word. The data sampling rate is the same as the RMU sampling rate.

Figure 7.1.3-1. RMU Block Diagram

7.1.3   HEAO-A REMOTE MULTIPLEXING UNIT (RMU)

General Description

Program: HEAO-A
Vendor: TRW
Part Number: TRW Equipment Specification Number: EQ4-1103

Performance Characteristics

Maximum Number of Data Channels: 256; 32 in redundant RMU
and up to 224 in nonredundant
submultiplexer (RMU expander).

Analog Inputs: Level: 0 to 5 volts nominal; input impedance $>$ 5
megohms; source resistance of 2K ohms max; accuracy
from RMU input to CPU output is $\pm$ 0.5% of full scale
(accumulated errors).

Digital Inputs: Binary "1" = nominal 5V; binary "0" = nominal OV;
input impedance minimum of 1 megohm; sampling rate
of each gate 9.76 us per bit for digital and 78 us
nominal per sample for analog; bit error in digital
transfer from RMU input to CPU output no greater
than one erroneous bit in 10^6.

Bi-Level (discretes):   Sampled in groups of 8 bits or less; true
state amplitude of +2.4 to +5.5 V; false
state amplitude of -0.5 to +0.5 V; source
resistance = 12K ohms max.

Parallel Digital Inputs: Sampled in groups of 8 bits; data can
not be updated during sampling; no
capability in submux; true state
amplitude of +2.4 to +4.5 V; false state
amplitude of -0.5 to +0.5 volts; source
resistance = 2K ohms max.

Serial Digital Inputs: NRZ data at RMU data sampling bit rate;
true state amplitude of +2.4 to +4.5 V;
false state amplitude of -0.5 to +0.5 V;
source resistance = 2K ohms max.

Over/Under Voltage Protection: Allowable $\pm$33V; 0.1 sec. recovery
time; data channel isolation; no
damage from $\pm$50 V spikes of 10 usec
or less.

A/D Converter: Encode each analog sample to 8-bit binary word; most
signigicant bit first. Zero scale output digital
equivalent of 0 V analog = binary count of 3. Full
scale output: digital equivalent of 5 V analog =
binary count of 253. Under V output: V of -60 mili-
volts or less digital equivalent = binary count of 0.

Monotonicity: provides digital equivalent for successive samples of increasing or decreasing analog voltages, increasing or decreasing progression respectively; no overlapping of consecutive codes or missing codes. Switching point separation: not less than 4 millivolts between 2 consecutive switching points; probability of correct codes rather than adjacent code is 0.999.

Output: Control signals - Bit rate, word rate, frame rate, subframe rate, format status, read envelope.
            Data - Manchester data to CPU
            Telemetry rate - 25.6 kbps (selectable from 23 kbps
                            to 28 kbps)

Physical Characteristics

Size: Basic RMU = 2.8 cm(1.1 in) by 15.2 cm(6.0 in) by 20.3 cm(8.0 in)
            +1 expander=5.6 cm(2.2 in) by 15.2 cm(6.0 in) by 20.3 cm(8.0 in)
            +2 expanders=8.4 cm(3.3 in) by 15.2 cm(6.0 in) by 20.3 cm(8.0in)

Weight: Basic RMU = .5 kg (1.0 lb.) +.5 kg (1.0 lb.) for each expander.

Input Power: $\pm$ 12 Vdc; +5 Vdc; 2.5 W max analog sampling;
                 1.5 W max digital sampling; 0.5 W max. standby

References

TRW, HEAO Preliminary Requirements Review, Volume III - A, "Command and Data Handling System," July 24, 1972

TRW, HEAO Design Approach, Aug. 27, 1971.

Design Status

The HEAO-A Program is currently in a state of redefinition.
This component is a viable candidate for application in the 1977
HEAO-A mission.

7.1.4 OSO-I DUAL REMOTE MULTIPLEXER

The dual remote multiplexer contains a pair of single remote multiplexers, each with 32 input channels. Input signals consist of high level analog data, parallel bilevel digital data, and serial digital data in various ratios. These data are gated in a pulse amplitude modulated (PAM) format onto a single output line in a time controlled sequence. An analog reference return is provided as a data return output with the PAM output data.

Figure 7.1.4-1 is a block diagram of a single remote multiplexer (RM). Each RM is programmed to operate in one of four different data handling configurations by external wiring of two connector pins. Upon receipt of a "power on" signal and an address on a single input control line, the RM performs as follows:

a) The high level analog input data is multiplexed onto the PAM output line for subsequent conversion to an 8-bit serial data word.

b) The parallel bilevel digital input data is sampled in 8-bit bytes and gated onto the PAM output line as an 8-bit serial word.

c) The serial digital input data is sampled in 8-bit bytes and gated onto the PAM output line by means of internally generated read clock and read envelope signals. One read clock and 16 read envelopes are available to provide up to 16 channels for multiplexing serial digital data.

Each RM provides synchronous switching of a precision constant current input onto selected input channels for signal conditioning of external transducers. Power strobing is utilized to minimize power dissipation during standby or noninterrogate periods.
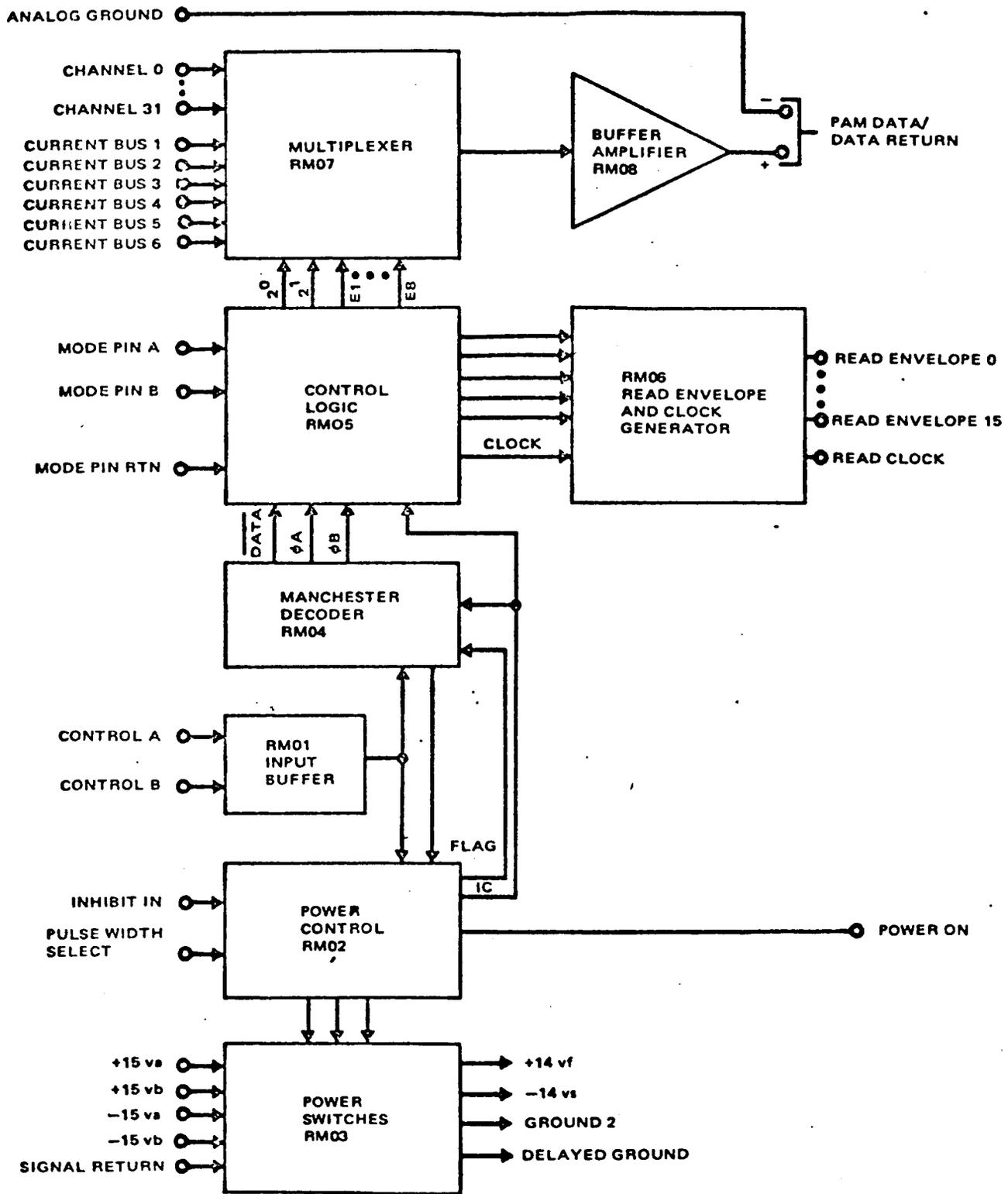
7-5

Figure 7.1.4-1. Single Remote Multiplexer

7.1.4   OSO-I DUAL REMOTE MULTIPLEXER

General Description

Program: OSO-I
Vendor:
Part Number: HAC 3280630-100 (Spec No. DS31331-164)

Performance Characteristics

Max No. of TM Inputs: 32
Data Mux Options: High level analog (A), parallel bilevel
                     digital (P), serial digital (S).
Input Configuration: Mode 1:32P; Mode 2:5A or S, 24P;
                        Mode 3:14 A or S, 8 A or P, 8P;
                        Mode 4:16 A or S
Output Format: NRZ-L/PAM
Bit Rate: 32 kbps
Address Control: 10 bit serial manchester coded digital word
On/Off Control: PWM on input control line
Bilevel Bit Sample Time: 31.2 microseconds
Analog Word Sample Time: 312.5 microseconds

Physical Characteristics

Size: 10.20 cm (4.0 in) by 8.89 cm (3.5 in) by 3.18 cm
         (1.25 in)
Weight: 0.23 kg (0.5 lbs)
Input Power: 1.01 watts power strobing interrogate
                (.023 W standby when not being interrogated,
                0.006 watt off)
Cooling Method: Cold Plate surface mounting

Environment: Hughes Spec SS31331-003

References

Data Handling and TM Subsystem, Spec SS31331-160
Hughes Aircraft, Sept. 8, 1972

Remote Telemetry Modules, NASA/GFSC Contract No. NAS5-11587,
Prepared by Hughes Aircraft Co., Oct. 1969.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

7.1.7-1   SKYLAB AM/MDA HIGH LEVEL MULTIPLEXER

The high level multiplexer (Figure 7.1.7-1) has thirty-two 0 to 5 volt
analog input channels and forty event input channels. The 32 analog
channels are sampled and time-multiplexed to provide a serial
0 to 5 Vdc PAM output to the interface box. The 40 event channels
include 16 bilevel pulse and 24 bilevel channels. The 24 channels
are signal conditioned so that an input of 5 Vdc or less results
in a "zero" bit output and an input of 15 Vdc or greater results
in "one" bit output. The 24 signal conditioned outputs are
sequentially sampled as three sets of eight channel groups. These
are bused into eight parallel output lines.

The 16 bilevel pulse channels are signal conditioned to inverted
outputs, so that an input of 5 Vdc or less results in a "one"
bit output and an input of 15 Vdc or greater results in a "zero"
bit output. If a momentary drop of an input to 5 volts or less
occurs for at least 10 milliseconds, the next sampled output will
remember the occurance by a "one" bit output. The 16 signal
conditioned outputs are sequentially sampled in two sets of eight
channel groups and bused into the eight parallel output lines,
connected to the interface box. The eight parallel lines are
used for bilevel and bilevel pulse data.

Figure 7.1.7-1. High Level Multiplexer

7.1.7-1   SKYLAB AM/MDA HIGH LEVEL MULTIPLEXER

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input, Analog Hi Level: 32 at 1.25 SPS
Input Discretes: 24 bilevel at 10 SPS, 16 bilevel pulse
                    at 10 SPS
Output Analog: Serial 0-5 Vdc PAM to the interface box
                  at input sampling rate (analog data)
Output Digital: 8 parallel lines to interface box at input
                   sampling rate (bilevel data)

Physical Characteristics

Size:
Weight:
Input Power: 0.050 watts at +5 Vdc, 0.020 watts at -5 Vdc

References

Skylab Operations Handbook, Vol. 1, MSC 04727, 20 July 1970,
Revised 24 January 1972.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.1.7-2   SKYLAB AM/MDA LOW LEVEL MULTIPLEXER

The low level multiplexer (Figure 7.1.7-2) has thirty-two 0 to
20 mv analog input channels. The 32 channels are sampled and
time-multiplexed to provide a serial 0 to 20 mv PAM stream to
a DC amplifier. The DC amplifier's input and output are grounded
between pulses by an amplifier clamp switch. The DC amplifier's
0 to 5 Vdc PAM output is routed to the programmer or the interface
box.
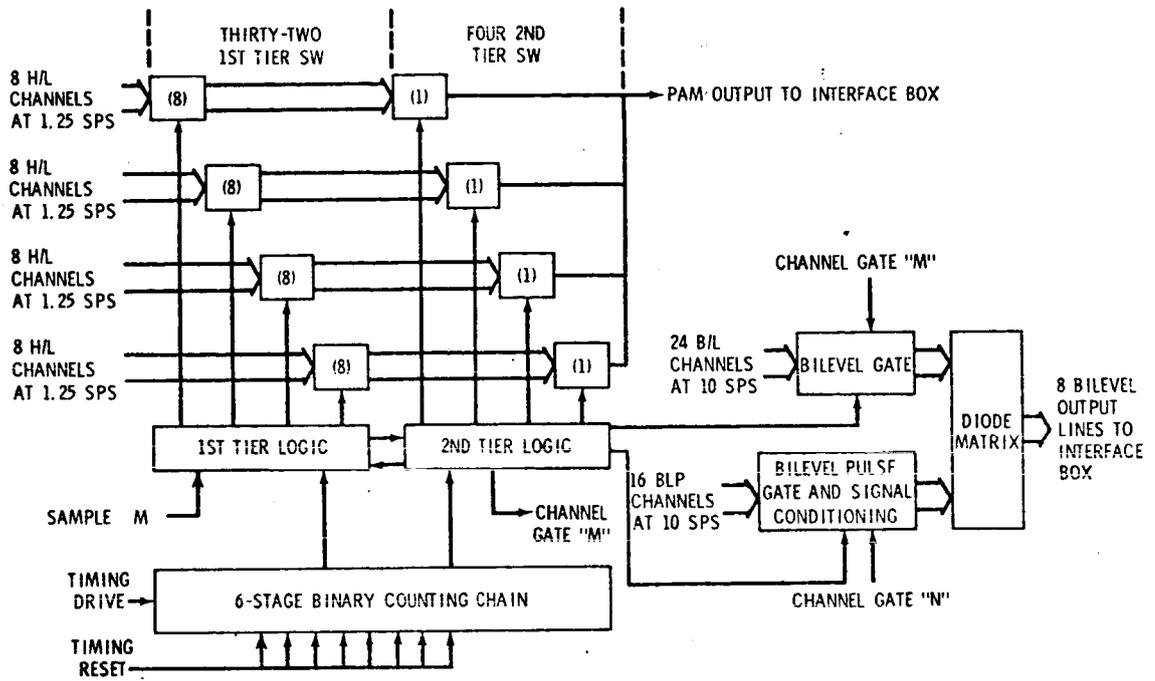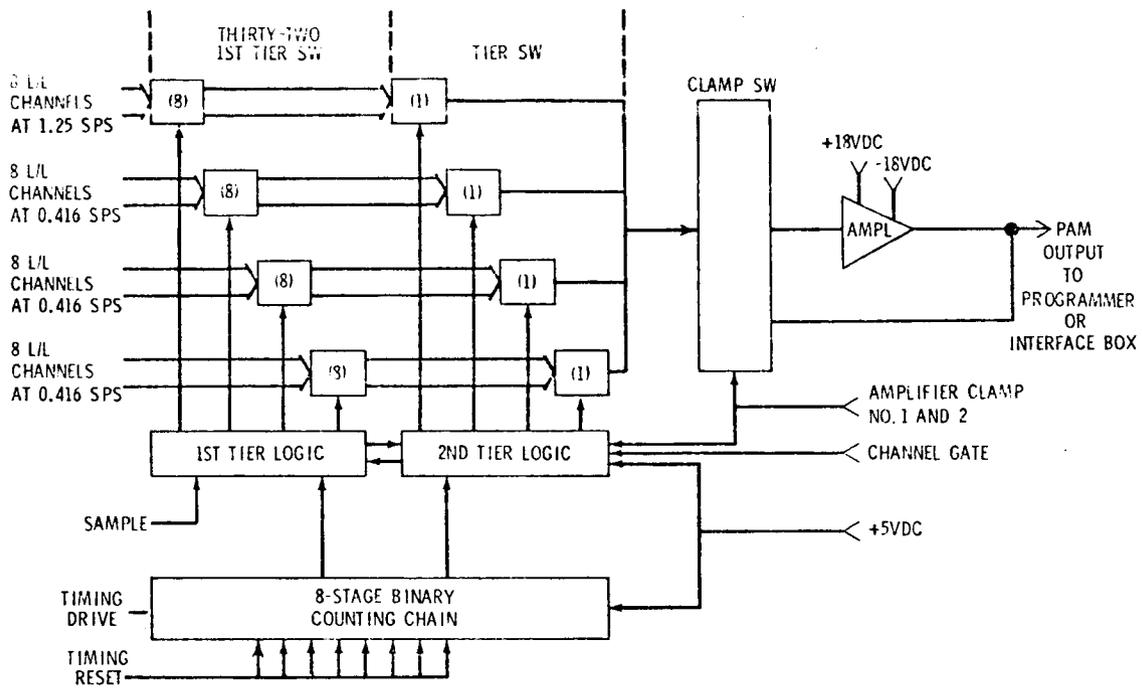
Figure 7.1.7-2   Low Level Multiplexer

7.1.7-2   SKYLAB AM/MDA LOW LEVEL MULTIPLEXER

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input Analog (20 mv) low level: 8 at 1.25 SPS, 24 at 0.416 SPS
Output Analog: Serial 0-5 Vdc PAM stream at input sample rate
                  (to programmer or interface box)

Physical Characteristics

Size:
Weight:
Input Power: 0.036 watts at +18 Vdc; 0.043 watts at -18 Vdc;
                0.060 watts at +5 Vdc

References

Skylab Operations Handbook, Vol. 1, MSC 04727, 20 July 1970,
Revised 24 January 1972

Design Status

This component was flown as part of the 1973 Skylab mission.

7.1.8-1   SKYLAB ATM MODEL 270 MULTIPLEXER

The Model 270 mux (Figure 7.1.8-1) is basically a 30 channel component. Channels 1 through 27 of these 30 primary channels are data channels, 28 is the frame identification channel, and 29 and 30 are amplitude reference channels. Primary channels 1 through 23 can be submultiplexed with 10 subchannels each. This gives the Model 270 the capability of accepting 23 x 10 + 4 (or 234) different measurements. Channels 29 and 30 carry a precise 5 Vdc reference level and are bridged together to form a constant amplitude and location reference.

Primary channels 1 through 30 are repeatedly monitored in sequence. One complete sequence constitutes a frame. In Figure 7.1.8-1, primary channels 1 through 23 are shown receiving outputs from 23 input submultiplexers. During each complete frame of 30 channels, only one input to each submultiplexer is sampled by the respective primary channel. Therefore, 10 frames are required to sample all inputs to each submultiplexer. These 10 frames constitute a master frame. Primary channel 28 is held to a zero level except during frame 10, when a 5 Vdc level is inserted. This change in reference level provides master frame identification.
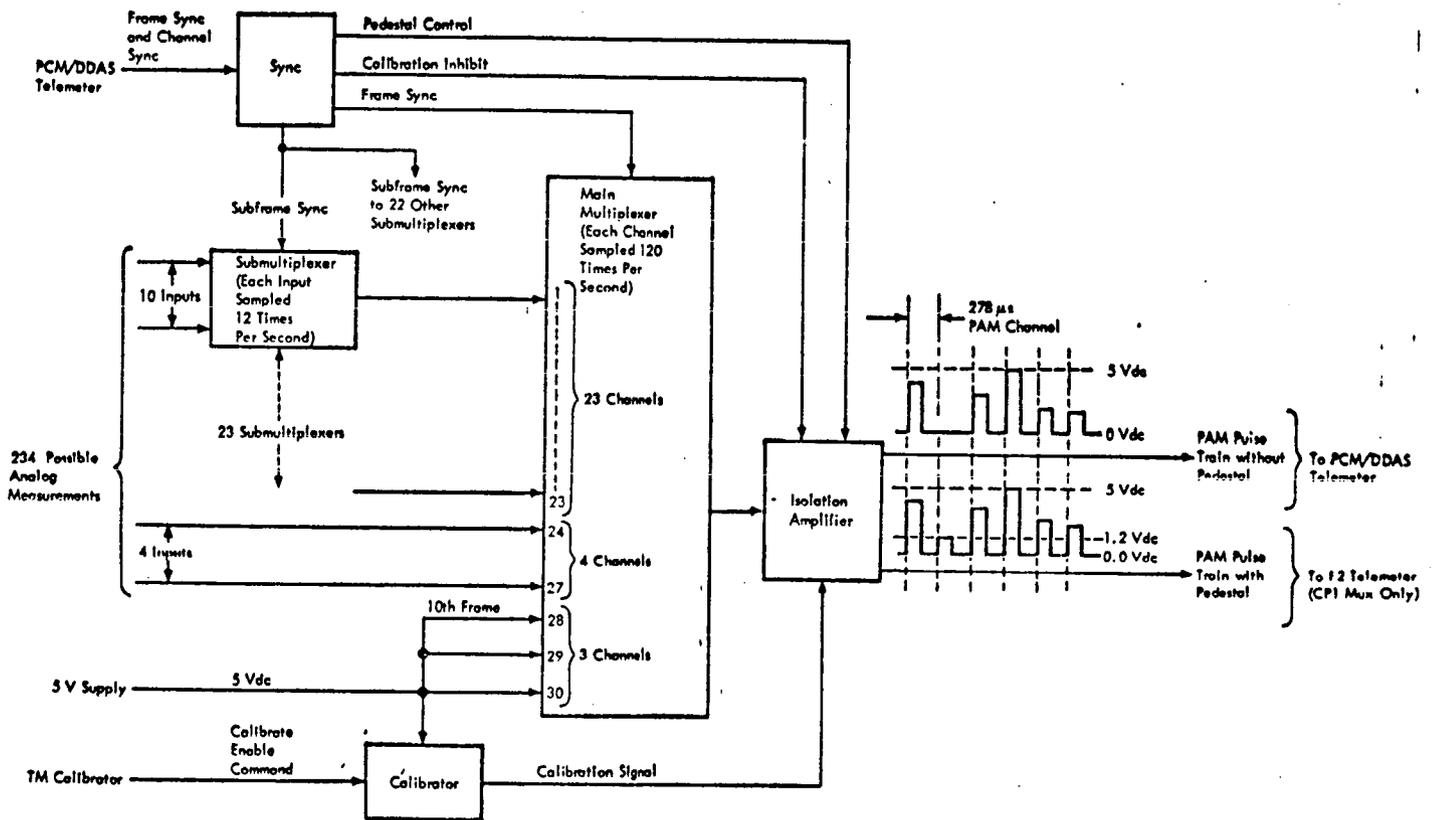
MODEL 270 MULTIPLEXER BLOCK DIAGRAM

Figure 7.1.8-1

7.1.8-1   SKYLAB ATM MODEL 270 MULTIPLEXER

General Description

Program: Skylab ATM
Vendor: Brown-Teledyne
Part Number:

Performance Characteristics

Input Signal Level: 0 to 5 V (nom)
Input Impedance: 100K ohms (min)
Number of Data Inputs: 234 (max)
Data Sample Rate: 12 and 120 sps (or 4 and 40 sps)
Data Output: PAM pulse train (27 data channels)

Physical Characteristics

Size: 15.2 cm (6 inch) by 27.9 cm (11 inch) by 33 cm (13 inch)
Weight: 9.5 kg (21 lbs)
Cooling Method: Cold plate mounting

References

"Skylab Operational Data Book", Volume IV (MSC-01549), Rev. A,
October 1972.

"Maintenance and Instruction Manual", (50M66506) for the 270
Multiplexer.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.1.8-2   SKYLAB ATM MODEL 410 REMOTE DIGITAL MULTIPLEXERS (RDM)

A Model 410 RDM (Figure 7.1.8-2) can accept up to 100 inputs in the form of discretes, bits of digital data, or both. These discretes and data bits are temporarily stored in the RDM as ten 10 bit words, then sent out in a repeating sequence to the PCM/DDAS telemeter. The RDM is preprogrammed to determine the order of monitoring its inputs and the order of sending output words to the telemeter. The RDM is synchronized from the PCM/DDAS telemeter to insure that the output words appear at the instant the PCM/DDAS telemeter is prepared to accept them.
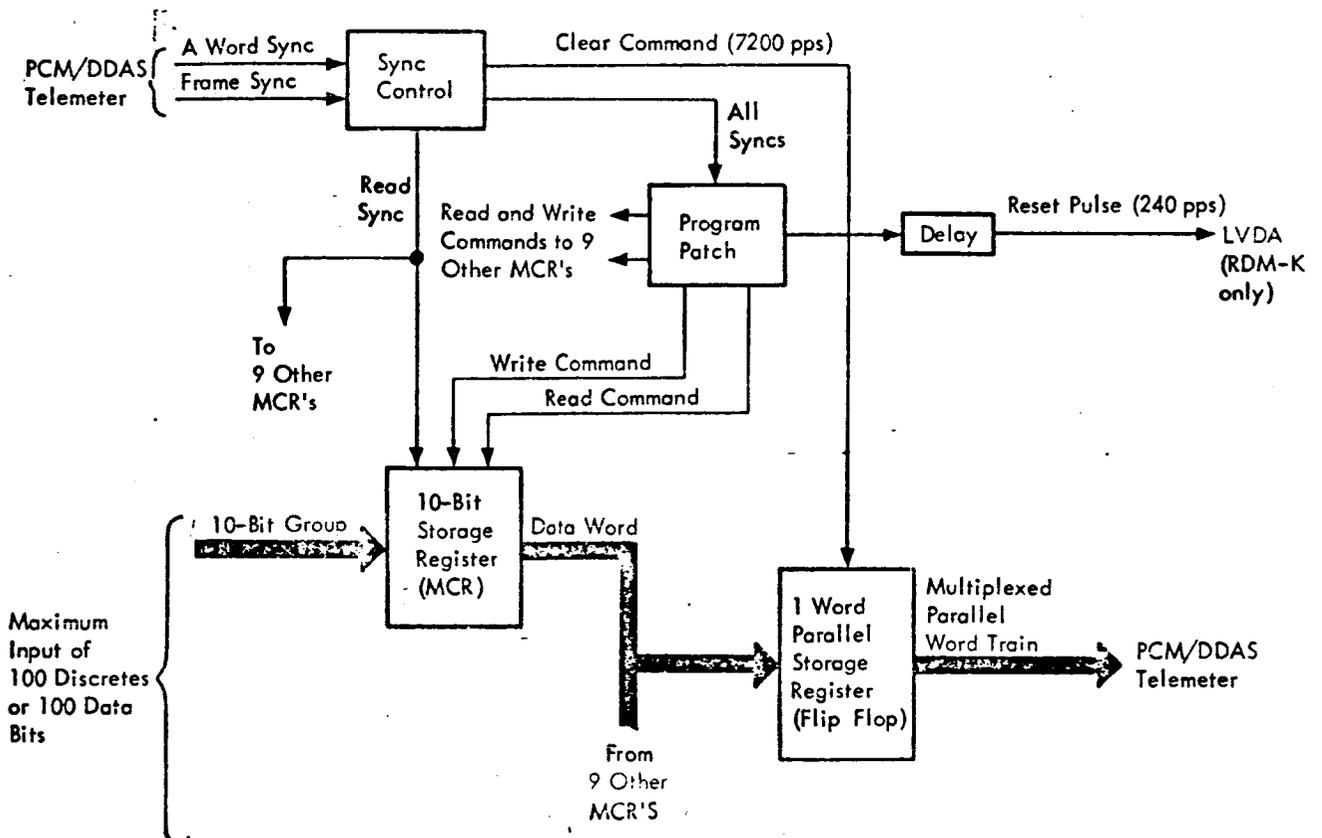
MODEL 410 REMOTE DIGITAL MUX (RDM)

Figure 7.1.8-2

7-17

7.1.8-2   SKYLAB ATM MODEL 410 REMOTE DIGITAL MULTIPLEXER (RDM)

General Description

Program: Skylab ATM
Vendor: SCI
Part Number:

Performance Characteristics

Input Signal: 0 or 5 Vdc
                   Logic "1" - 3.5 to 6.0 Vdc
                   Logic "0" - 0 to 1.5 Vdc

                   0 or 28 vdc
                   Logic "1" - 19.6 to 33.6 Vdc
                   Logic "0" - 0 to 8.4 Vdc
Input Impedance: 100K ohms (min)
Number of Inputs: 100 bits
Number of Outputs: 10 words
Output Signal Level: 0 or 5 V (nom)
Data Sample Rate: 12 or 120 sps
Sync Signals (two waveforms):   3.6 kHz squarewave, 278 microseconds
                                  pulse with a PRR of 4 pps

Physical Characteristics

Size: 15.2 cm (6 inch) by 27.9 cm (11 inch) by 25.4 cm (10 inch)
Weight: 7.3 kg (16 lbs)
Cooling Method: Cold plate mounting

References

"Skylab Operational Data Book", Volume IV, Rev. A, MSC-01549,
October 1972.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.1.8-3   SKYLAB ATM MODEL 103 REMOTE ANALOG SUBMULTIPLEXER (RASM)

The ATM RASM (Figure 7.1.8-3) accepts 60 low level inputs from
signal conditioners or transducers. The inputs are time shared,
amplified, and fed to the Model 270 multiplexer. Sync signals
from the Model 270 multiplexer synchronize the RASM with the
interval timing of the Model 270 multiplexer.

Six data output channels are provided by the RASM. These channels
feed PAM data to the Model 270 multiplexer.
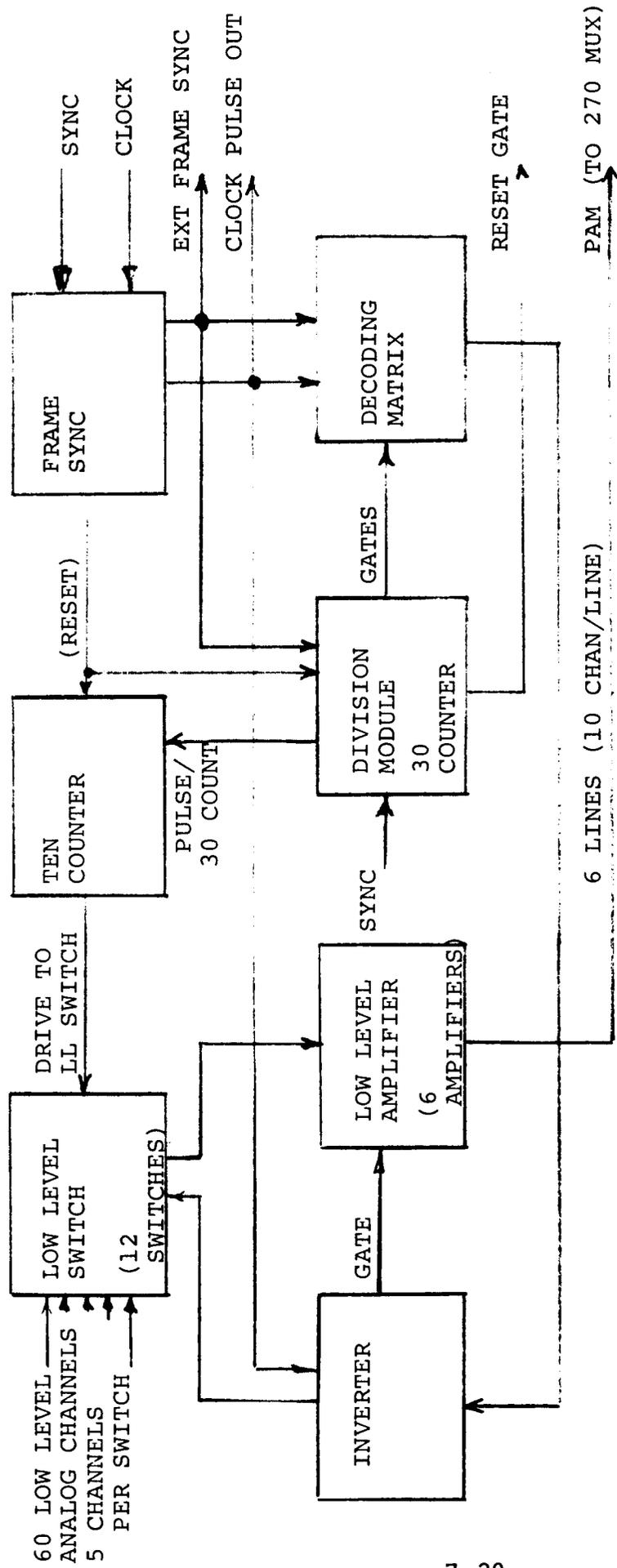
Figure 7.1.8-3. RASM Block Diagram

7.1.8-3   SKYLAB ATM MODEL 103 REMOTE ANALOG SUBMULTIPLEXER
           (RASM)

General Description

Program: Skylab ATM
Vendor:
Part Number:

Performance Characteristics

Input Signal Level: 0 to 20 MV dc
Number of Input Signals: 60
Sample Rate: 12 sps
Number of Outputs: 6 Channels
Frame Synchronization Signals: Required from 270 Mux
   1)   Amplitude 5.0 ± 1.0 Vdc
   2)   Duration   278 usec +2%
   3)   Repetition Rate 12 pps $\pm$ 0.1%

Physical Characteristics

Size: 24.94 cm (9.82 in) by 19.30 cm (7.6 in) by 15.52 cm
     (6.11 inches)
Weight: 8.62 kg (19 lbs)

References

Skylab Operational Data Book Volume IV (MSC-01549)
Rev. A, October 1972

Maintenance and Instruction Manual for Model 103 RASM (50M66532)

Design Status

This component was flown as part of the 1973 Skylab mission.

7.1.11   MARINER MARS ANALOG MULTIPLEXER

The Mariner Mars Analog Multiplexer consists of two major parts:
analog commutator and analog-to-digital converter (ADC).

The analog commutator is composed of 101 single and double pole,
field effect transistor (FET), switches arranged as shown on
Figure 7.1.11-1. Control signals for the switches are generated
by the programmer. Bucking supplies are used to condition the
+1.5 volt signal or the 500 to 600 millivolts signal to either
$\overline{0}$ to 3 volts or 0 to 100 millivolts, respectively. The 0 to
100-millivolt signals are than amplified through the low level
amplifier to 0 to 3 volts.

The ADC (Figure 7.1.11-2) uses the successive approximation
technique to encode the analog input voltage (0 to 3.0 V) into
an equivalent 7-bit binary number. This process takes 58.31 μsec.
The combiner takes these equivalent bits from the ADC digitizer,
forms a 7-bit NRZ word, and serially feeds this data to the data
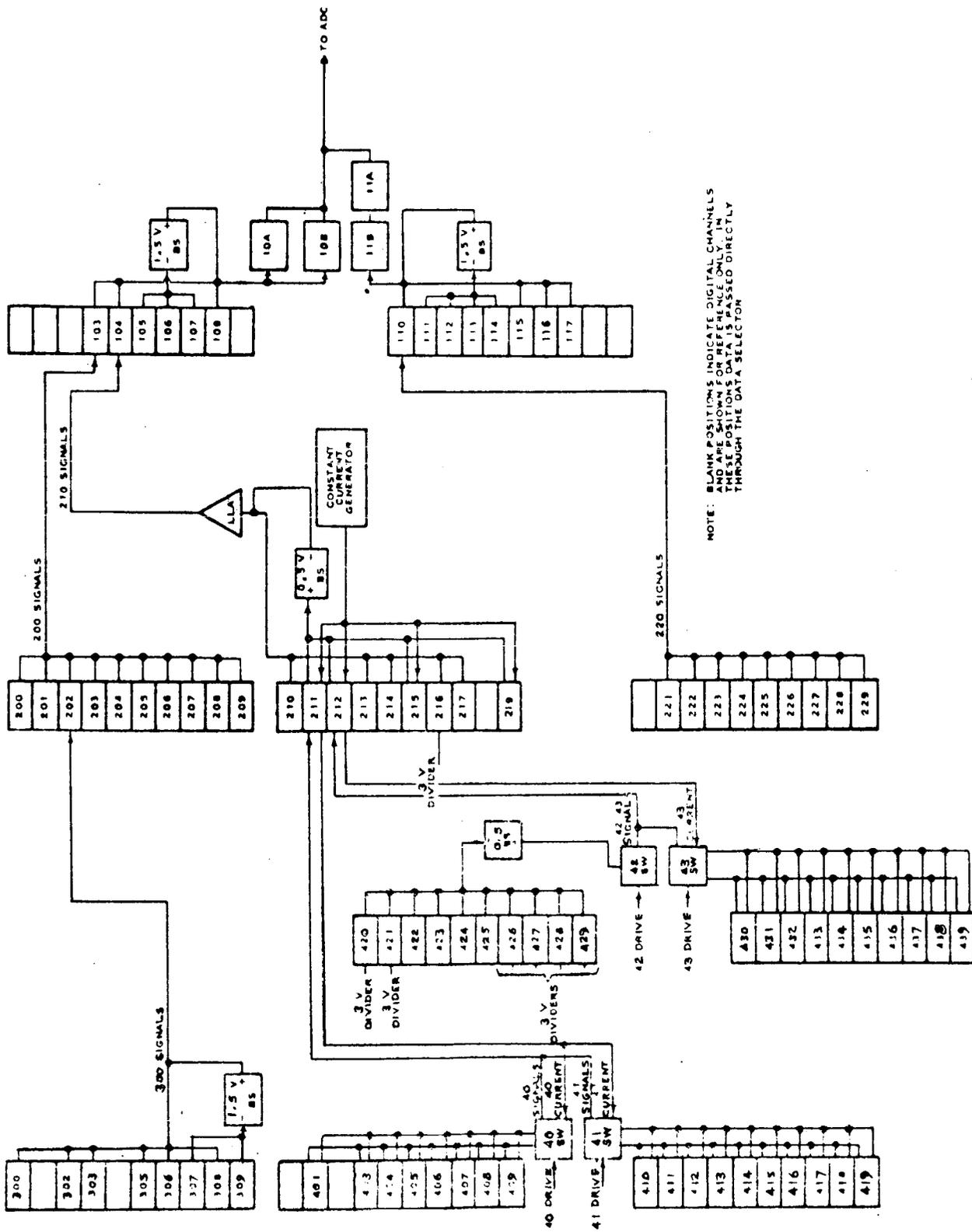processor with the MSB first. The ADC is standby redundant.

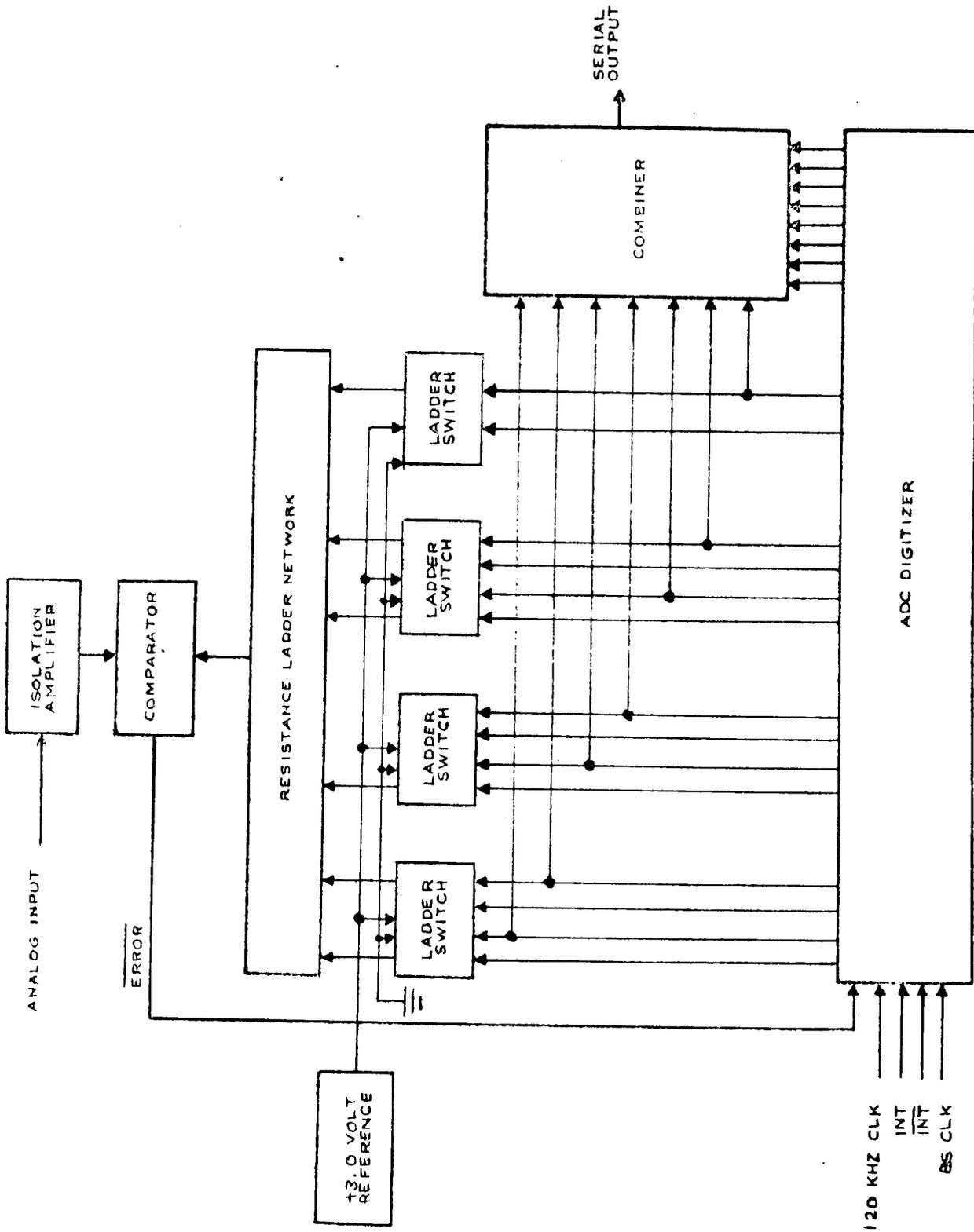Figure 7.1.11-1.   Commutator Block Diagram

Figure 7.1.11-2 . ADC Block Diagram

7.2.2   ERTS-B WIDEBAND VIDEO TAPE RECORDER

Two Wideband Video Tape Recorders (WBVTR) record, store, and reproduce the data outputs from either the Return Beam Vidicon (RBV) or the Multi-spectral Scanner (MSS) during remote sensing operations (Figure 7.3.2-1). Each recorder can record 30 minutes of either 3.2 MHz video analog data from the RBV or 15 Mbps digital data from the MSS. Data are recorded by four heads (on one wheel) rotating across the 2 inch wide tape (Figure 7.3.2-2). Recording and playback are each at 30.5 cm/sec (12 inches per second) tape speed and in the same direction. Total usable tape length is 548 m (1,800 feet) for each recorder.

The RBV analog video signal is transformed into the FM domain by video circuitry in the WBVTR. The signal is received as a negative analog signal, is dc level shifted, frequency modulated, amplified and recorded. To insure head switching during the horizontal blanking interval of the video signal during playback, the RBV signal is rephased to the WBVTR headwheel at the beginning of each triplet exposure during recording. In playback, the RBV signal is read out sequentially by the same four rotating heads, with appropriate switching, producing a continuous RBV signal in the FM domain. The signal is then demodulated on the ground producing the original analog video waveform.

The MSS digital video data is received as a Non-Return to Zero Level (NRZ-L), 15 Mbps data stream. In the WBVTR, the data stream is reclocked and then frequency modulates an FM carrier. The resulting frequency shift keyed (FSK) signal is recorded by four rotating heads. The MSS data are recorded asynchronously; that is, the data stream and rotating heads are not synchronized. In playback, the MSS signal is read out sequentially by the same four rotating heads, with switching and demodulation producing a continuous NRZ-L, 15 Mbps data stream.

Each WBVTR can record and playback either RBV or MSS data at any given time. The selection of RBV data or MSS data for each WBVTR during record or playback, plus appropriate tape motion to select the proper tape location, is made by appropriate ground commands which can be stored by spacecraft equipment for subsequent remote execution.
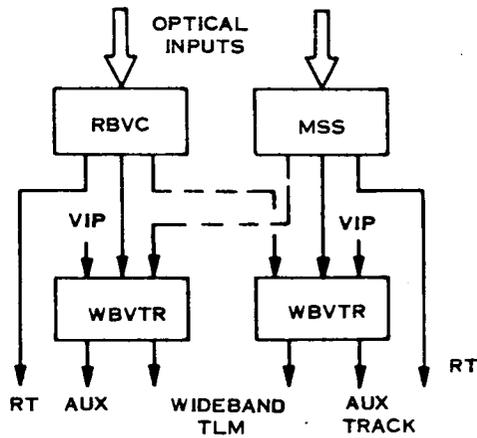
WIDEBAND VIDEO TAPE RECORDER SYSTEM BLOCK DIAGRAM

Figure 7.2.2-1
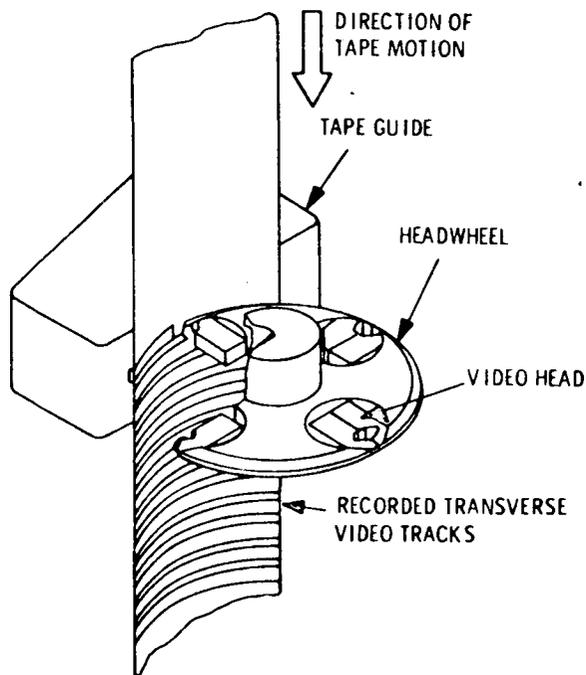
WIDEBAND VIDEO TAPE RECORDER ROTARY HEAD RECORDER

Figure 7.2.2-2

7.2.3-1   HEAO-A TAPE RECORDER

The magnetic tape recorders provide the onboard storage that preserves data during out of contact time and in the case of data "misses" by a ground station. Typically, all observatory data are stored on a tape recorder at 25.6 kbps and played back to ground stations at 512 kbps. As a baseline, three recorders are onboard with each recorder having a storage capacity of 4.5×10^8 bits. This capacity is sufficient to cover three orbits of data equal to the longest gap between ground station contacts at end of mission. Each recorder is designed for a maximum bit error (on playback) of 1 bit in 10^6 over its lifetime of two years continuous operation in a space environment.

Each magnetic tape recorder consists of two subassemblies, the Tape Transport Subassembly and the Tape Recorder Electronics Subassembly. The Tape Transport Subassembly (Figure 7.2.3-1) is a sealed unit, consisting of magnetic tape, heads, preamplifiers, drive train, motor, structure, and electrical interface circuits. The transport is of coaxial reel-to-reel configuration with capstan drive, using a negator spring assembly for tape tensioning and crown idlers for tape guidance. While recording, the transport receives a modulated signal from the electronics unit and performs the recording and erasure functions. During playback, it recovers the signal for processing by the electronics subassembly to a digital PCM output for downlink transmission.

The Electronics Subassembly (Figure 7.2.3-2) performs the modulation/demodulation, bit synchronization, serial-to-parallel and parallel-to-serial conversions, and provides for all buffering of data.
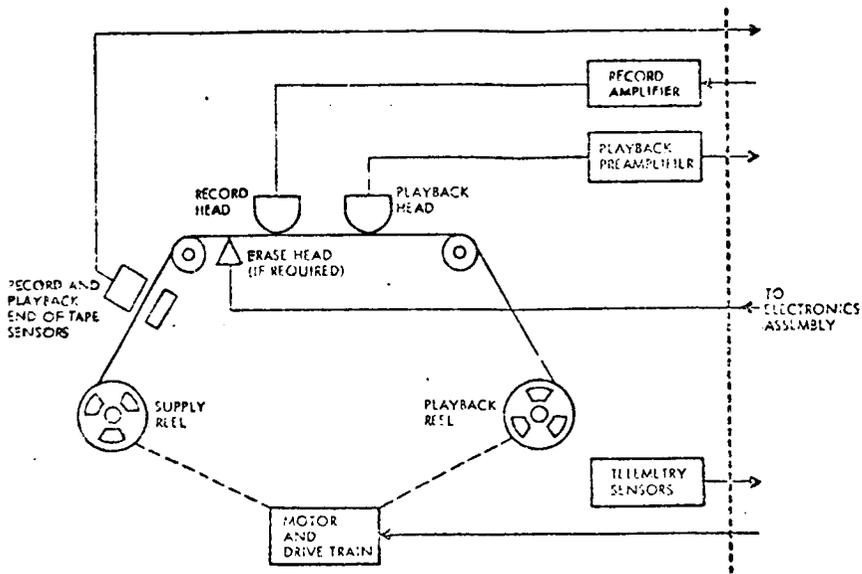
Figure 7.2.3-1.   HEAO-A Tape Transport
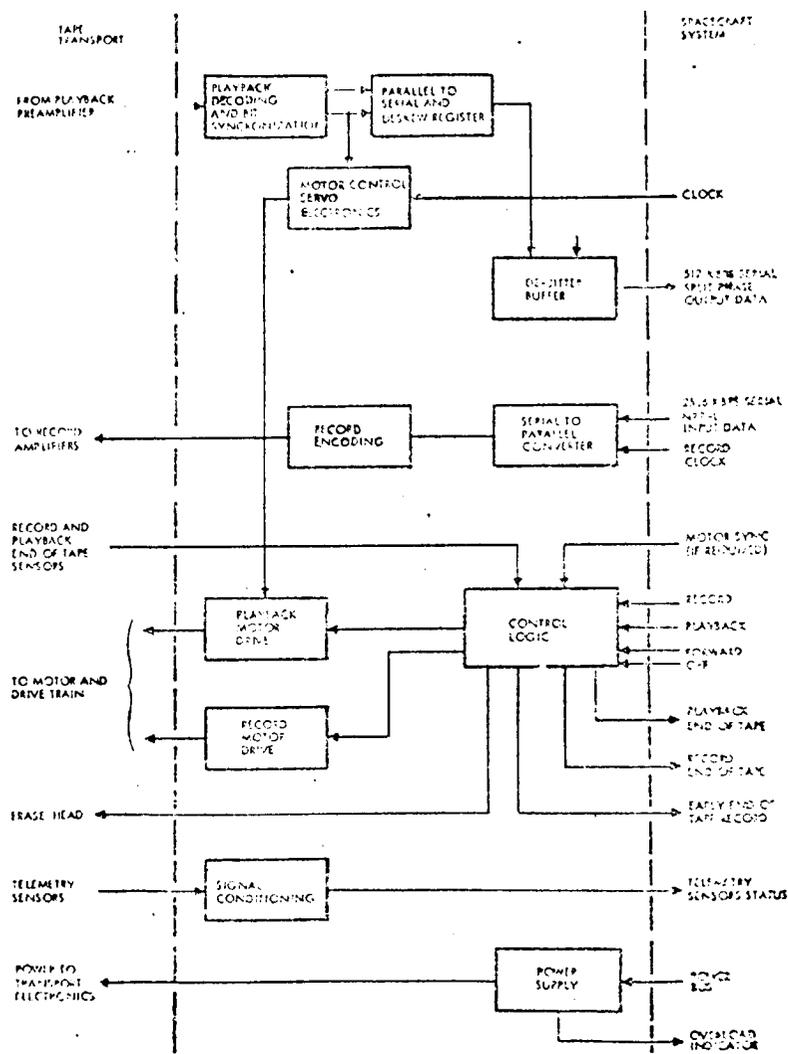
Figure 7.2.3-2.   Recorder Electronics Subassembly

7.2.3-1   HEAO-A TAPE RECORDER

General Description

Program: HEAO-A
Vendor: Odetics or RCA-AED
Part Number: TRW Equipment Specification No. EQ2-330

Performance Characteristics

Input Data Format: Serial digital NRZ
Input Data Bit Rate: 25.6 kbps
Input Data Signal Levels: "One" level = 2.4 V min, 5.5 V max, load current = 100 u amp max
"Zero" level = 0 V +0.5 V, current sink capability = 2 m amp
Output Data Format: Serial Manchester level bit stream
Output Data Bit Rate: 512 kbps; synchronous with spacecraft clock; any reproduced output data bit period shall be within +0.25% of preceding bit period and when averaged over a 10 sec or greater time interval shall be within +0.25% of 512 kbps; cumulative jitter less than +2.0% where referenced to any bit within a 400 bit sequence.
Output Data Signal Levels: "One" level = 2.4 V min, 5.5 V max, load current = 100 u amp max.
"Zero" level = 0 V, 0.5 V max. current sink capability = 16 m amp
Output Load Capacitance: Max of 1500 pf

	Odetics	RCA-AED
Storage Capacity (bits)	4.5×10^8	4.5×10^8
Record Speed (ips)	1.54	1.1
Playback Speed (ips)	28.0	20.5
Number of Tracks	3	3
Bit Packing Density/Track	5940	8330
Recording Format	Biphase	Double Density
Bit Error Rate	1 in 10^6	1 in 10^6
Tape Length (feet)	2100	1500
Tape Width (inch)	1/4	1/4

Physical Characteristics

Size: 22.9 cm (9 in) by 30.5 cm (12 in) by 12.7 cm (5 in)
          for Odetics;
          35.8 cm (14.1 in) dia. by 15 cm (5.9 in) for RCA.
Weight: 7.0 kg (15.5 lb) for Odetics; 9.4 kg (20.7 lb) for RCA.

Cooling Method: Conduction through mounting fixtures and
                   radiation from unit housing.

References

Part I - "Equipment Specification Performance/Design and
Qualification Requirements for Tape Recorder," HEAO. (Preliminary),
No. EQ2-330 April 21, 1972.

Design Status

The HEAO-A program is currently in a state of redefinition.
This component is a viable candidate for application in the
1977 HEAO-A mission.

7.2.3-2   HEAO-A TAPE RECORDER INTERFACE UNIT

The Tape Recorder Interface Unit (TRIU) provides automatic sequencing and control of the tape recorders. Specifically, it performs as follows:

   a.   Record. Upon receipt of record command or end of tape warning signal of the recorder in use, the TRIU shall select the next empty recorder in sequence or the next partially dumped recorder in sequence.

   b.   Playback. Upon receipt of playback command and with uplink RF signal present, the TRIU shall select partially dumped recorder in sequence or next full recorder in sequence. Playback shall cease upon the absence of uplink RF signal, presence of end of tape warning signal, or receipt of stop playback command.

   c.   Stop Playback. The TRIU removes any recorder in the playback mode from this mode and commands it to rewind the tape to a point where the recorded data can be reconstructed on the ground after subsequent playback.

   d.   Stop Record. The TRIU places any recorder in the record mode into the off mode.

The TRIU shall be designed such that the automatic sequencing and control functions will be superseded by ground commands.

7.2.3-2   HEAO-A TAPE RECORDER INTERFACE UNIT (TRIU)

General Description

Program: HEAO-A
Vendor: TRW
Part Number: TRW Equipment Specification No.:   EQ4-1098

Performance Characteristics

Data In: 25.6 kbps, NRZ-L serial data
Data Out: 512 kbps, split-phase serial data tape recorder
Record Clock: 51.2 kbps, RZ square wave
Playback Clock: 512 kbps, RZ square wave
Command Inputs: (10 bit)
Normal Commands:
    Record
    Stop Record
    Playback
    Stop Playback
Override Commands:
    Record 1
    Record 2
    Record 3
    Playback 1
    Playback 2
    Playback 3
    Rewind 1
    Rewind 2
    Rewind 3
    Stop Rewind
Recorder Status Inputs (From each of three recorders)
    End of Tape Record (EOTR)
    End of Tape Playback (EOTP)
    Power On
    Record Mode
    Playback Mode
    Rewind Mode
    Warning End of Tape
Outputs (each of three recorders)
    Record
    Playback
    Forward
Telemetry Status

Physical Characteristics

Size: 2.8 cm (1.1 in) by 15.2 cm (6 in) by 20.3 cm (8 in)
Weight: .45 kg (1 lb)

References

TRW, HEAO Preliminary Requirements Review, "Command and Data
Handling System,"Volume III-A, July 24, 1972.

Design Status

The HEAO-A program is currently in a state of redefinition.
This component is a viable candidate for application in the
1977 HEAO-A mission.

7.2.4   OSO-I TAPE RECORDER

The tape recorder is a reel-to-reel design with data reproduced
in the reverse order to which it was recorded. Recording
capacity is 220 minutes at an input rate of 6.4 kbps for a
capacity of 84.48 x 10^6 bits; output rate is 128 kbps. The
unit may be operated in parallel or series with another unit.

7.2.4   OSO-I TAPE RECORDER

General Description

Program: OSO-I
Vendor:
Part Number: 3280640-100 (specification No. PS31331-193)

Performance Characteristics

Type: Digital tape
Capacity: 84.48×10^6 bits
Record: 128 by 128 matrix of 8-bit words at 6400 bps
Playback: 20 x record (128 kbps playback and transmission rate)
Maximum Record Time: 220 minutes

Physical Characteristics

Size: 32.5 cm (12.8 in) by 25.9 cm (10.2 in) by 13.2 cm (5.2 in)
Weight: 7 kg (15.5 lbs)
Input Power: 5 watts record, 12 watts playback

Environment: Hughes Spec SS31331-003

References

Data Handling TM Subsystem, Hughes Aircraft Spec. No. SS31331-160,
Sept. 12, 1972.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

7.2.6   OAO-C TAPE RECORDER

The spacecraft tape recorder (Figure 7.2.6-1) is a 9 parallel
channel recorder with a bit packing density of 375 bits per
inch of tape per track for a total storage capacity of 48.5
x 10^6 bits. There are separate synchronous motors for playback
and record. The maximum starting time for each is 2 seconds.
The complete operation of the tape recorder is controlled by
3 commands: record, reproduce, and recorder off. Data
are recorded at a rate of 1042 bits per second. The total
recording time is 12.9 hours at a speed of 0.297 inch per
second. The data playback rate is 66,688 bits per second.
The playback time for 1065 feet of tape is 11.7 minutes
with a tape speed of 18.297 inches per second.

The tape recorder is controlled via a Government Furnished Equipment
Interface (GFEI) box. The GFEI contains a non-resettable clock
which provides a basic time reference for all recorded data and
also provides the tape recorder interface to the OAO subsystems
electronics. Figure 7.2.6-1 illustrates the interfaces between
the Recorder Electronics, Recorder Transport and Government
Furnished Equipment Interface.
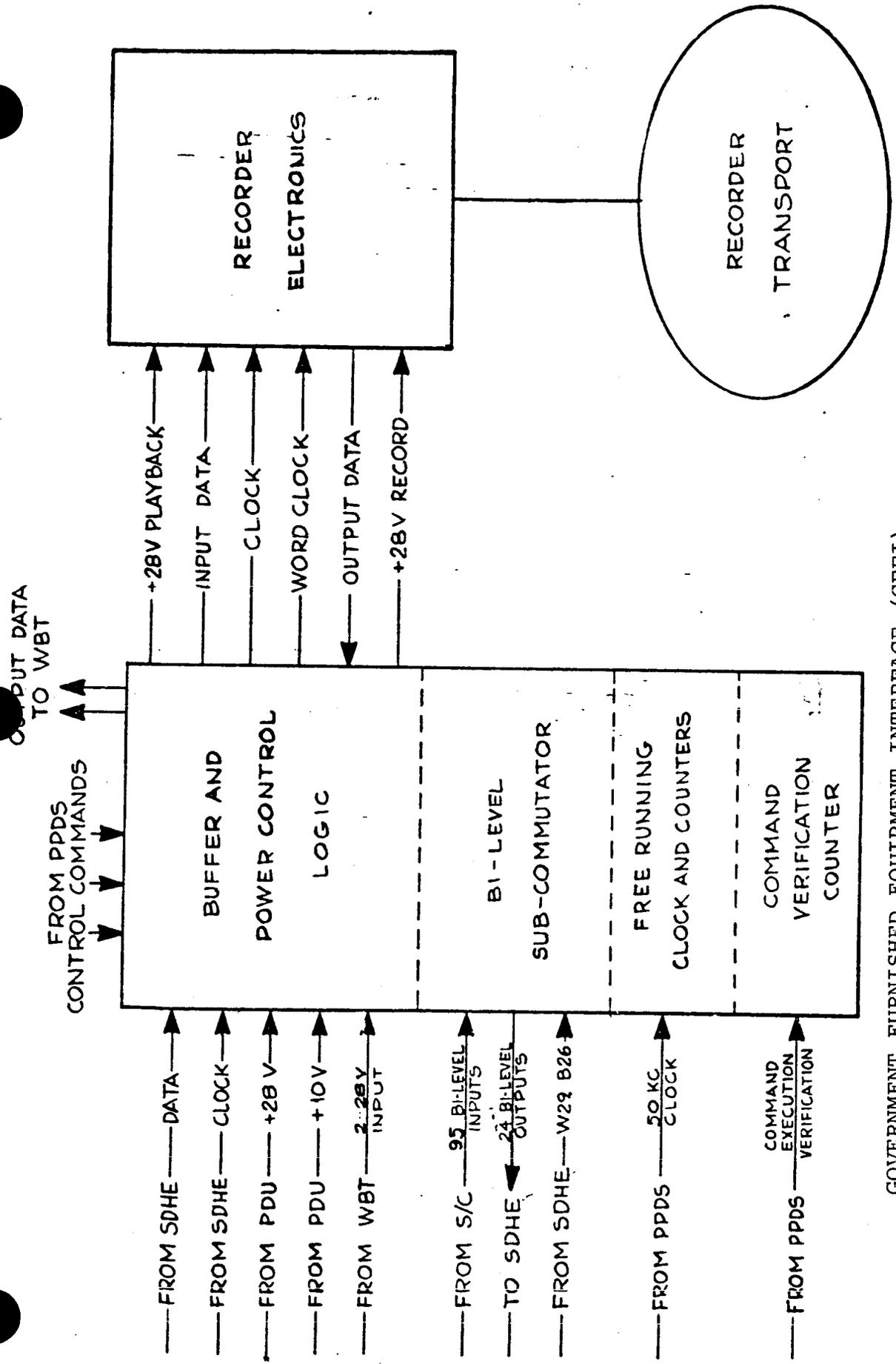
GOVERNMENT FURNISHED EQUIPMENT INTERFACE (GFEI)

Figure 7.2.6-1. OAO-C Recording Interfaces

7.2.6   OAO-C TAPE RECORDER

General Description

Program: OAO-C
Vendor: RCA
Part Number:

Performance Characteristics

Capacity: 48.5×10^6 bits (375 bits/inch/track)
Data Rate: 1042 bps - record 0.297 inches per second
              (Total recording time of 12.9 hours)
Playback: 66.7 Kbps - playback 18.297 inches per second
Bit Error Probability: 10^{-5}
Type of Transport: Coaxial-Negator
Tape Length: 1150 feet
Tape Width: 1/2 inch
Tape Tracks: 9
Total Mission Life: 30,600 hours
Operational Life: 28,000 hours
Recorder Type: Digital
Input: PCM-NRZ at 1.042 bps

Record Mode: 2-level RZ for 8 channels (pulse = "1", blank = "0")
                3-level RZ for 1 channel (clock info) pulse is
                present for "1", opposite polarity for "0"
Playback Mode: Full reel of 66,688 bits (NRZ) in 11.7 minutes
                  at 18.297 inches per second

Physical Characteristics

Size: Recorder: 30.5 cm (12 inch) diameter by 19.1 cm (7.5 inch)
         Electronics Unit: 16.5 cm (6.5 inch) by 19.1 cm (7.5 inch)
                            by 16.5 cm (6.5 inch)
Weight: 7.7 Kg (17 lbs)
Input Power: 7 watts record, 14 watts playback

References

"Report of the Tape Recorder Action Plan Committee",
NASA SP-307, 21 March 1972.

"OAO Spacecraft Design Manual", Grumman Aircraft Engineering
Corp., June 1968.

"Operations Plan 1-68 (OAO-A2)", X-513-68-301, Goddard Space
Flight Center, August 1968.

Design Status

This component was flown as part of the 1972 OAO-C mission.

7.2.7 SKYLAB AM/MDA TAPE RECORDER

The tape recorder is a two-track, audio/digital, record and reproduce machine. The tape travels betweens two concentric reels, with four negator springs to maintain equal tape tension. The tape is fed from the reels over the tape deck by a twisted 90-degree turn to the erase head, past a drive capstan to the record/playback head, and then through a similar path back to the other reel (Figure 7.2.7-1).

The record speed is 1 7/8 inches per second (ips) with a playback speed of 41 1/4 ips. This means 22 minutes of recording is played back in 1 minute. The magnetic tape is erased in the record mode to allow a new recording to be made. In the playback mode, the tape reverses direction and plays back the recording in reverse order. Replay of the playback requires a fast forward discrete (non-record mode at 41 1/4 ips) to reposition the tape, then removal of the discrete to initiate a playback mode again. The recorder has two end-of-tape limit switches that turn the recorder off to prohibit the tape from completely unwinding from the reels. The tape recorder has approximately 4 hours of recording time.

The tape motion output detects tape reel motion. A neon lamp powered from a 400-Hz inverter illuminates through the spoked tape reel that is in line with a photocell. As the spoked reel rotates, indicating tape motion, it cuts the light on and off to the photocell developing an AC voltage. The AC voltage is detected and conditioned into the output.

The recorder uses regulated +24 Vdc to energize a 1 7/8 ips clutch or a 41 1/4 ips clutch for drive capstan speed. The motor is driven from two 400-Hz inverter signals, 90 degrees out of phase. The +24 Vdc powers the inverter that excites the motor.

The digital record electronics accepts the 5.12 kbps PCM bit stream and the clock signal to provide a biphase coded signal to the record head. A data bit "zero" is represented by a square wave at one-half the clock frequency; a data bit "one" by a square wave at the clock frequency. The digital playback electronics accepts the biphase signal from the playback head and the decodes, converts, and filters it for transmission.

The analog record electronics accepts an audio signal of 300 Hz to 3000 Hz from the communication system for direct recording. The analog playback electronics accepts the audio signal from the playback head and amplifiers and conditions the signal for an output to the transmission subsystem.
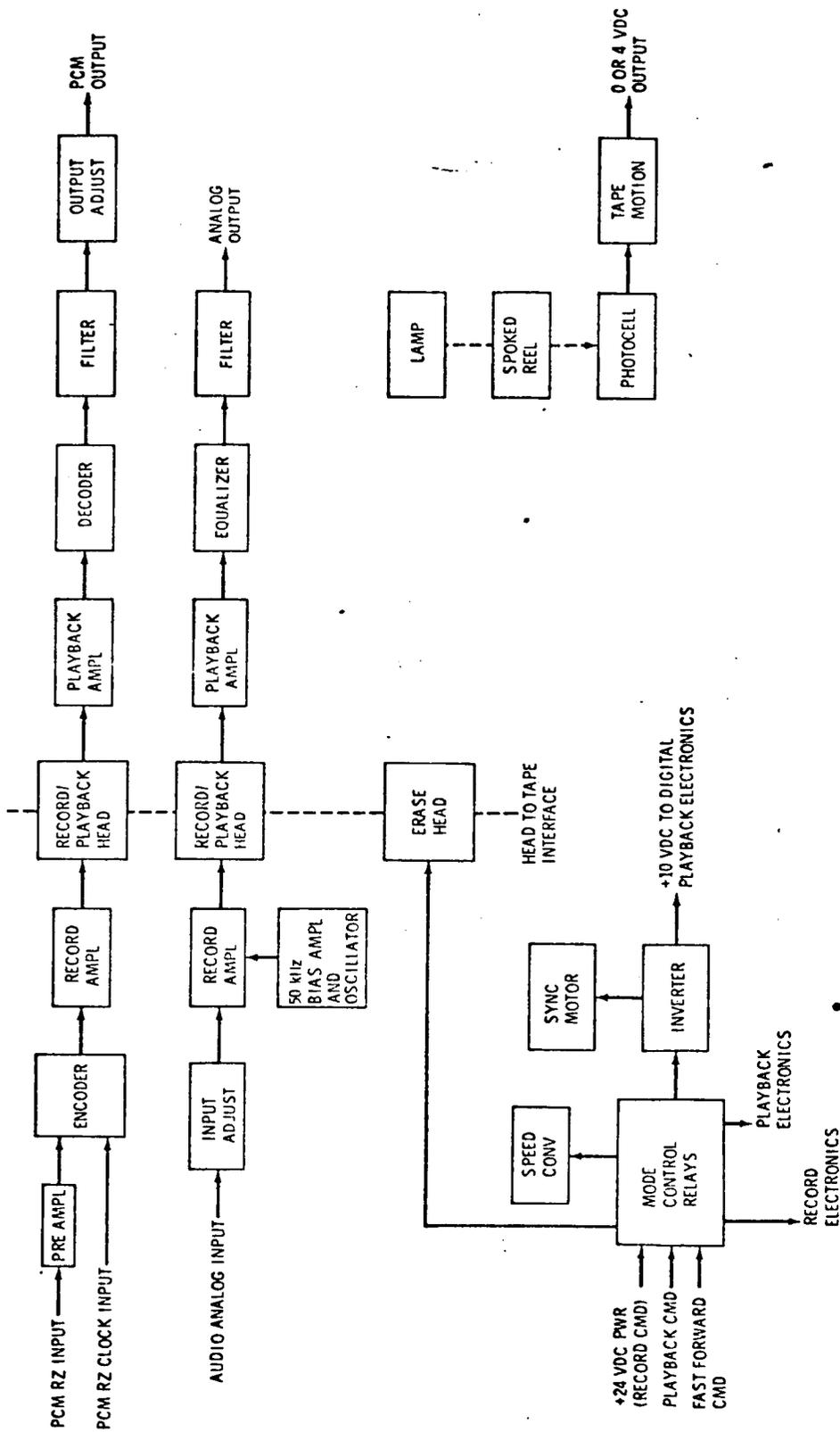
Figure 7.2.7-1. Tape Recorder Block Diagram

7.2.7   SKYLAB AM/MDA TAPE RECORDER

General Description

Program: Skylab-AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input: 5.12 Kbps Rz (subframes 1,2,3 & 4), 5.12 Kbps clock
            5.76 Kbps Rz (experiments M509 & T013), 5.76 Kbps clock
            300 to 3000 Hz audio @ 1.5 V rms nominal
Sub Frame Length (& Format):
   112.6 kbps NRZ; space at 2 +0.5 V peak to peak
   126.7 kbps NRZ; space at 2 +0.5 V peak to peak
     6.6 KHz to 66 KHz at 2 V +3 db peak to peak

Physical Characteristics

Size:
Weight:
Input Power: 14.5 watts record, 15.5 watts playback and
                 fast forward

References

Skylab Operations Handbook, Orbital Workshop (OWS) Airlock Module (AM)
Multiple Docking Adapter (MDA) Volume I Systems Descriptions,
Manned Spacecraft Center, Houston, Texas, (MSC 04727) 20 July 1970.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.2.8   SKYLAB ATM AUXILIARY STORAGE AND PLAYBACK (ASAP) ASSEMBLY

The ASAP assembly accepts parallel data and sync signals which come from the PCM/DDAS and are routed through the amplifier and switch assembly (ASA). The ASAP assembly stores the PCM data and upon command, plays back the stored data for modulating the ASAP RF assembly. The ASAP contains five subassemblies: memory module, primary tape recorder, redundant tape recorder, interface unit and a redundant dc-to-dc converter power supply. A block diagram of the assembly is shown in Figure 7.2.8-1.

Each of the two tape recorders (Figure 7.2.8-2) contained within the ASAP has five major elements: command logic, servo elec-tronics, dejittering electronics, record system and data recovery system.

AMPLIFIER AND SWITCH ASSEMBLY

PLAYBACK
SERIAL DATA
(72 KBPS)

TAPE
RECORDER
NO. 1

SERIAL DATA (4 KBPS)

TAPE
RECORDER
NO. 2

CONTROL

PARALLEL DATA (72 KBPS)

SYNCHRONIZATION

ASAP
INTERFACE
UNIT

PARALLEL DATA
(72 KBPS)
PARALLEL DATA
(4 KBPS)
ASAP INTERNAL
CONTROL

COMPUTER
INTERFACE
UNIT

PARALLEL DATA
(4 KBPS)

ASAP
INTERNAL
CONTROL

POWER

MEMORY
MODULE

POWER

DC-DC
CONVERTER
POWER SUPPLY

AUXILIARY STORAGE AND PLAYBACK ASSEMBLY (ASAP)

ASAP BLOCK DIAGRAM AND INTERFACES

Figure 7.2.8-1

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Speed Command

Servo Electronics

Tachometer

Motor Direction Command

Motor Switching

Playback Motor

Record Motor

Motor

Dejittering Electronics

Data/Clock Recovery Electronics

Read Pre-Amp

Track Switch

"A"   "B"

Read Head

Data Recovery System

Data Output NRZ-L

72 kHZ

144 kHz Xtal. Osc.

144 kHz

NRZ-L to Bi-Phase Converter

72 kbps

Clock Select Gate

144 kHz

Record Head

"A"   "B"

NRZ-L to Bi-Phase Converter | Record Ampl.

Record System

External Clock Enable

Freq. Doubler

Output Amplifier

Track Select Command

RFI Filter DC/DC Convert. Command Logic

Speed Command

End of Tape Sensor

+28 V   Return

Record Command

Playback Command

Data Input NRZ-L

4.0 kHz Clock Input

Signal Ground

External Clock (72 kHz)
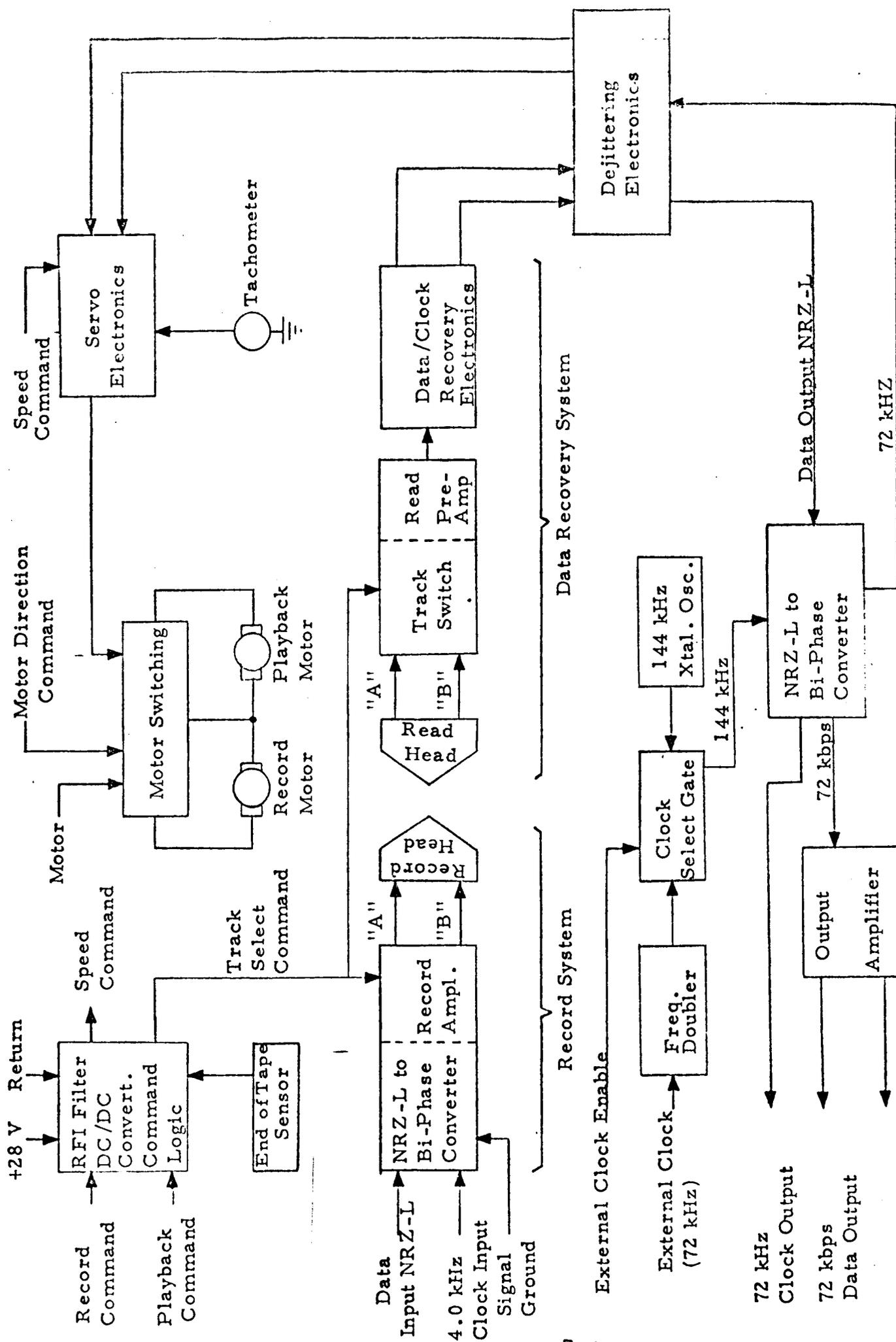
72 kHz Clock Output

72 kbps Data Output

Figure 7.2.8-2.   TAPE RECORDER BLOCK DIAGRAM

7-44

7.2.8   SKYLAB ATM AUXILIARY STORAGE AND PLAYBACK (ASAP) ASSEMBLY

General Description

Program: Skylab ATM
Vendor: Borg Warner
Part Number:

Performance Characteristics

Record Rate: 4.0 kbps +0.1% NRZ-L serial data
Playback Rate: 72.0 kbps biphase (L) serial data
Record Time: 89 +2 min
Playback Time: 290 to 300 sec
Record/Playback Ratio: 19:1 +0.1%
Automatic Record Mode: After 6 minutes in the playback mode
Serial Output: 72 kbps serial biphase (L)

Physical Characteristics

Size: 22.9 cm (9 inch) by 22.9 cm (9 inch) by 12 cm (4.7 inch)
Weight: 5.4 Kg (12 lbs)
Input Power: 28 watts max
Cooling Method: Cold plate, uses heaters and thermal blanket in
                    flight

References

"Skylab Operational Data Book", Volume IV (MSC-01549), Rev. A,
October 1972.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.2.11   MARINER MARS DATA STORAGE TAPE RECORDER

The Data Storage System (DSS) Tape Recorder is broken up into two functional areas: tape transport (DSST) and electronics (DSSE). A block diagram of this tape recorder can be found in Figure 7.2.11-1.

The function of the DSST is to record digital data received from the DSSE, and to play back this data at several different and preselected playback rates into the DSS signal conditioning circuitry for distribution. Track switching and playback rate selection are not a part of the DSST; however, the motor is capable of operation at the several selected rates. The DSST consists of the tape transport mechanism, including the motor, the record and playback heads, end-of-tape sensors, pressure transducer, temperature transducer, input and output connectors, and the case in which these components are housed.

The DSSE provides all the electronics functions for the tape recorder. The DSSE is divided into the following sections for description: record electronics, playback electronics, tape speed control, mode controller, telemetry coder, power conditioner, and interfaces.

The record electronics provides proper drive to the record heads to record the incoming data from the Data Automation Subsystem (DAS). The data is split into two tracks and recorded in parallel. The same two tracks are reproduced in parallel and combined in the data combiner.

The playback electronics provides an amplifier for each playback track. The playback amplifiers and limiters provide signal levels required by the data detectors. The data detector uses a coherent detection technique to extract data and clock from the playback signal. The data combiner combines the two parallel tracks. A buffer isolates the data output from jitter in the data, not compensated for by the servo speed control.

During record and tape slew, the DSST motor runs at synchronous speed. During playback the motor is controlled by a two loop servo system. A ninth track on the DSST is used as a tachometer track for frequency control. A feedback signal from the playback data buffer is used in the second loop for phase control.

In response to other subsystem commands, the mode controller generates logic signals which enable the playback, record, ready, and slew modes. The bit rate selector provides selected clock signals to the servo and playback electronics, to select the desired playback rate. The tape pass sequencer controls which tape pass the DSS shall be on. The telemetry conditioner formats
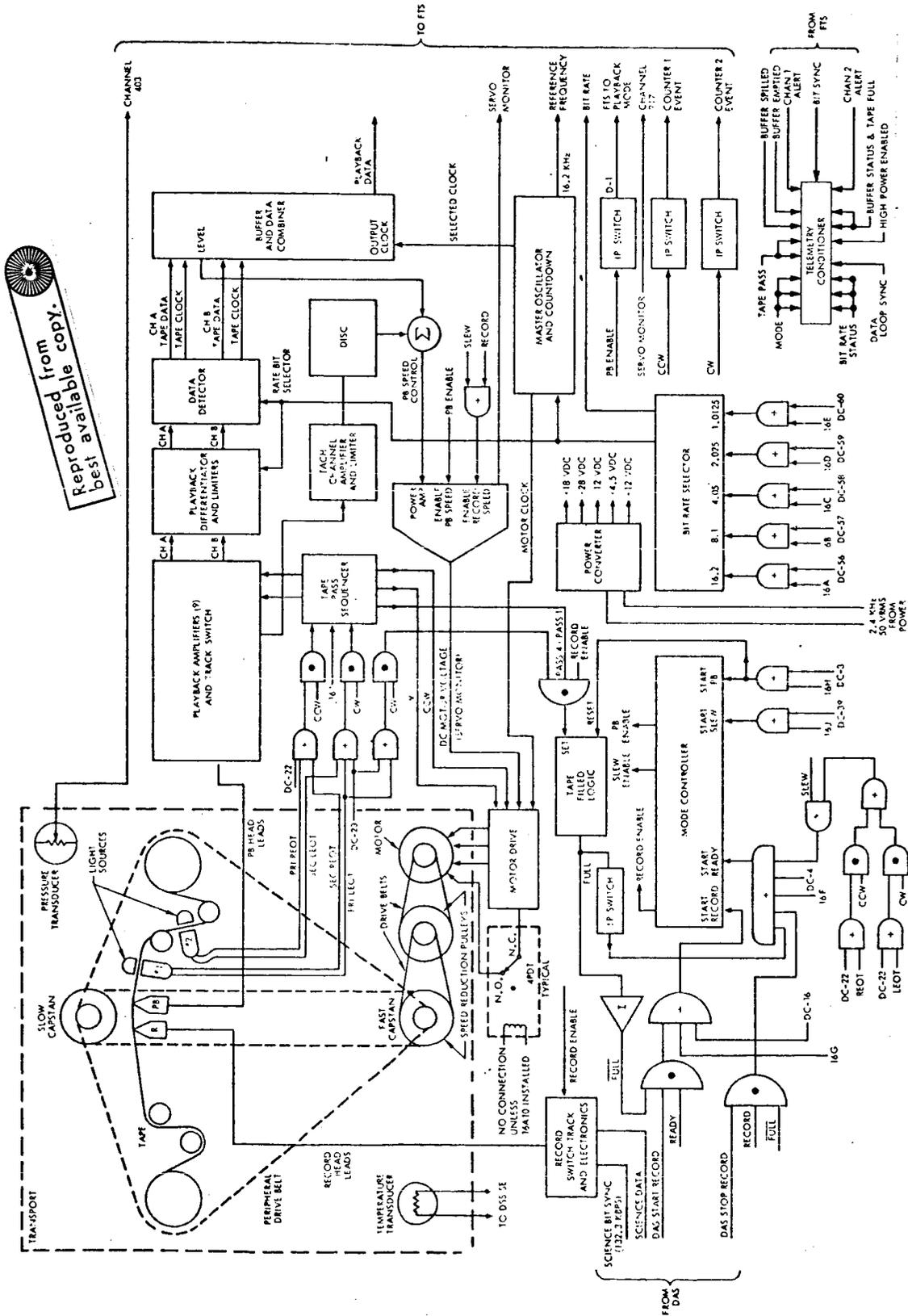
Figure 7.2.11-1   Data Storage System

DSS status information which is sent to the Flight Telemetry
Subsystem (FTS). This data becomes part of the engineering
telemetry. The power conditioner converts power from the power
subsystem into a form used by the DSS. All connections to the
DSS are made through the ring harness cable, the power cable,
or the direct access cable. The ring harness cable contains all
spacecraft functions except power from the power subsystem, which
is in the power cable. The direct access cable is used to monitor
DSS performance during testing.

7.2.11 MARINER MARS DATA STORAGE TAPE RECORDER

General Description

Program: Mariner Mars 71
Vendor: JPL
Part Number:

Performance Characteristics

Storage Capacity: 1.8×10^8 +5% bits (9 track)
Tape Length: 165 meters (550 feet)
Playback Rates: 8.1, 4.05, 2.025, 1.0125, .50625 Kbps.
                   (2.4, 1.2, 0.6, 0.3, 0.15 ips)
Record Rate: 132.3 Kbps (19.44 ips)

Physical Characteristics

Size: 22.9 cm (9 in) by 15.5 cm (6.1 in) by 17.8 cm (7 in)
Weight: 5 Kg (11 lbs)
Input Power: 35 watts

References

"Mariner Mars 1971 Flight Equipment Data Storage Subsystem
Tape Transport" JPL Design Requirement Document, April 9, 1971.
Rev. B.

"Design Requirement Mariner Mars 1971 Flight Equipment Data
Storage Subsystem Electronics", JPL Design Requirement Document,
June 30, 1970.

Design Status

This component was flown as part of the 1971 Mariner Mars mission.

7.3.2-1   ERTS-B COMMAND CLOCK

The Command Clock (Figure 7.3.2-1) contains a redundant configuration of equipments for generating spacecraft precision frequencies, storing and subsequently routing stored commands, and routing or executing real-time commands. There is no "Power OFF" mode of operation. All major units are powered in "Exclusive OR" fashion; i.e., one (and only one) unit is operational at all times except for the power supply/command decoders (COMDEC) and the command storage (COMSTOR) modules. Special provision is made to power these units simultaneously or singly. Also, the COMSTORS can both be turned off. The primary functions of the major units comprising the Command Clock are as follows:

1.   Power Supplies - Two independent, redundant units designated primary and redundant, each capable of accepting the externally generated -24.5 Vdc bus inputs and generating all internal secondary voltages required by the Command Clock.

2.   COMDEC's - Two independent, identical units (designated primary and redundant), each capable of performing the command decoding functions of disabling or enabling encoded command inputs, bit synchronization, data strobing, format checking and routing of both real-time commands (executed when received) and stored commands (commands executed in accordance with the associated time tag). A different 5-bit key is wired into each COMDEC. The 5-bit key accompanying each real-time command must match a wired key for execution.

3.   COMSTOR's - Two independent, identical units (designated primary and redundant), each capable of storing time-dependent (SPD) commands (capacity 15 commands each), continuously processing time tags, input error checking and command readout at command execution times. Readout of the memory can be commanded via encoded commands for command verification at the ground station.

4.   Matrix (MTX) Decoders - Two independent, identical units (designated primary and redundant), each capable of decoding and routing stored commands (from COMSTOR's) or real-time commands (from COMDEC's) via strobe enabling pulses to the MTX drivers.
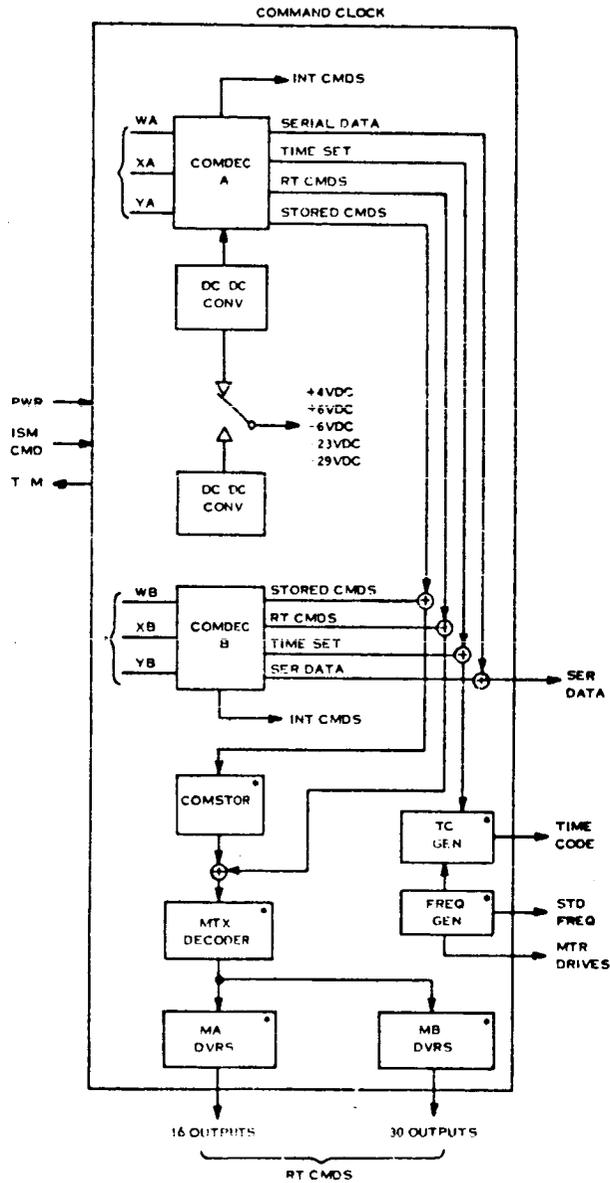
Figure 7.3.2-1   ERTS-B Command Clock

5. Matrix (MTX) Drivers - Two sets (A and B) of independent,
    identical units (designated primary and redundant), each
    capable of routing selective command strobe pulses to the inter-
    facing subsystems. Enabling signals from the decoders
    are translated into a unique -24.5 Vdc (MTX A) connection
    and a unique return (MTX B) connection. Associated latching
    functions are contained as required in the interfacing
    subsystems. There are 16 MTX A lines and 32 MTX B lines
    yielding 512 unique command connections; however, 32 con-
    nections are reserved for real-time internal functions.

6. Oscillators - Two independent, identical units (designated
    primary and redundant), each capable of generating the
    precise base clock frequency for all spacecraft timing
    functions. The oscillators will both be continuously
    powered and their outputs will be enabled in "Exclusive
    OR" fashion as commanded by real time commands.

7. Frequency and Time Code Generators - Two independent,
    identical units (designated primary and redundant), each
    capable of accepting either oscillator output and con-
    tinuously developing a 40-bit time code (resolution to one
    second) and a variety of precision frequencies for cen-
    tralized time correlation of all spacecraft events. The
    precision frequencies are amplified and made available
    to all subsystems on an individual, buffered basis. The
    40-bit time code is utilized as a time reference in the
    telemetry format and on the Minitrack tape.

8. Command Execution Counter - A single 6-bit counter that
    maintains a cumulative total (0 to 63) of all executed
    commands. The counter is reset to 1 by a real-time command
    and its count status is telemetered for ground station com-
    mand correlation.

7.3.2-1   ERTS-B COMMAND CLOCK

General Description

Program: ERTS-B
Vendor: California Computer Products, Anaheim, Calf.
Part Number:

Performance Characteristics

Inputs from Command Integrator Unit:

- ° 128 bps NRZ data (50 bits/command)
- ° 128 Hz square wave strobe
- ° Enable signal compatible with command clock

Command Storage Capacity: 15 commands per each of 2 command
                            storage modules
Outputs:
- ° Discrete commands (stored or real time)
    16   -24.5 Vdc unique output lines } providing 480 unique
    30 unique return lines   } connections
- ° Serial Data - 1 output providing 3 serial 12-bit words
    to Versatile Information Processor (VIP)
- ° Time Code - 100 bps pulse width modulated (PWM)
    GMT time capable of being updated by ground command
    to one second resolution

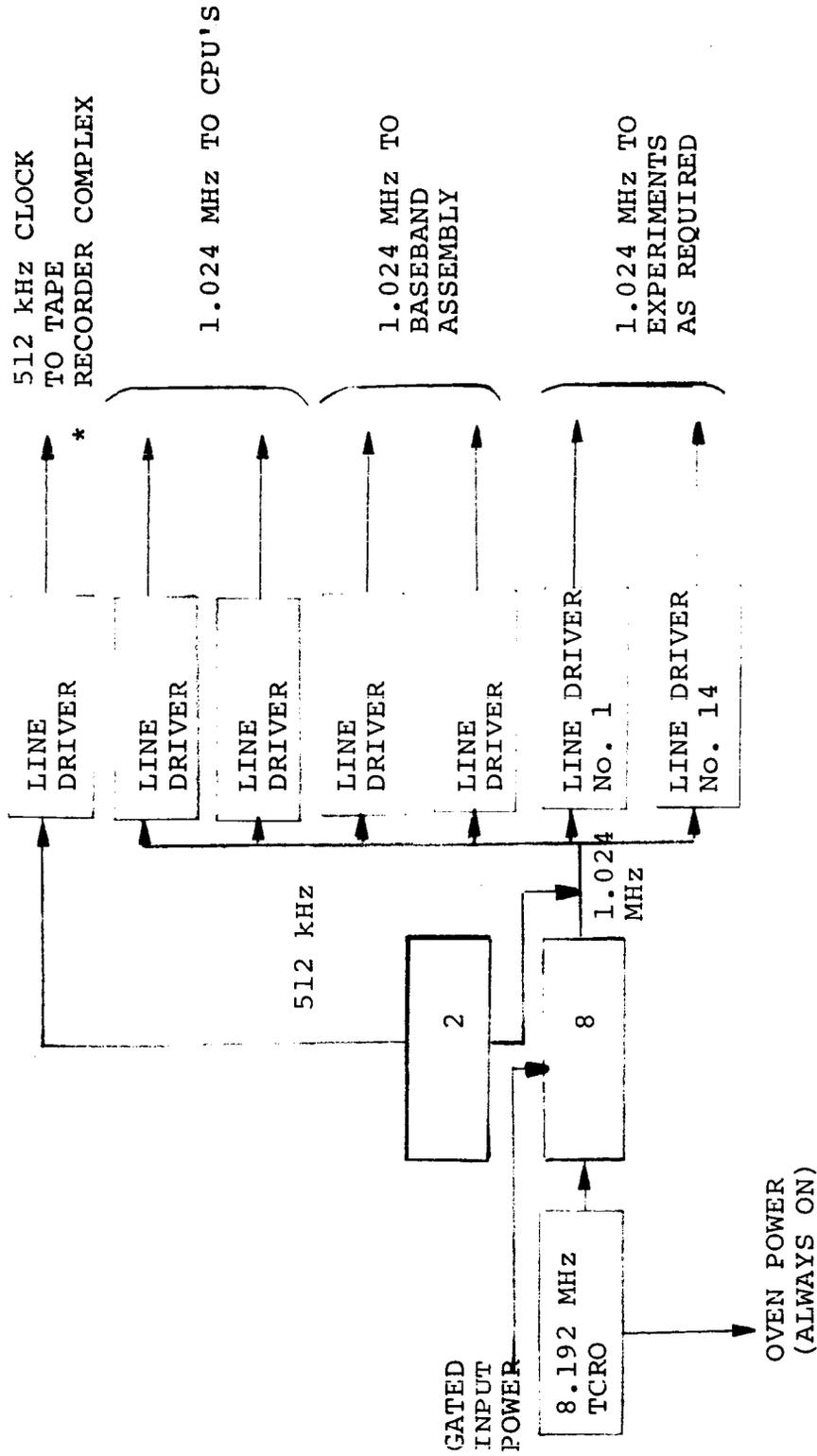## Physical Characteristics

Size:
Weight:

References

Earth Resources Technology Satellite Reference Manual,
General Electric, Space Division

Design Status

This component is scheduled to be flown as part of the planned
late 1973 ERTS-B mission.

7.3.3   HEAO-A CENTRAL CLOCK UNIT

Timing for the system is derived from a stable oscillator and countdown chain located in the central clock unit (Figure 7.3.3-1). The central clock unit provides 1.024 MHz outputs for distribution by the Remote Multiplexer Units (RMUs) to all experiments and other spacecraft systems. This highly stable (1 part in 10^9 over a 24 hour period) 1.024 MHz signal is sent to the Central Programming Unit for timing and to the Baseband Assembly where it serves as a subcarrier for the 25.6 kHz telemetry data. The 1.024 MHz signal can be counted down to any convenient frequency required for internal processing (e.g., 512 kHz to the tape recorder). The clock outputs are routed through the same assemblies which contain the RMUs and secondary decoders to preserve the isolation and interface integrity.

Figure 7.3.3-1. CENTRAL CLOCK UNIT (CCU)

*ALL LINE DRIVERS ARE AC COUPLED

7-55

7.3.3   HEAO-A CENTRAL CLOCK UNIT

General Description

Program: HEAO-A
Vendor: TRW
Part Number: TRW Equipment Specification No. EQ4-110[2]

Performance Characteristics

Outputs: 1.024 MHz, 512 kHz
Frequency stability: ± 1 part in 10^9 over a 24 hour period
Time resolution: Better than 4×10^{-5} sec for all telemetry coordinates; better than 1×10^{-6} sec for time tags from experiments using 1.024 MHz timing

Physical Characteristics

Size: 4 cm (1.6 inch) by 15.2 cm (6 inch) by 20.3 cm (8.0 inch)
Weight: .9 kg (2.0 lbs)

References

TRW, "HEAO Preliminary Requirements Review", "Command and Data Handling System", Vol. III-A, 24 July 1972.

TRW, "HEAO Design Approach", 27 August 1971.

Design Status

The HEAO-A program is currently in a state of redefinition. This component is a viable candidate for application in the 1977 HEAO-A mission.

7.3.4-1   OSO-I WHEEL SPACECRAFT CLOCK

The wheel spacecraft clock (Figure 7.3.4-1) contains the primary precision frequency source for timing of all observatory functions. This source has a 2.560 MHz and a 1.024 MHz output, both generated by a 5.120 MHz oscillator with a stability of ± 1 part in 10^9 per day. The most significant bit (MSB) has a recycle time of 1.36 years. The wheel spacecraft clock generates the synchronizing signals and time codes for the users on the wheel. The timing signal frequencies and periods are given in Table 7.3.4-1.
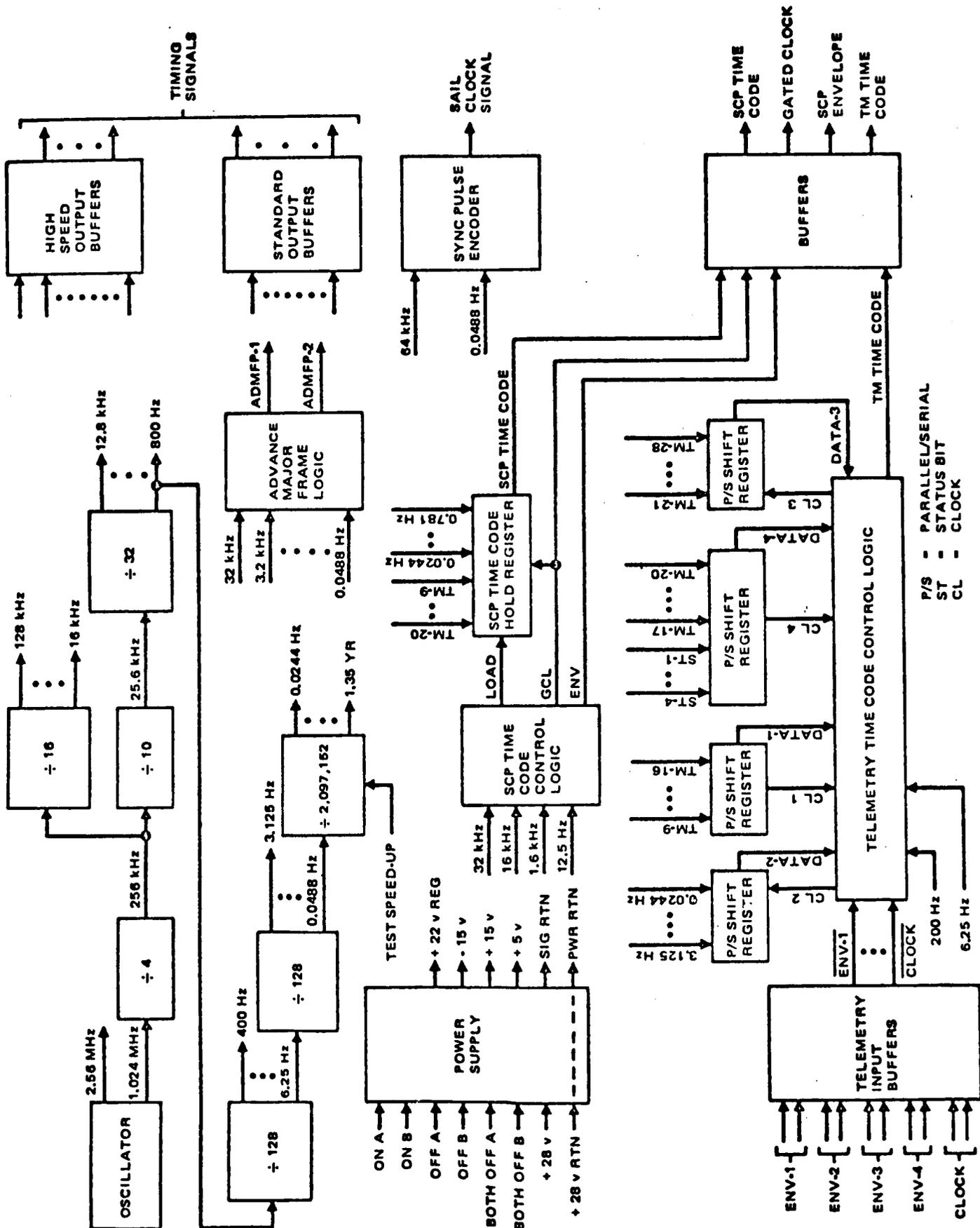
Figure 7.3.4-1   Wheel Spacecraft Clock Block Diagram

Item No.	Frequency	Period	Item No.	Frequency	Period
1	2. 560 MHz	0. 391 μs	26	0. 195 Hz	5. 12 sec
2	1. 024 MHz	0. 977 μs	27	0. 0977 Hz	10. 24 sec
3	512 kHz	1. 953 μs	28	0. 0488 Hz	20. 48 sec
4	256 kHz	3. 906 μs	29	0. 0244 Hz	40. 96 sec
5	128 kHz	7. 8125 μs	30	—	1. 365 min
6	64 kHz	15. 625 μs	31	—	2. 73 min
7	32 kHz	31. 25 μs	32	—	5. 46 min
8	16 kHz	62. 5 μs	33	—	10. 92 min
9	25. 6 kHz	39. 06 μs	34	—	21. 84 min
10	12. 8 kHz	78. 125 μs	35	—	43. 68 min
11	6. 4 kHz	156. 25 μs	36	—	1. 456 hr
12	3. 2 kHz	312. 5 μs	37	—	2. 912 hr
13	1. 6 kHz	625. 0 μs	38	—	5. 824 hr
14	800 Hz	1. 25 ms	39	—	11. 65 hr
15	400 Hz	2. 50 ms	40	—	23. 3 hr
16	200 Hz	5. 0 ms	41	—	1. 94 days
17	100 Hz	10. 0 ms	42	—	3. 88 days
18	50 Hz	20. 0 ms	43	—	7. 76 days
19	25 Hz	40. 0 ms	44	—	15. 5 days
20	12. 5 Hz	80. 0 ms	45	—	31. 0 days
21	6. 25 Hz	160. 0 ms	46	—	62. 0 days
22	3. 125 Hz	320. 0 ms	47	—	124. 0 days
23	1. 56 Hz	640. 0 ms	48	—	248. 0 days
24	0. 781 Hz	1. 28 sec	49	—	1. 36 yr
25	0. 391 Hz	2. 56 sec			

Table 7.3.4-1   Wheel Spacecraft Clock Timing Signal
Frequencies and Periods

7.3.4-1   OSO-I WHEEL SPACECRAFT CLOCK

General Description

Program: OSO-I
Vendor:
Part Number: 3280690-100 (Spec. No. DS31331-161)

Performance Characteristics

Oscillator Stability: ± 1 part in 10^9 per day
Output Timing Signals: See attached Table 7.3.4-1

Physical Characteristics

Size: 41.9 cm (16.5 in) by 14.7 cm (5.8 in) by 8.4 cm (3.3 in)
Weight: 3.4 Kg (7.5 lbs)

References

Data Handling and TM Subsystem Specification, Hughes Aircraft
Spec. No. SS31331-160, Sept. 12, 1972.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

7.3.4-2   OSO-I SAIL SPACECRAFT CLOCK

The sail spacecraft clock (Figure 7.3.4-2) accepts a precision 64 kHz synchronizing signal from the wheel spacecraft clock. It decodes this synchronizing signal and generates the additional signals listed in Table 7.3.4-2. These signals are used in the sail remote decoders and sail telemetry subsystem.
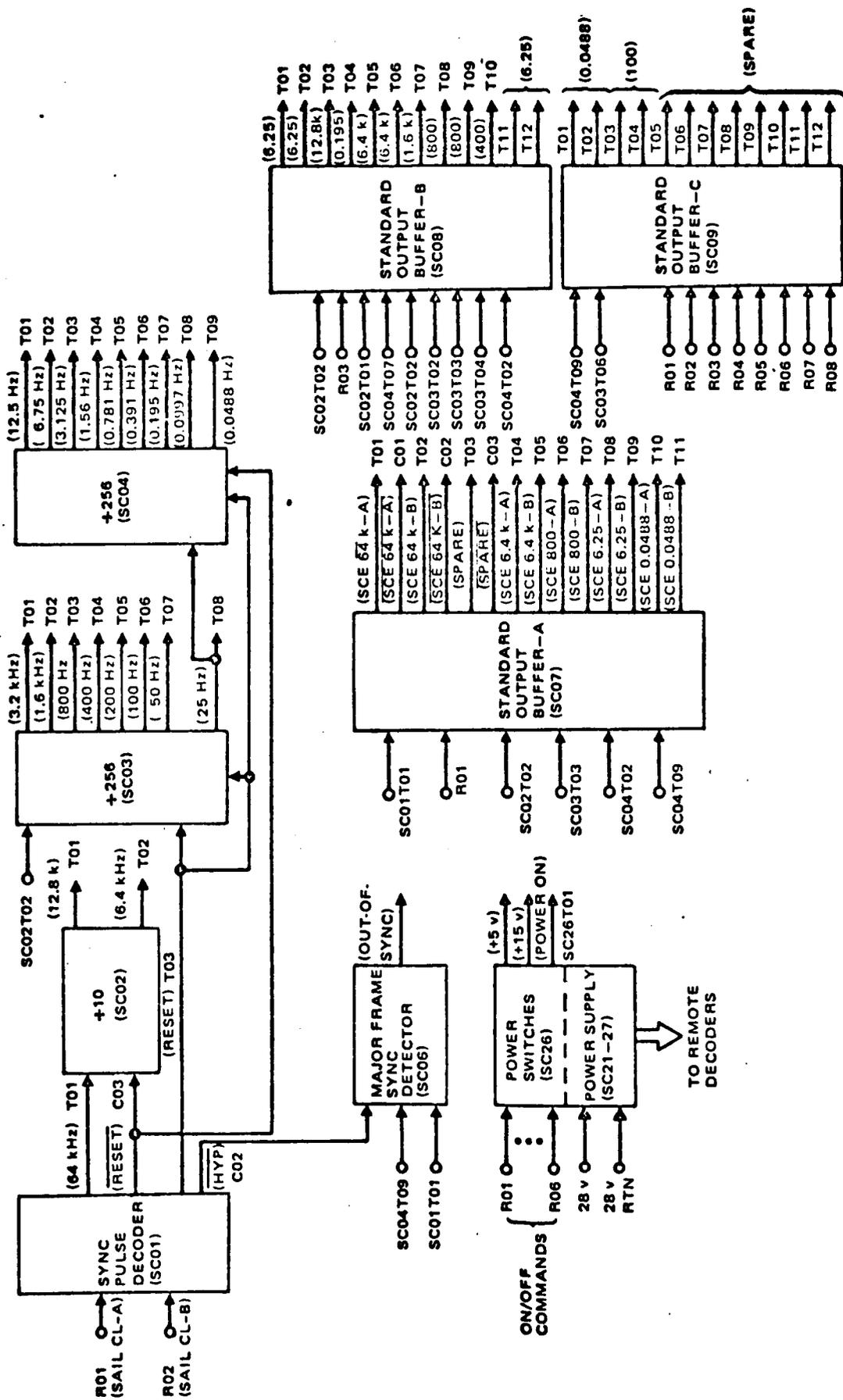
Figure 7.3.4-2. SAIL SPACECRAFT CLOCK BLOCK DIAGRAM

Item No.	Frequency		Period	
1	64	kHz	15.625	μsec
2	12.8	kHz	78.125	μsec
3	6.4	kHz	156.25	μsec
4	3.2	kHz	312.5	μsec
5	1.6	kHz	625.0	μsec
6	800	Hz	1.25	ms
7	400	Hz	2.5	ms
8	200	Hz	5.0	ms
9	100	Hz	10.0	ms
10	50	Hz	20.0	ms
11	25	Hz	40.0	ms
12	12.5	Hz	80.0	ms
13	6.25	Hz	160.0	ms
14	3.125	Hz	320.0	ms
15	1.56	Hz	640.0	ms
16	0.781	Hz	1.28	sec
17	0.391	Hz	2.56	sec
18	0.195	Hz	5.12	sec
19	0.0977	Hz	10.24	sec
20	0.0488	Hz	20.48	sec

SAIL SPACECRAFT CLOCK TIMING SIGNAL FREQUENCIES AND PERIODS

Table 7.3.4-2

7.3.4-2 OSO-I SAIL SPACECRAFT CLOCK

General Description

Program: OSO-I
Vendor:
Part Number: 3280690-100 (Spec. No. DS31331-167)

Performance Characteristics

Cross-strapped to wheel spacecraft clock
Output Signals: See Table 7.3.4-2

Physical Characteristics

Size: 19.6 cm (7.7 inch) by 14.7 cm (5.8 inch) by 3.5 cm (1.4 inch)
Weight: 0.6 Kg (1.2 lbs)
Cooling Method: Surface mounting

References

"Data Handling and TM Subsystem Specification", Hughes Aircraft,
Spec. No. SS31331-160, 12 September 1972.

"Sail Spacecraft Clock Specification", Hughes Aircraft, Spec No.
DS31331-167, 7 December 1972.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

7.3.4-3   OSO-I SAIL CONTROL UNIT

The Sail Control Signal (SCS) unit converts spacecraft sensor
and ground commands into appropriate motor torque signals.
These signals control the azimuth and the elevation position
of the sail-mounted pointed instrument package (PIA). A func-
tional block diagram of the SCS unit is shown in Figure 7.4.3-3.
The SCS unit provides the discrete functions described below:

   a.   Command Distribution Logic (CL) subunit:

      1.   Receives up to sixteen 16 bit serial commands,
           decodes and distributes commands to the appro-
           priate SCS subunit.

      2.   Receives and reshapes a 64 KHz clock signal for
           utilization in all normal SCS timing functions.

      3.   Detects failures of the spacecraft clock and
           switches to a SCS internal oscillator when
           failures occur.

      4.   Monitors command input lines for verification
           pulse and rejects input commands that are without
           a verification pulse.

   b.   Telemetry Distribution (TL) subunit:

      1.   Periodically samples SCS unit analog data and
           serial digital data, converts analog data to
           serial digital data, and multiplexes the serial
           and converted analog data onto a single serial
           digital channel for transmission to the space-
           craft telemetry subsystem.

      2.   Generates control and timing signals required to
           sample data and output subcommutated signals
           to the spacecraft telemetry.

   c.   Power Conditioning (PW) subunit performs power con-
        version and conditioning necessary to supply all
        voltage forms required by subunits within the SCS
        unit.

   d.   Raster and Pointing Generator (RP) subunit provides
        offset and raster pointing signals which bias the
        aximuth and elevation position of Pointed Instrument
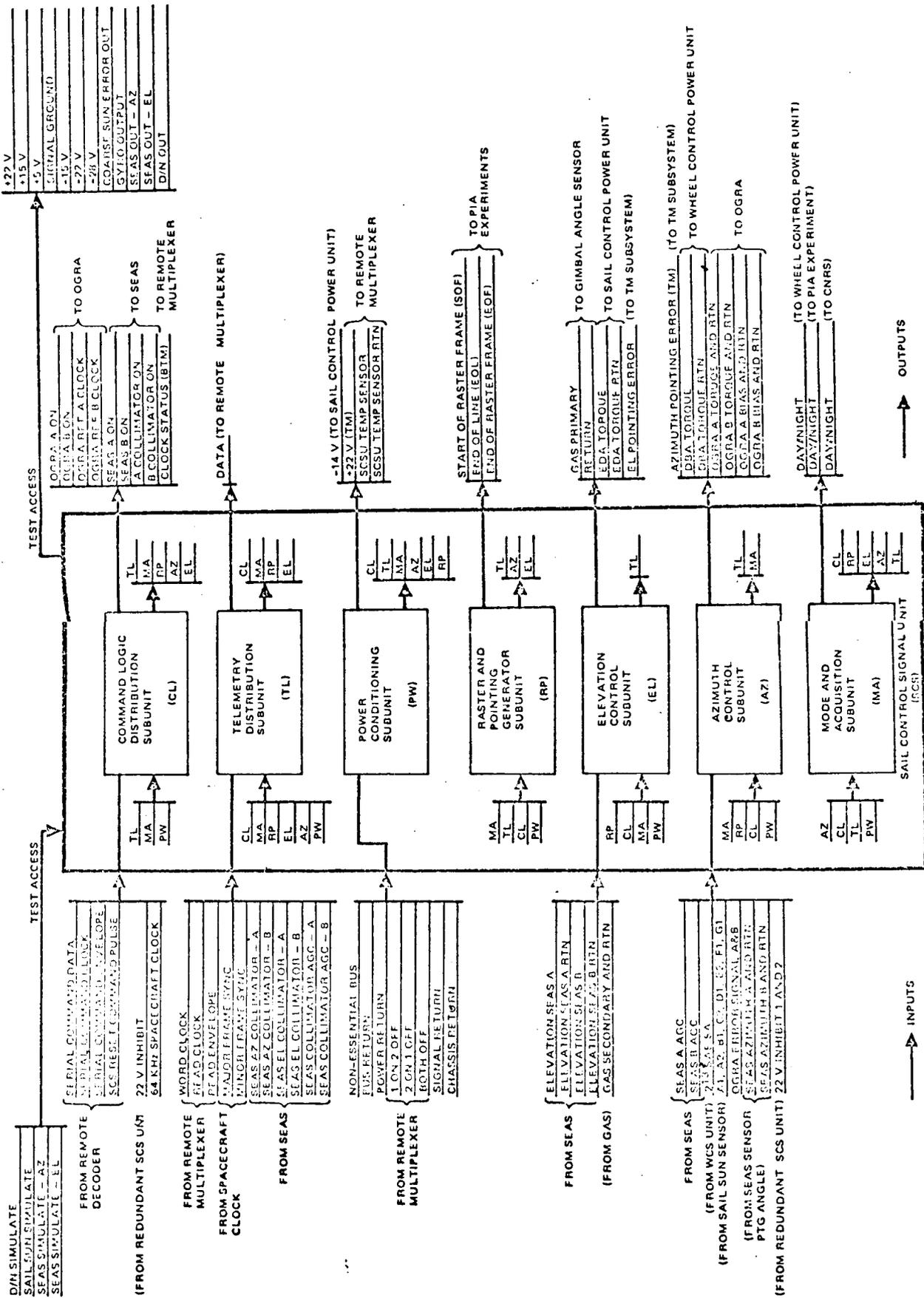   Assembly (PIA) experiments during daytime operation.

Figure 7.3.4-3. SAIL CONTROL SIGNAL UNIT

e. Elevation (EL) subunit utilizes dc and ac detection to provide elevation pointing signals and gimbal angle telemetry. These pointing signals are derived from gimbal angle sensor null error voltages or PIA sun sensor analog error signals.

f. Azimuth Control Electronics (AZ) subunit generates azimuth pointing signals derived from the processing of sun sensor signals, or the output of a rate integrating gyro, or the shaft angle encoder. These signals generate a torque signal that is applied to the despin bearing assembly motor driver.

g. Mode and Acquisition (MA) subunit:

1. Provides the switching drive signals to control the transitional and commandable states of the azimuth control and elevation control subunits.

2. Provides a command register for storage, decoding and distribution of mode commands.

7.3.7-1   SKYLAB AM/MDA COMMAND RELAY DRIVER UNIT (CRDU)

The CRDU contains redundant primary and secondary electronics which are connected to the primary and secondary receiver/decoder respectively (Figure 7.3.7-1). A ready pulse from the active receiver/decoder is delayed 3 milliseconds in the corresponding CRDU electronics before the timing control generates shift pulses (data clocks). This insures that the instrumentation system has enough time to read the previous message. The shift pulses clock in data from the receiver/decoder to the CRDU input register and parity counter. The parity counter counts the number of binary ones and generates an enable signal to the CRDU relay drivers if the number of binary ones is odd (odd parity). The enable signal and the 3 ms delay signal generate the validity pulse that is monitored by the instrumentation system. The data in the input register is routed in parallel to both the instrumentation system, for downlinking to STDN, and to the decoding logic. The decoding logic decodes the message to determine which relay driver is to be activated. One of the 480 relay drivers is activated and sends the driving pulse to a corresponding CRDU command relay. The Electrical Power System (EPS) inhibits 144 relay drivers (corresponding to commands S0 through S143) when the EPS is put into the manual mode. The CRDU electronics includes integrated circuits supplied with a regulated +5 Vdc from an internal power supply.
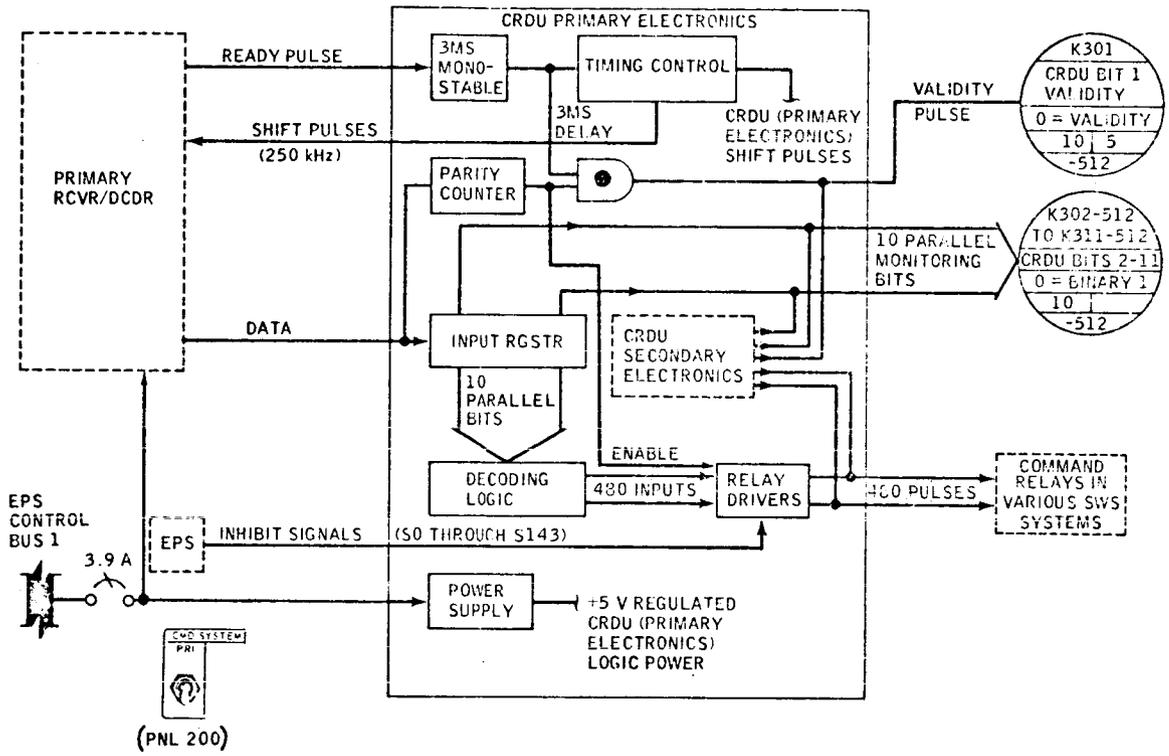
Figure 7.3.7-1 CRDU Operation

7.3.7-1   SKYLAB AM/MDA COMMAND RELAY DRIVER UNIT [CRDU]

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input Voltage: 22 to 30 Vdc
Input Power: 40.5 watts @ 27 Vdc
Output: 480 relay drivers, 0.85 amp for 200 ms

Physical Characteristics

Size:
Weight:

References

Skylab Operations Handbook, Orbital Workshop (OWS), Airlock
Module (AM) Multiple Docking Adapter (MDA) Volume I - Systems
Descriptions, Manned Spacecraft Center, Houston, Texas
(MSC 04727) 20 July 1970.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.3.7-2   SKYLAB AM/MDA ELECTRONIC TIMER

Each electronic timer (Figure 7.3.7-2) contains three magnetic
shift registers: elapsed time (Te), time to go to equipment
reset (Tx) and time to go to redundant receiver/decoder (Tr).
The Te register counts up from 0 seconds by cycling its register
contents through an incremental circuit every 1/8 second. The
Tx and Tr registers are updated via the receiver/decoder when the
receiver/decoder sends a Tx or Tr ready signal. Shift pulses
(data clock) are enabled and data from the receiver/decoder is
shifted to the corresponding Tx or Tr register. The Tx or Tr
register contents are cycled through a decremental circuit every
1/8 second for countdown.

When the Tx register counts down to Tx=0 seconds, the Tx relay is
activated for 50 ms. This activation sends a Tx=0 signal to the
receiver/decoder and to the common contact of the Te relay. When
the Te relay is set (command S294) and Tx=0, a count inhibit signal
resets the Te register to 0 seconds and sends a Tx=0 closure signal
to a Time Correlation Buffer (TCB). The Te register is reset
manually when the ZERO RESET switch (panel 212) is activated. The
Tx closure signal insures that the TCB will request the reset Te
register data upon Te relay reset.

When the Tr register counts down to Tr=30 seconds, it sets the
Tr relay providing a Tr=30 signal to the DCS. At Tr=0 seconds,
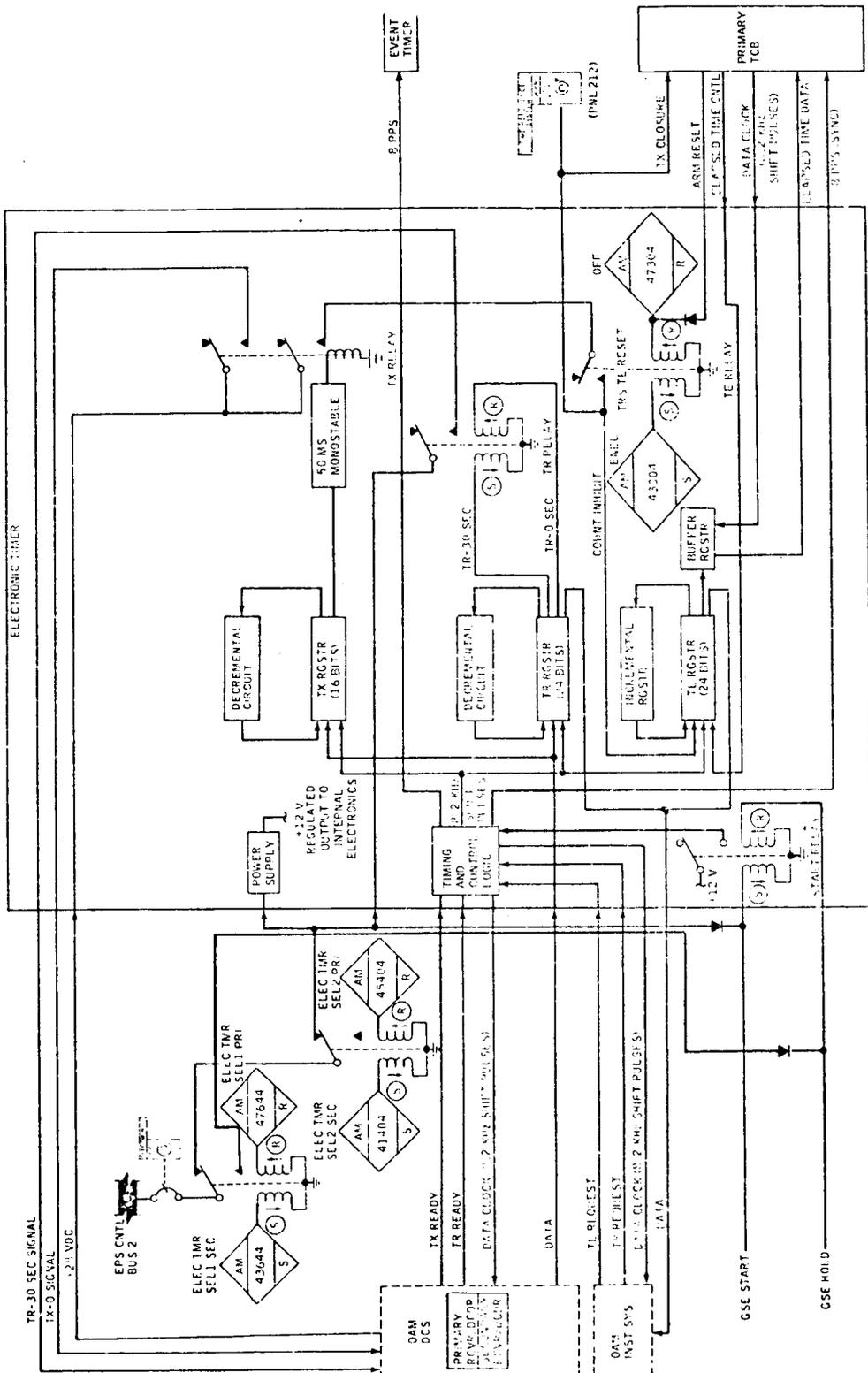the Tr relay is reset, thus disabling the Tr=30 signal.

Figure 7.3.7-2   Electronic Timer Operation

7.3.7-2   SKYLAB AM/MDA ELECTRONIC TIMER

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input Voltage: 22 to 30 Vdc
Input Power: 7.2 watts @ 27 Vdc
Crystal Oscillator Frequency: 1.049 MHz
Typical Accuracy: 0.125 second/day
Output to Event Timer: 8 pps
Te Register
    Capacity: 582 hours, 32 minutes, 31.875 seconds
    Bit Capacity: 24
    Resolution: 0.125 second
Tx Register
    Update Capcity: 2 hours, 16 minutes, 31.8575 seconds
    Bit Capacity: 16
    Resolution: 0.125 second
Tr Register
    Update Capacity: 582 hours, 32 minutes, 31.875 seconds
    Bit Capacity: 27 bits
    Resolution: 0.125 second

Physical Characteristics

Size:
Weight:

References

Skylab Operations Handbook, Orbital Workshop (OWS), Airlock
Module (AM) Multiple Docking Adapter (MDA) Volume I – Systems
Descriptions, Manned Spacecraft Center, Houston, Texas
(MSC 04727) 20 July 1970.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.3.7-3   SKYLAB AM/MDA TIME CORRELATION BUFFER (TCB)

Each Time Correlation Buffer (TCB) (Figure 7.3.7-3) contains
an oscillator and countdown chain to generate the various shift
pulses. Synchronization is provided by an 8 pps signal from the
electronic timer. An elapsed time control signal, generated
every 1/8 second, enables the transfer of elapsed time data from
the selected electronic timer. Elapsed time data enters the TCB
input register. The data is then shifted in parallel to the
binary coded decimal (BCD) converter, which converts the binary
data to the BCD data used to drive the GMT clock. The BCD data
is serially shifted to the GMT clocks when the six-bit register
contains integer seconds (no fraction of seconds) as determined
by the integer detector. The DAY COUNT switch (panel 212) allows
the crew to override the BCD input to the 24 hour day detector
at anytime. The BCD data and six binary bits of data (containing
fine time correlation information) are also serially shifted to
EREP.

The TCB contains an internal power supply that provides regulated +5
Vdc and +10 Vdc to the TCB internal electronics.

Figure 7.3.7-3.   TCB OPERATION

7.3.7-3   SKYLAB AM/MDA TIME CORRELATION BUFFER (TCB)

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input Voltage: 22 to 30 Vdc
Input Power: 17.8 watts @ 27 Vdc
Oscillator Frequency: 1.049 MHz
Typical Accuracy: 0.125 second/day
Output to EREP
    Time Word: 30 bits binary coded decimal
    Resolution: 15.625 ms (6 bits binary)
Output to GMT Clocks
    Time Word: 30 bits binary coded decimal
    Resolution: 1.0 second

Physical Characteristics

Size:
Weight:

References

Skylab Operations Handbook, Orbital Workshop (OWS), Airlock
Module (AM) Multiple Docking Adapter (MDA) Volume I - Systems
Descriptions, Manned-Spacecraft Center, Houston, Texas
(MSC 04727) 20 July 1970.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.3.7-4   SKYLAB AM/MDA GMT CLOCK

Each GMT clock (Figure 7.3.7-4) has an input register to
receive BCD data from a TCB. The data is transferred to
the BCD-to-dot-matrix-converter, which converts the data
to a form capable of driving the digital display. The data
(TE register data with DAY COUNT override capability) is
displayed by a 5 by 7 dot matrix of light emitting diodes
(LED's). Display illumination is controlled by the BRIGHTNESS
control, which varies the duty cycle of the LED excitation
(100 Hz squarewave) from 1 percent to 70 percent.
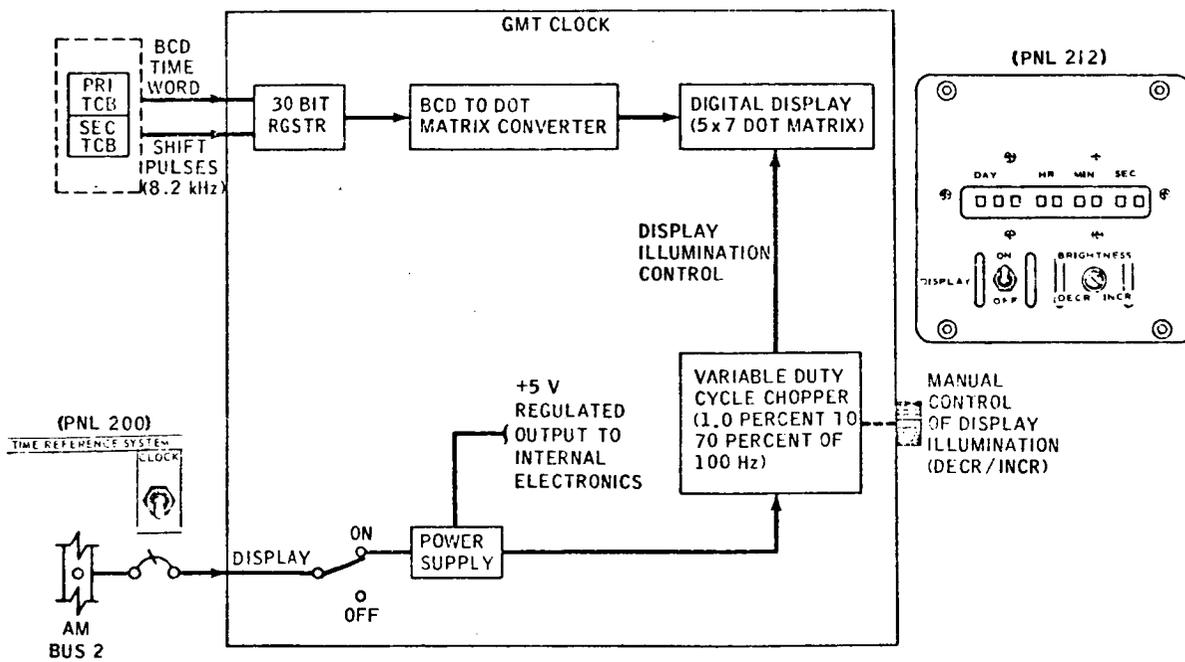
Figure 7.3.7-4   GMT CLOCK OPERATION

7.3.7-4   SKYLAB AM/MDA GMT CLOCK

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input Voltage: 22 to 30 Vdc
Input Power: 10.8 watts @ 27 Vdc
Timing Input: 30 bits binary coded decimal
Typical Accuracy: 0.125 second/day
Display Capacity: 399 days, 23 hours, 59 minutes, 59 seconds

Physical Characteristics

Size:
Weight:

References

Skylab Operations Handbook, Orbital Workshop (OWS), Airlock
Module (AM) Multiple Docking Adapter (MDA) Volume I – Systems
Descriptions, Manned Spacecraft Center, Houston, Texas (MSC
04727) 20 July 1970.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.3.7-5 SKYLAB AM/MDA EVENT TIMER

The event timer (Figure 7.3.7-5) is synchronized by an 8 pps
signal from the electronic timer. This 8 pps enables the
stepping logic which controls the internal stepping motor.
When the face mounted [DECR/INCR] switch is in the center position,
the stepping motor drives in the forward direction (1, 2, 3, 4).
When the [DECR/INCR] switch is in the DECR or INCR positions,
the stepping motor drives in the backward (4, 3, 2, 1) or
forward (1, 2, 3, 4) direction respectively at 0.3, 4.0 or 25
times the normal rate in accordance with the position of the switch.

The stepping motor mechanically drives a seven digit display
composed of seven rotary wheels. Each rotary wheel contains
the numbers 1 through 9 with the exception of the 10 minute and
10 second wheels, each of which contain the numbers 1 through 5.

The event timer contains an internal power supply that provides
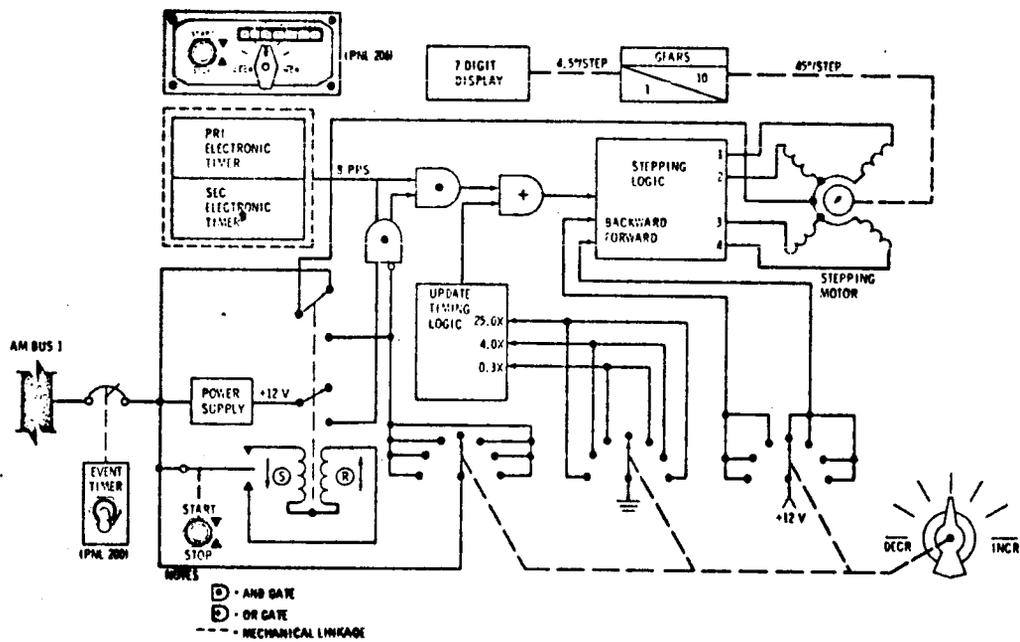a regulated +12 vdc to the internal electronics.

Figure 7.3.7-5   Event Timer Operation

7.3.7-5   SKYLAB AM/MDA EVENT TIMER

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input Voltage: 22 to 30 Vdc
Input Power: 4.3 watts @ 27 Vdc
Timing Input: 8 pulses/second (from electronic timer)
Accuracy: 0.125 second/day
Display Accuracy: 999 hours, 59 minutes, 59 seconds
Counting Rates:
    Count up or down 25 $\pm$ 25% times normal rate
    Count up or down 4 $\pm$25% times normal rate
    Count up or down 0.$\overline{3}$ $\pm$25% times normal rate
    Normal rate

Physical Characteristics

Size:
Weight:

Reference

Skylab Operations Handbook, Orbital Workshop (OWS), Airlock
Module (AM) Multiple Docking Adapter (MDA) Volume I - Systems
Descriptions, Manned Spacecraft Center, Houston, Texas
(MSC 04727), 20 July 1970.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.3.7-6   SKYLAB AM/MDA PORTABLE TIMER

The portable timer (Figure 7.3.7-6) contains the timing
mechanism which drives the hour, minute, and second hands.
A clutch disengages the timing mechanism from the display
to allow setting of the hands. When the hour, minute, and
second hands pass 12, an 800 Hz tone is initiated. The
portable timer contains one mercury battery for the timing
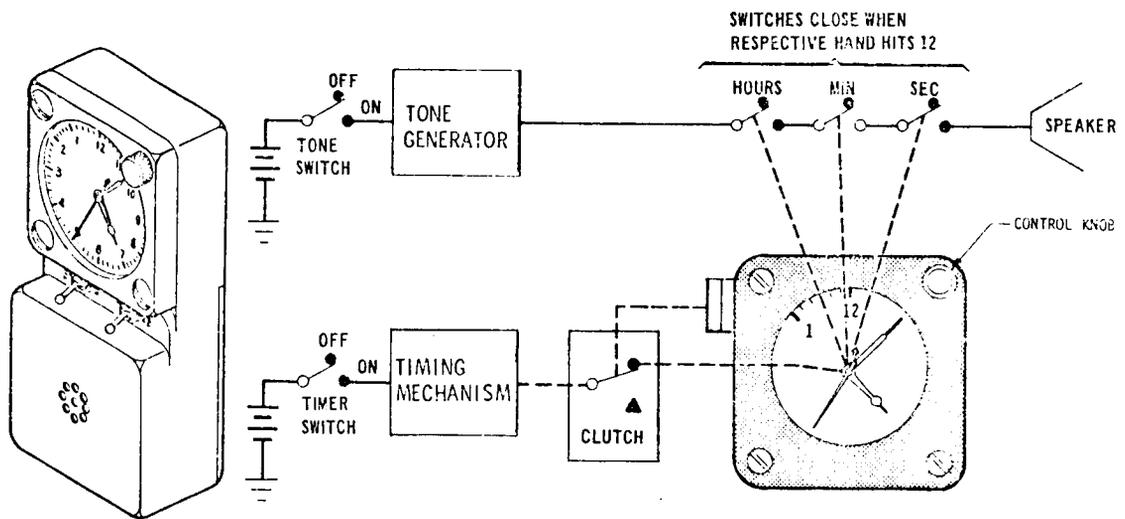mechanism and two mercury batteries for the tone mechanism.

Figure 7.3.7-6   Portable Timer Operation

7.3.7-6   SKYLAB AM/MDA PORTABLE TIMER

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input Voltage
    Timing Mechanism (one 75 ma-hr Hg battery): 1.4 Vdc (nom)
    Tone Mechanism (two 500 ma-hr Hg battery):   5.4 Vdc (nom)
Input Power
    Timing Mechanism: 8.4 microwatts (nom)
    Tone Mechanism: 0.1 watts without tone (nom)
                        1.0 watts with tone (nom)
Tuning Fork Frequency: 360 Hz
Typical Accuracy: 0.6 second/day
Audio Output
    Frequency: 800 Hz
    Sound Pressure Level (SPL) Output: 70 db SPL at 5 PSIA
    Tone Duration: Continuous

Physical Characteristics

Size:
Weight:

References

Skylab Operations Handbook, Orbital Workshop (OWS), Airlock
Module (AM) Multiple Docking Adapter (MDA) Volume I - Systems
Descriptions, Manned Spacecraft Center, Houston, Texas
(MSC 04727), 20 July 1970.

Design Status

This component was flown as part of the 1973 Skylab Mission.

7.3.11   MARINER MARS TIMING SUBASSEMBLY

The timing subassembly generates all of the necessary timing
signals for the Data Management Subsystem with the exception
of the block coder timing and block coder subcarrier signals.
The timing subassembly consists of two major subdivisions:
a 480 kHz oscillator and a countdown logic. Each of the sub-
divisions are standby redundant (i.e., power is turned off to
the timing subassembly not being used). Figure 7.3.11-1 shows
a functional block diagram of the timing subassembly.

The crystal-controlled oscillator outputs a square wave at a
fundamental frequency of 480 kHz. It maintains +0.01 percent
frequency stability while operating over a temperature range
of 0 to +55°C. The oscillator stage is isolated from its load
by a driver circuit. The countdown logic divides down the 480
kHz frequency to provide all frequencies required for system
operation. All timing signals generated by the countdown logic
are synchronous, i.e., bear a fixed time relationship to all
other timing signals. Table 7.3.11-1 is a tabulation of the
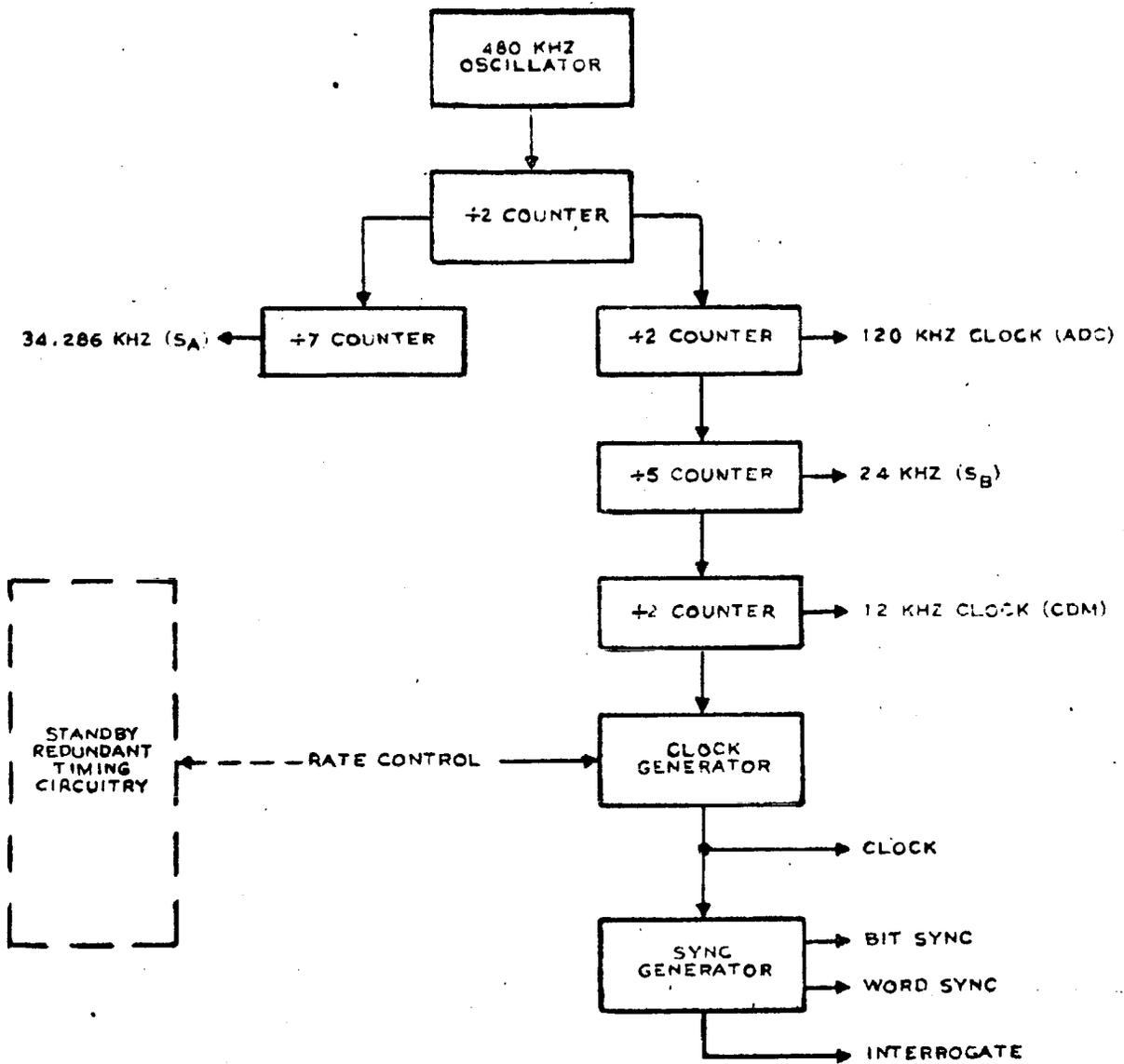timing signals.

Figure 7.3.11-1   Timing Subassembly Functional
Block Diagram

Table 7.3.11-1   TIMING SIGNALS AND PERIODS

Signal	Period
480 kHz	2.08 usec
120 kHz CLK	8.33 usec
34.2857 kHz	29.17 usec
24 kHz	41.67 usec
12 kHz CLK	83.33 usec
Clock at 33-1/3 bps	3.33 msec
Clock at 8-1/3 bps	13.33 msec
BS CLK at 33-1/3 bps	30.00 msec
BS CLK at 8-1/3 bps	120.00 msec
INT CLK at 33-1/3 bps	210.00 msec
INT CLK at 8-1/3 bps	840.00 msec
WS CLK at 33-1/3 bps	210.00 msec
WS CLK at 8-1/3 bps	840.00 msec

7.4.1 ATS-F DATA ACQUISITION AND CONTROL UNIT (DACU)

The DACU (Figure 7.4.1-1) is a fixed-format encoder with dwell capability. It accepts digital and analog data from the spacecraft subsystems and experiments, digitizes each analog sample in a 9-bit analog to digital converter, and sequences each telemetry point into its preassigned position in the telemetry format. The DACU includes (1) the spacecraft clock which provides the time code, 0 milliseconds through 365 days, for insertion into the DACU telemetry data stream; (2) the 6-hour timer used to satisfy spacecraft special timing functions; and (3) the 100-kHz clock also used to satisfy spacecraft special timing requirements. The DACU uses the 800-kHz output from the spacecraft clock as an input to frequency dividers and logic functions which generate the switching functions required to establish the telemetry format. In the dwell mode, the first 16 words are present in each minor frame irrespective of which word is being dwelled on. Thus, sync, status, calibration, command verification, and other telemetry points of prime importance are present for ground station use in each minor frame, independent of the DACU mode of operation.
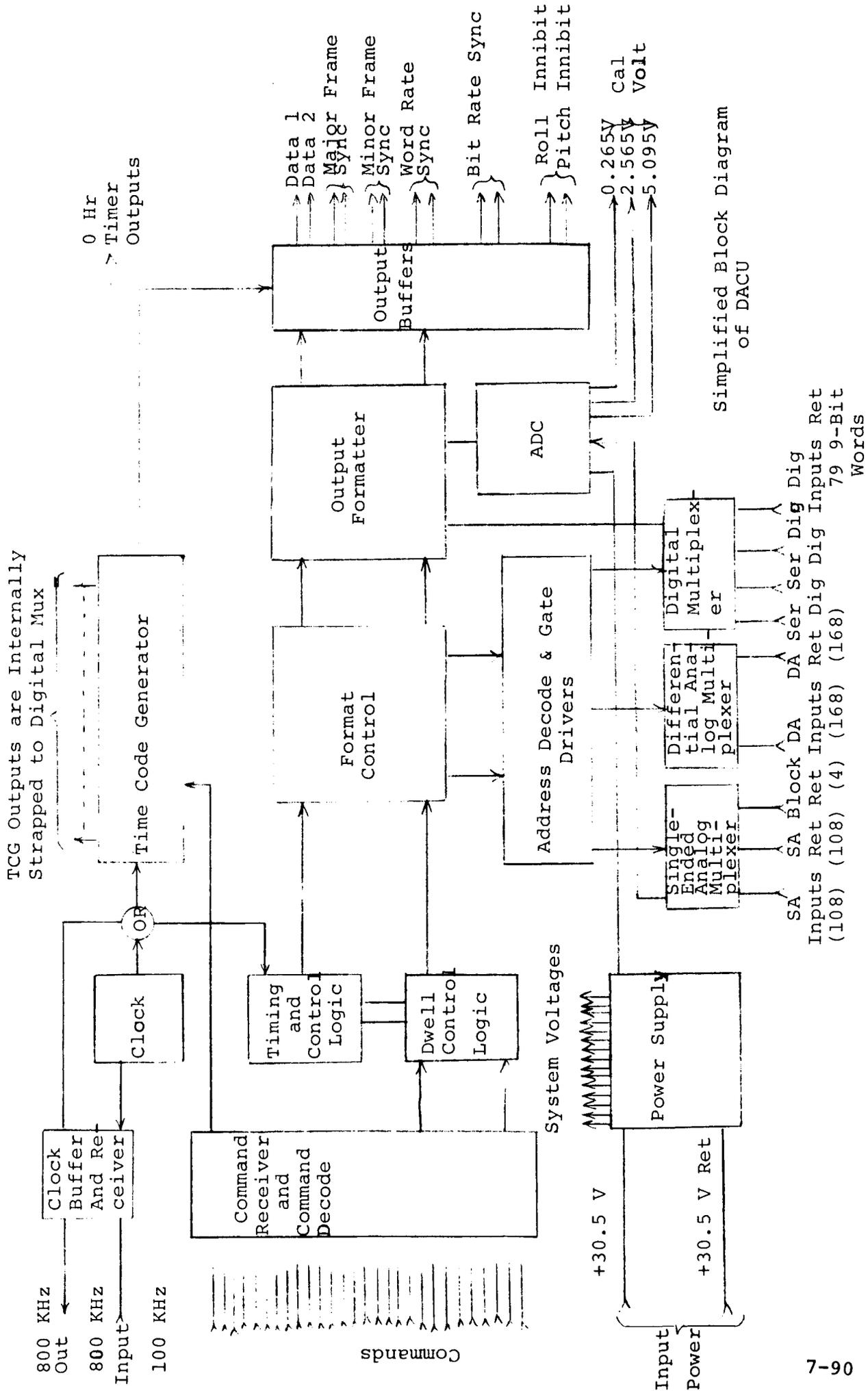
Figure 7.4.1-1. DACU Functional Block Diagram

7.4.1   ATS-F DATA ACQUISITION & CONTROL UNIT (DACU)

General Description

Program: ATS-F
Vendor: SCI
Part Number: 7922159-1 (IBM)

Performance Characteristics

Accepts data and control inputs:
   Analog single ended - 108 channels
   Analog differential - 168 channels. (Total: 276 analog channels)
   Digital - 79 nine-bit parallel digital words.
   Digital - One 72-bit serial word
   Commands - Responds to 12 commands
Output Data
   Format: Fixed format with dwell capability (manchester
        II +180°)
   Capacity: 368 9-bit words (112 words @ 1/3 sps,
        256 @ 1/48 sps)
   Sampling Rate: 1/2.95 sps and 1/47.19 sps
   Word Rate: 43.40 words/sec.
   Minor Frame: 128 words per frame at 1/2.95 FPS
   Major Frame: 16 minor frames, 1/47.19 FPS
     Sync and timing outputs also provided.

Physical Characteristics

Size: 31 cm (12.2in) by 21.6 cm (8.5 in) by 21.6 cm (8.5 in)
Weight: 93 kg (20.5 lbs)
Input Power: 14.0 W max at 30.5 Vdc (0.35 W standby)
        27.5 to 33.6 Vdc operation
Cooling Method: Mounting surface

Environment: IBM Spec 7919095

References

Specification: 7919095 (IBM)
ICD: 2854001 (SCI)
The ATS-F&G Data Book, GSFC, Sept. 1972

Design Status

This component is scheduled to be flown as part of the planned
mid-1974 ATS-F mission.
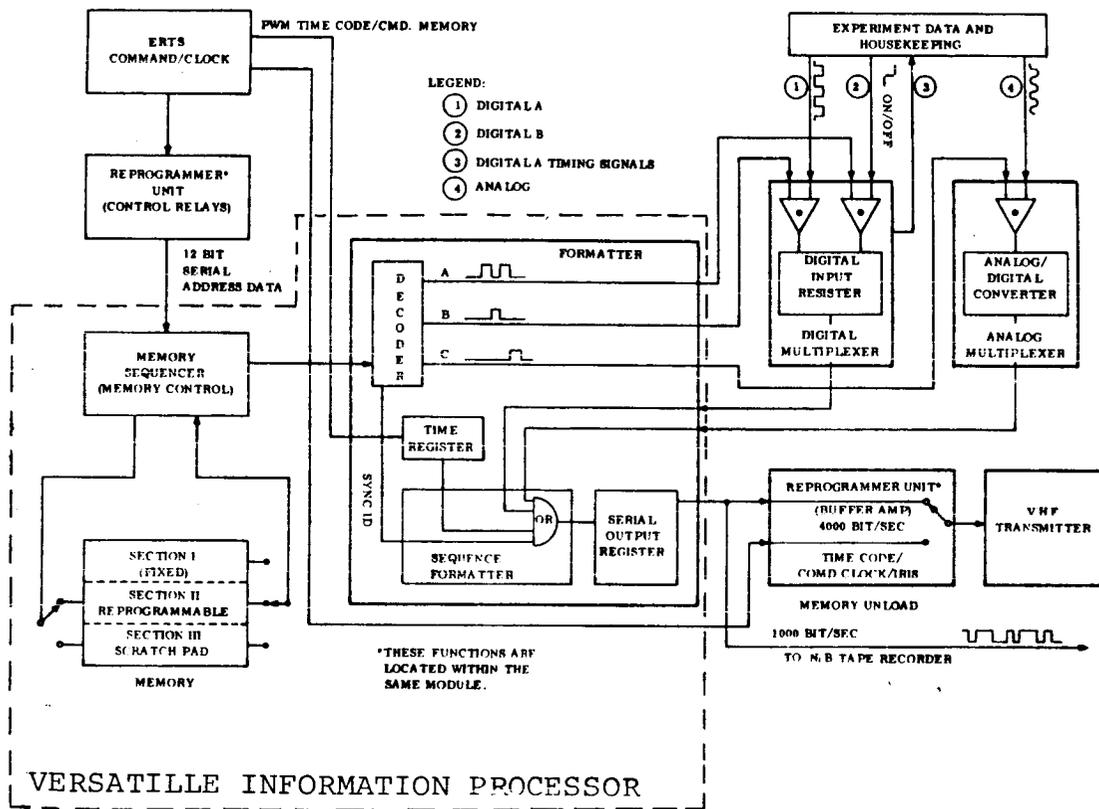
7.4.2   ERTS-B VERSATILE INFORMATION PROCESSOR

The Versatile Information Processor (VIP) (Figure 7.4.2-1) samples the output of approximately 900 sensors, processes the data, and inserts it into an output bit stream to be stored and/or transmitted in real-time. Data is digitized, time multiplexed, and formatted into a 1000 bit/second serial bit stream. The serial bit stream is recorded in biphase on the narrow band tape recorder (NBTR) and may be transmitted simultaneously over either the 137.86 MHz VHF or 2287.5 MHz USB transmission links.

The VIP has two other modes of operation plus an emergency mode. Ground command will cause the VIP to transmit the entire contents of its memory in place of data or cause the VIP to transmit the data gate addresses instead of data. In the emergency mode all channels will be sequentially sampled at a reduced rate, thus allowing data to be received at the ground station although there has been a major failure in VIP.

The VIP uses a memory and its associated logic to generate a desired sampling sequence. When memory locations are decoded, a 10 bit binary instruction is generated. Some of these instructions produce control pulses which are used to select any one of approximately 900 data input channels to be sampled. Other memory locations will generate synchronization words, time code, and mode and minor frame identification. With either of these two types of data output words, a tag bit is generated (GATE/VALUE) which specifies whether the 10 bit data output word is to be decoded to select a particular data input (i.e., GATE) or whether the 10 bit output word is to be inserted directly into the VIP output bit stream as a synchronization word, identification, etc. (i.e., VALUE).

The ERTS telemetry matrix consists of 20 columns, each 80 rows deep. Two columns are used for synchronization, one for time, and one for minor frame identification. The remaining 16 columns contain sampled input data. To generate a particular sampling sequence a portion of the words in memory are sequentially decoded. The completion of one cycle constitutes a minor frame. Input gates may be sampled as often as desired during a minor frame. At the end of each minor frame, a minor frame counter is incremented by one, and the same memory words are recycled to generate the second minor frame of the program. This process repeats until the minor frame counter has reached a predetermined value (i.e., 80 minor frames) which signifies the end of a major frame of data.

The VIP memory has storage capacity for 640 words, each consisting of 10 bits. Section 1, composed of 496 words, is a nondestructive readout only μ-biax memory array which is programmed on the ground by special equipment hardwired to the spacecraft. Section 2, composed of 128 words, is a nondestructive readout section which can be altered at any time both prior to launch or in orbit through

VERSATILE INFORMATION PROCESSOR BLOCK DIAGRAM

Figure 7.4.2-1

the ERTS command link. It provides the capability to alter the
sampling rates and thus provides added flexibility to be used
during on-orbit operations for troubleshooting, malfunction
analysis, observation of unforeseeable phenomena, elimination
of inputs from those experiments which have failed, etc. Section
3 of the memory provides a "scratch pad" function. It serves as
a temporary storage medium during the execution of the various
programs.

Sections 1 and 2 provide the equivalent of 4 sampling sequences,
three of which are determined prior to launch. The fourth
program may be altered in orbit. Ground commands are used to
select specific memory sections and are used to verify the VIP
memory contents by causing the entire contents to be transmitted
over the beacon link to ground at the rate of 400 words/second.

The VIP provides for the sampling of approximately 900 distinct
input signals from experimental and housekeeping sources. These
inputs are digitized to 10 bits with a resolution of 1 part in
256 (8 bits), and are output, least significant bit first, into
the VIP 1000 bit/second data stream. The two least significant
bits, although transmitted, are considered useless due to vehicle
noise and A/D conversion error allocation.

7.4.3 HEAO-A CENTRAL PROGRAMMING UNIT

The Central Programming Unit (CPU) (Figure 7.4.3-1) performs the functions of a programmer and formatter. It can control and sample up to 30 Remote Multiplexer Units (RMUs) with up to 256 channels each for a total capacity of 7680 data channels. The CPU sends addresses to and receives data from the RMU channels in a pre-determined format sequence. Instructions that control which data are inserted into each of the 256 format word slots are stored in Read Only Memories (ROMs). One 16-bit instruction is required for each word slot. Stored programs in Read Only Memories (selectable on command) may choose any one of seven (7) minor frame formats (each with 256 8-bit words) to meet various experiment and mission requirements.

The CPU has twelve subcommutators, each with 128 8-bit words. The subcommutator format instructions are stored in ROMs.

Fixed words are inserted into each format to provide frame synchronization, subcommutator word and format identification, and elapsed time for data reduction purposes.

The eight major functions performed by the CPU are described below:

Timing and Control Logic. The timing and control logic receives a 1.024 MHz signal from the operating central clock unit. This signal is the basic time reference for all CPU operations and has a stability of one part in 10^{-9} for 24 hours.

Power Gating and Format Select Logic. The power gating and format select logic controls power to the ROMs. The format select commands determine which minor frame ROM is selected; all others are gated off when they are not required. This technique greatly reduces power and is simple to implement.

Read Only Memories. Each ROM is programmed prior to each mission to fit the format requirements. The use of ROMs gives full flexibility to program any RMU channel to any telemetry word slot. Super-commutation of a data channel is accomplished by programming the ROM to repeat the channel address. Accelerated subcommutation is accomplished simply by programming subcommutator channels in the 256 word minor frame format. Twelve ROMs (128 words, 16-bits each) provide for twelve subcommutators. Any RMU channel can be assigned to any subcommutator word slot by programming the subcommutator ROM.

Instruction Formatter. The instruction formatter decodes the 16-bit words from the minor frame and subcommutator ROMs, formats them into RMU instructions, and selects the clock and instruction/data line to the desired RMU.
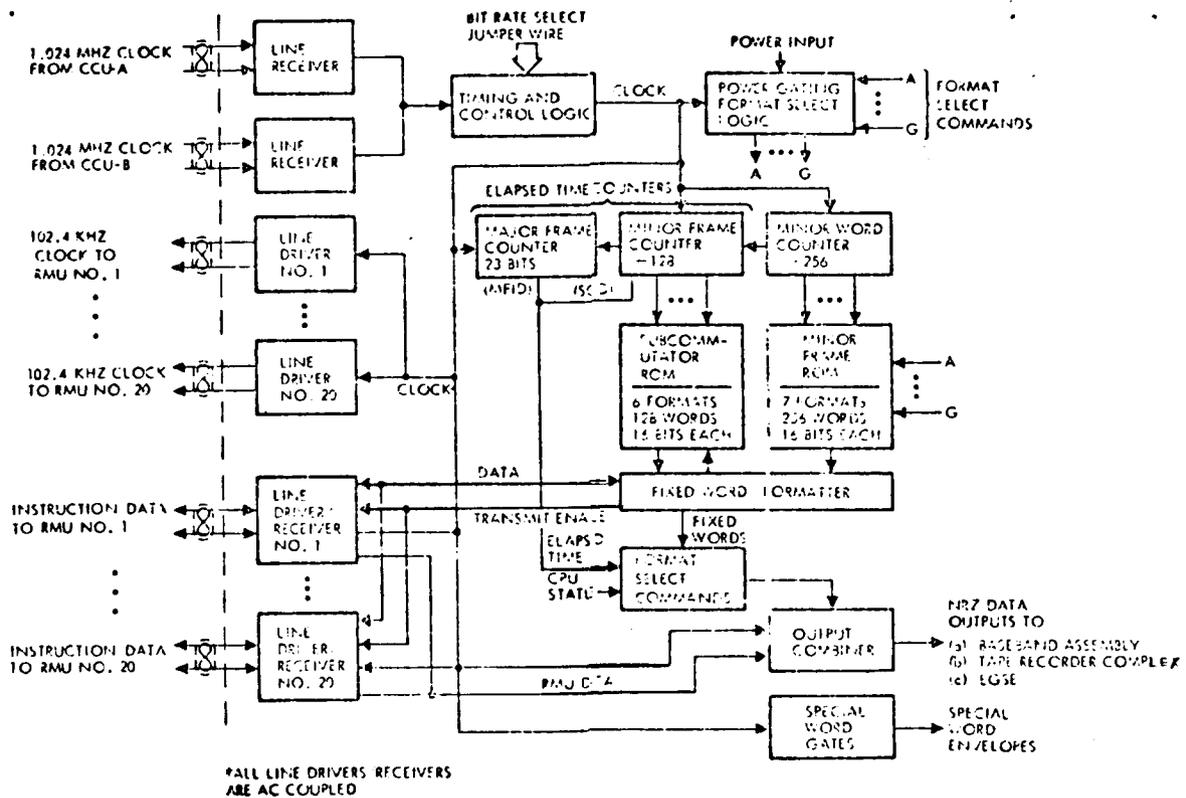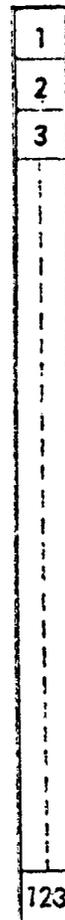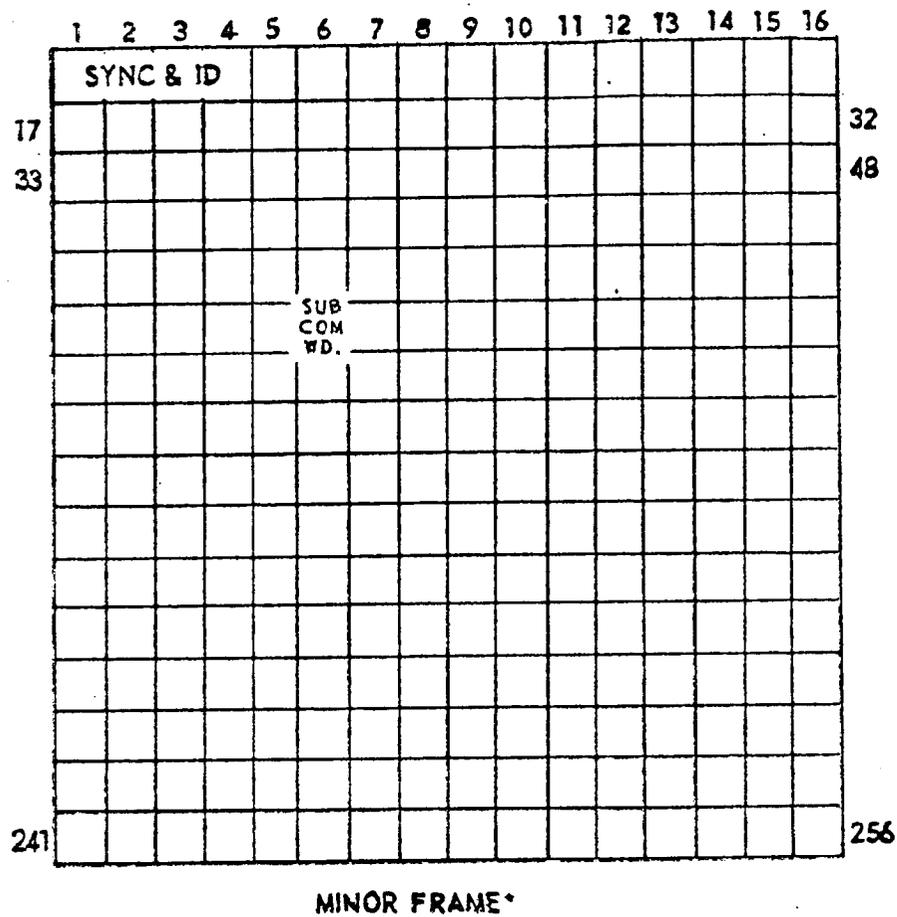
Figure 7.4.3-1. CENTRAL PROGRAMMING UNIT

Fixed-Word Formatter. The fixed-word formatter is a register plus logic that collects fixed words and shifts them to the output combiner at the appropriate word times. The following fixed words are collected: frame sync and format identification from the instruction formatter, subcomm ID and minor frame ID from the elapsed time counters, and CPU/RMU redundancy status.

Line Drivers and Receivers. The line drivers and receivers are ac coupled, cross-strapped circuits that interface with the CCUs and the RMUs and provide the required dc isolation and protection against single-point failures.

Output Combiner. The output combiner is a group of gates which have their outputs or'd together. The gates are enabled at the appropriate times to interlace the fixed words and data into the telemetry bit stream. The logic is implemented such that data from a malfunctioning RMU cannot interfere with data from a properly addressed RMU.

Operationally the CPU selects RMUs by activating the instruction/data lines. The selected RMU recognizes the presence of a signal on the line and will turn on its power to respond by sampling the channel addressed by the CPU. The RMU response is an eight-bit word to the CPU. If selected data is analog it is converted to an eight-bit digital word by an internal A/D converter. If the selected word is serial digital, a read envelope is generated by the multiplexer that has a duration of eight-bit periods. Eight inputs are sequentially sampled to form an eight-bit word for bilevel data. Each RMU has a mixture of 256 channels of input data (analog, bilevel, and serial digital). A typical data format data frame is shown in Figure 7.4.3-2. The analog data into the RMU is in the range of 0 to 5 volts. Bilevel and serial data will be less than 2 volts for a logic zero and greater than 3 volts for a logic one.

Formatted data streams are transmitted from the CPU to the Baseband Assembly for real time transmission, and to the tape recorder via the TRIU (Tape Recorder Interface Unit) which controls and provides data to the three tape recorders for storage. When the spacecraft is in contact with a ground station, the tape recorders are commanded to dump the stored data at 512 kbps.

MINOR FRAME*

*REQUIRES 128 MINOR FRAMES TO SAMPLE COMPLETE FIELD OF DATA WHEN A SUB COM IS USED.

SUB COM

Figure 7.4.3-2.   TYPICAL DATA FORMAT

7-98

7.4.3   HEAO-A CENTRAL PROGRAMMING UNIT

General Description

Program: HEAO-A
Vendor: TRW
Part Number: TRW Equipment Specification EQ4-1099

Performance Characteristics

Format:	See Figure 7.4.3-2
Bit Rate:	25.6 kbps
Word Size:	8-bits
Minor Frame:	256 words
Major Frame	128 minor frames
Subcommutation:	Up to 12 subcoms. A minor frame word is subcommutated into a 128 word subcom.
Supercommutation:	Supercommutation accomplished by addressing and provided as required.
Addressing:	Sends addresses to and receives data from RMU channels in a predetermined format sequence
Formats Selectable:	Up to 7 shall be selectable on command from ground, stored in ROMs. Format ID identifies particular format; commanded format changes not made until completion of present minor frame Format changes will not alter bit rate and specified measurement locations
Minor Frame Sync:	At beginning of each minor frame, length and pattern: 111 110 101 111 001 100 100 000
Format ID:	3-bit code representing count of 0 to 7
Subcom ID:	7-bit ID representing count of 0 to 127
Format ID and Subcom ID:	Immediately follows minor frame sync
Redundant Component ID:	Unique bits used to identify backup components when in use
Output to Transmitter/ Tape Recorder/GSE:	25.6 kbps NRZ data, 1.024 MHz clock, subframe rate sync
Absolute Accuracy:	Maximum error $\pm$ 1/2 LSB quantization; $\pm$ 0.5% due to all other sources; digital error rate from RMU to CPU 10^{-7}

Physical Characteristics

Size:	3.81cm (1.5in) by 15.24cm (6.0in) by 20.32cm (8.0in); ROMs: .009cc for MOS; .036cc for bipolar; .108cc for core; .097cc for plated wire
Weight:	.998kg; ROMs: .122kg for MOS; .240kg for core; 2.67kg for plated wire
Input Power:	±12Vdc, ± 5Vdc, 3.5 watt max; ROMs: -22 Vdc, .5 W for MOS; 5 Vdc, 3.36 W for bipolar; +28 Vdc, 2.03 W for core; +28 Vdc, 1.07 W for plated wire

References

TRW, HEAO Preliminary Requirements Review, "Command and Data Handling System," Volume III-A, July 24, 1972.

TRW, HEAO Design Approach, Aug. 27, 1971.

Design Status

The HEAO-A program is currently in a state of redefinition. This component is a viable candidate for application in the 1974 HEAO-A mission.

7.4.4-1   OSO-I PCM ENCODER

The PCM encoder (Figure 7.4.4-1) accepts PAM analog and serial digital telemetry data from remote multiplexers. Primary timing and control of the PCM encoder is derived from the Manchester coded (split phase) address provided by the format generator. Functions performed by the PCM encoder are:

1. Decode address input words (Manchester coded data from format generator) to determine:

   a. Output line selection for transferring the remote multiplexer (RM) address portion of the input word.

   b. Output line selection for switching an internal current source.

   c. Selection of an RM input line pair (differential input) and whether to treat the expected input as analog or serial digital data.

2. Process RM input data of either analog or serial digital form to generate a synchronized non-return-to-zero pulse code modulated (NRZ-L/PCM) output bit stream. Analog data is encoded into 8 bit digital words. Timing requirements are shown in Figure 7.4.4-2.

3. Provide RM power control outputs in accordance with internally stored command data words. execution of these commands is determined by unit power turn on, the command envelope, and the minor frame sync input. The RM power control outputs share the RM address output lines.

4. Provide telemetry status outputs upon receipt of telemetry clock and envelope inputs.
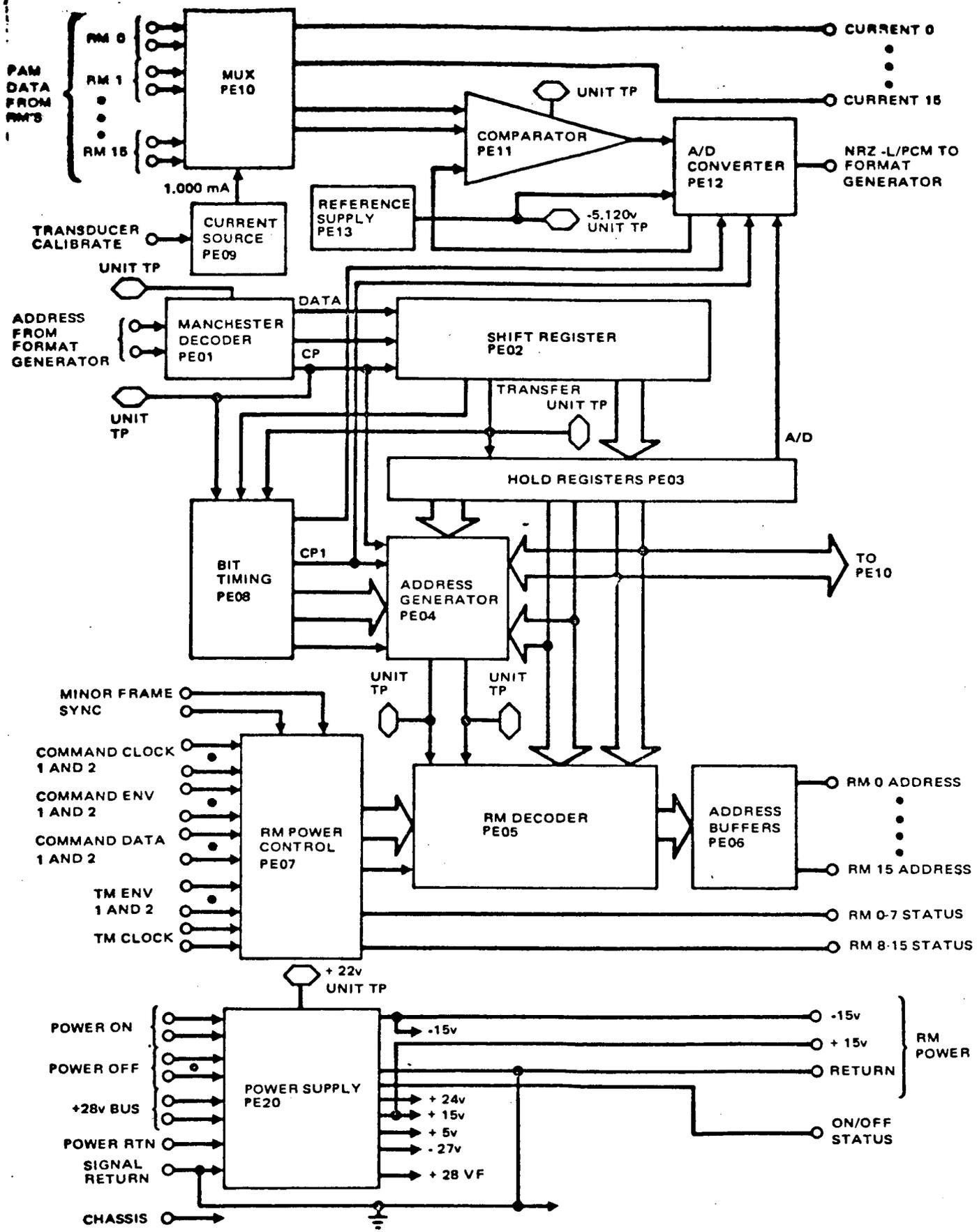
Figure 7.4.4-1.   PCM ENCODER FUNCTIONAL BLOCK DIAGRAM
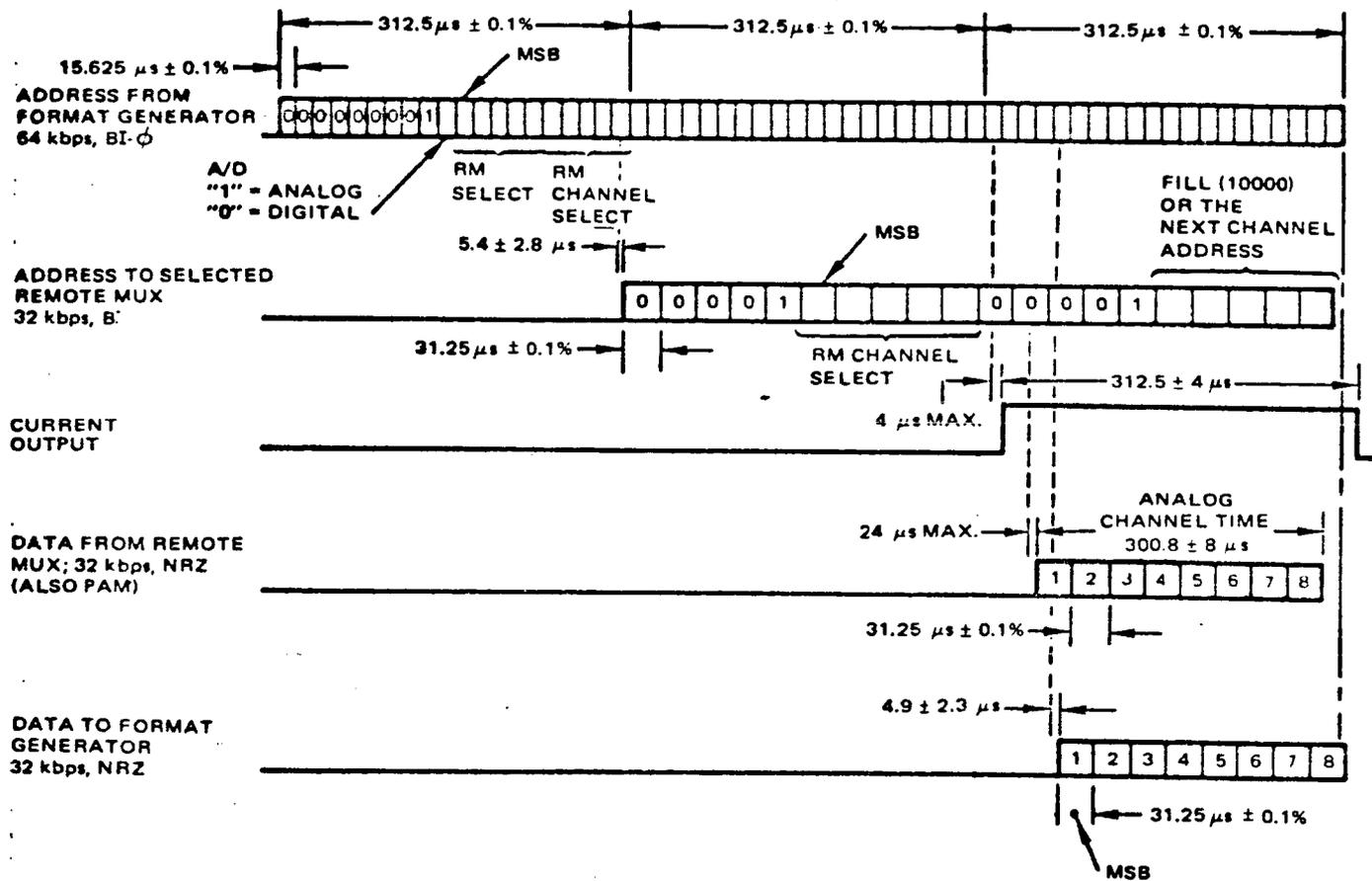
Figure 7.4.4-2. PCM Encoder Timing Diagram

7.4.4-1   OSO-I PCM ENCODER

General Description

Program: OSO-I
Vendor:
Part Number: 3280620-100 (Spec. No. DS31331-163)

Performance Characteristics

Accepts data in either analog or serial digital form. Encodes
0 - 5 V analog data into 8 bit digital words with accuracy of
+10 mv + one-half of the least significant bit. Output data
stream Is NRZ-L/PCM to the format generator at 32 kbps. This
is 5 times the speed words are transferred from format generator
to telemetry transmitter.

Physical Characteristics

Size: 33.53 cm (13.2 inch) by 14.73 cm (5.8 inch) by 3.56 cm
         (1.4 inch)
Weight: 1.54 Kg (3.4 lbs)
Input Power: 28 +5 Vdc including 300 mv ripple
                2.27 watts +30% nominal power
Cooling Method: Cold plate surface mounting

Environment: Hughes Spec SS31331-003

References

"Data Handling and TM Subsystem", Hughes Aircraft Spec No.
SS31331-160, 12 September 1972.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

7.4.4-2   OSO-I FORMAT GENERATOR

The format generator (Figure 7.4.4-3) is a central component of the telemetry processing and data storage group. It generates a sequence of instruction words to interrogate data sources, formats the data into a fixed telemetry format (Figure 7.4.4-4) and provides buffering and output data source switching. This operation is based on four equal time intervals within each word period as shown in Figure 7.4.4-5.

The sequence of interrogation words to sample the data is derived from a read-only memory defining two unique telemetry formats, either of which shall be selectable by external command to increase data handling capability. Both formats may be selected concurrently for simultaneous real time telemetry transmission of one set of telemetry data while recording another set of telemetry data in an onboard tape recorder. Simultaneous operation under control of the two format generators is accomplished by interleaving time shared interrogation signals to the remote multiplexers with both format generators powered. Simultaneous tape recording of data from both format generators is excluded.

Other features of the Format Generator are:

1.   It provides commandable switching circuitry to:

   a.   Enable S-Band, VHF, or tape PCM outputs.
   b.   Select a source for the S-Band output
        (RT, OBP memory, SCP memory, or tape).

2.   Upon command, it accepts an externally supplied addressing sequence and provides the resulting formatted data as a serial NRZ output (OBP mode).

3.   It provides unit status telemetry outputs upon receipt of telemetry clock and envelope inputs.

4.   It provides timing for onboard processor (OBP) interface.
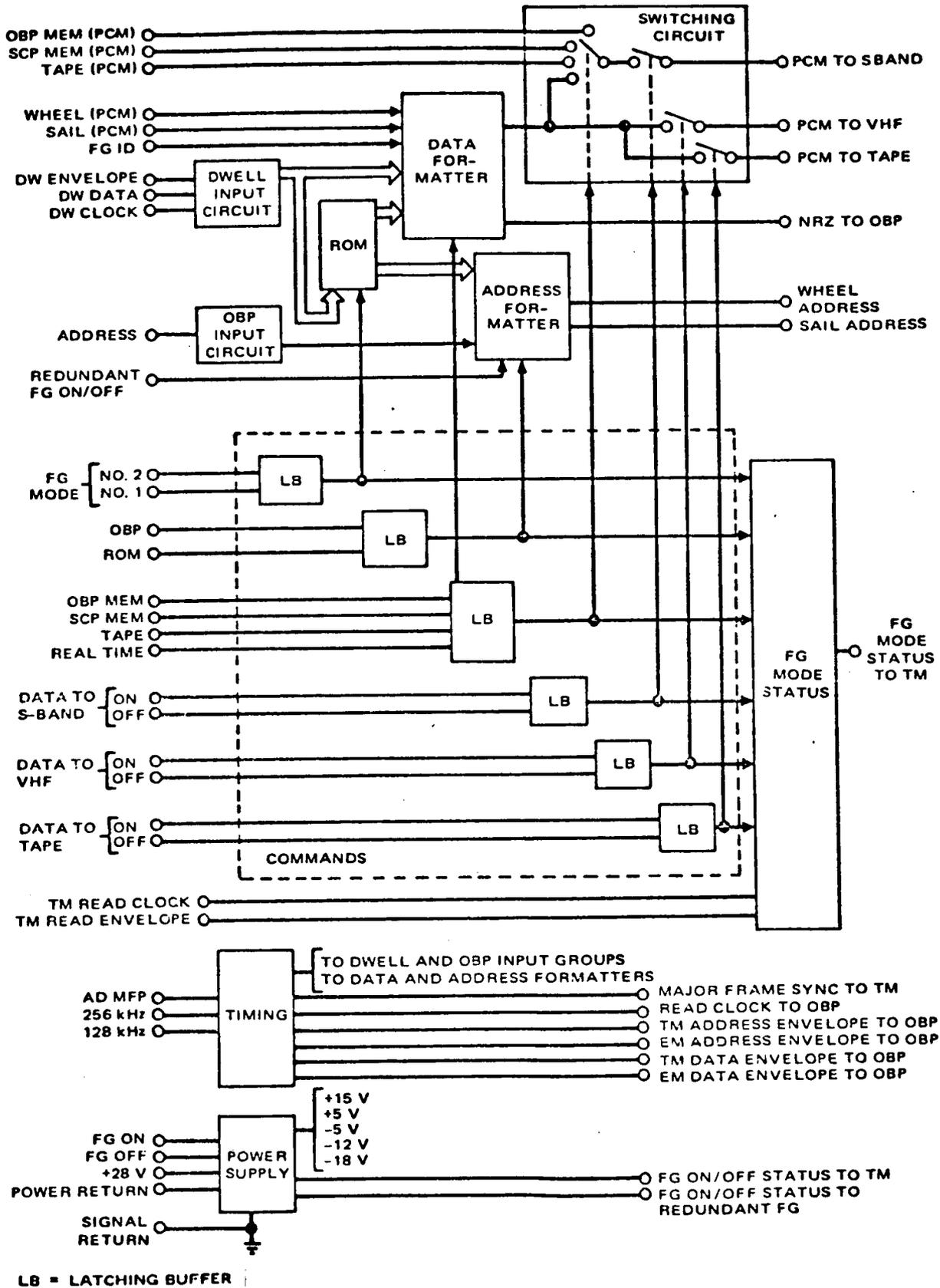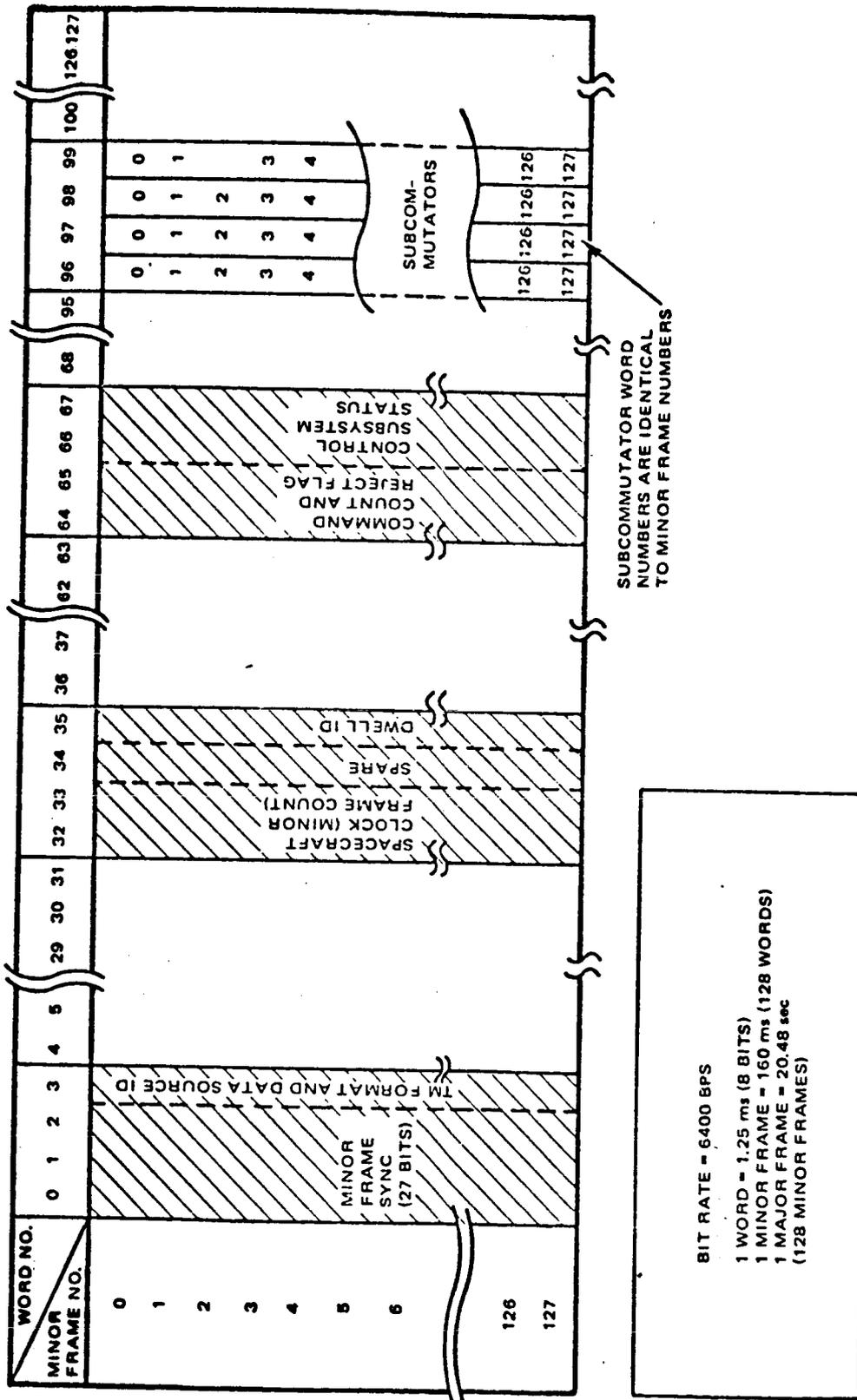
5.   Upon command, it accelerates sampling rate (dwell).

Figure 7.4.4-3   Format Generator Functional Block Diagram

Figure 7.4.4-4. TELEMETRY MAJOR FRAME FORMAT

BIT RATE = 6400 BPS

1 WORD = 1.25 ms (8 BITS)
1 MINOR FRAME = 160 ms (128 WORDS)
1 MAJOR FRAME = 20.48 sec
(128 MINOR FRAMES)

NOTE: SIXTEEN MINOR FRAME WORDS (I.E., 0, 1, 2, 3, 32, 33, 34, 35, 64, 65, 66, 67, 96, 97, 98, 99) are RESERVED FOR SPECIFIC SYSTEM DATA AS INDICATED. THE REMAINING 112 MINOR FRAME WORDS are AVAILABLE FOR EXPERIMENT TELEMETRY AND OTHER SPACECRAFT HOUSEKEEPING DATA.
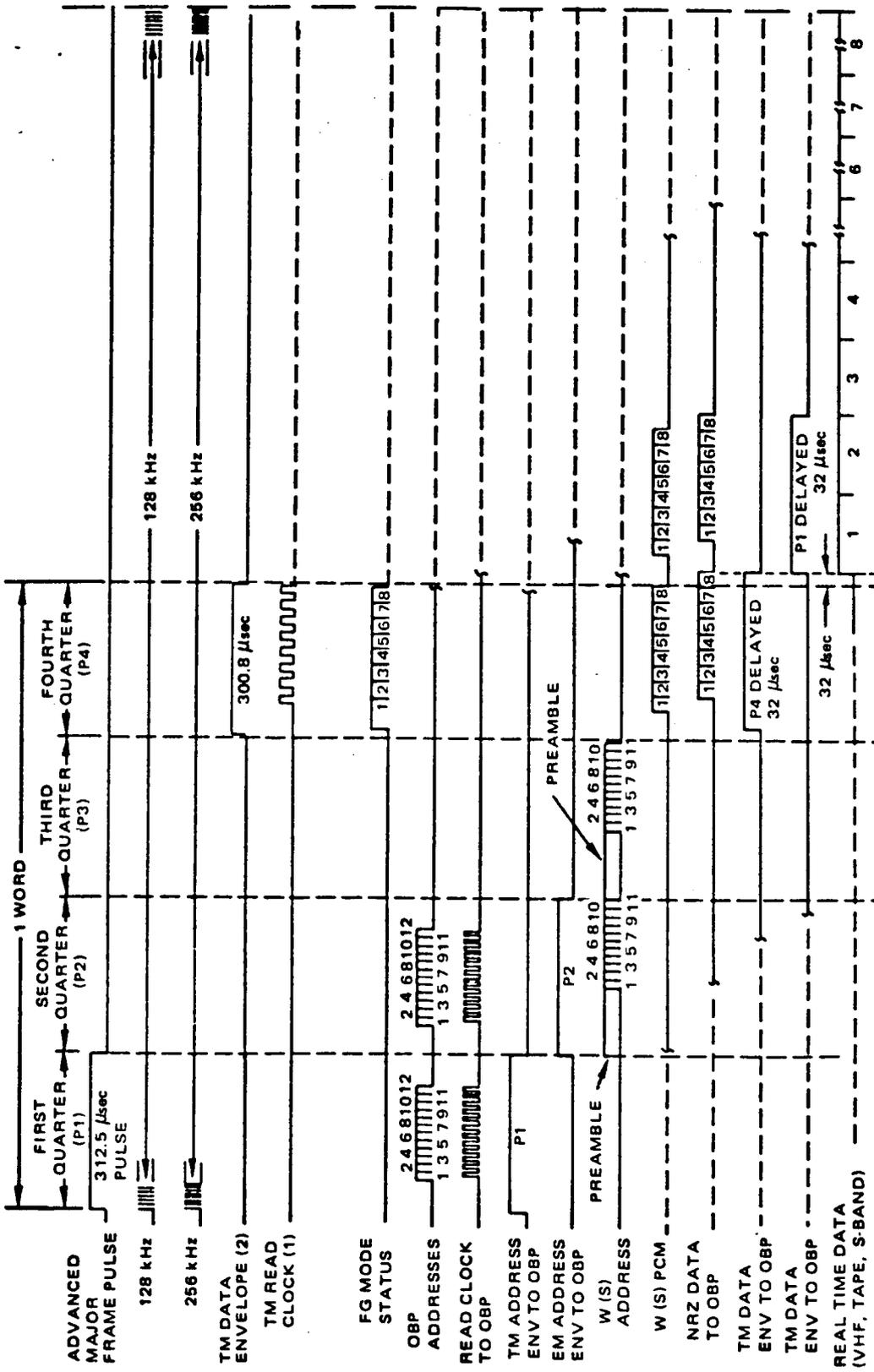
Figure 7.4.4-5. Format Generator Unit Timing Diagram

7.4.4-2   OSO-I FORMAT GENERATOR

General Description

Program: OSO-I
Vendor:
Part Number: 3280610-100 (Spec No. DS31331-162)

Performance Characteristics

Format: 1 word = 1.25 microsecond (8 bits)
           1 minor frame = 160 milliseconds (128 words)
           1 major frame = 20.48 seconds (128 minor frames)
           Bit Rate = 6400 bps (real time transmission)

Physical Characteristics

Size: 37.08 cm (14.6 inch) by 14.73 cm (5.8 inch) by 3.56 cm
         (1.4 inch)
Weight: 1.33 Kg (2.9 lbs)
Input Power: 2.5 watts +30% nominal (28 +5 Vdc)
Cooling Method: Cold plate surface mounting

Environment: Hughes Spec SS31331-003

References

"Data Handling and TM Subsystem Spec", Hughes Aircraft Spec
SS31331-160, 12 September 1972.

Design Status

This component is scheduled to be flown as part of the planned
1974 OSO-I mission.

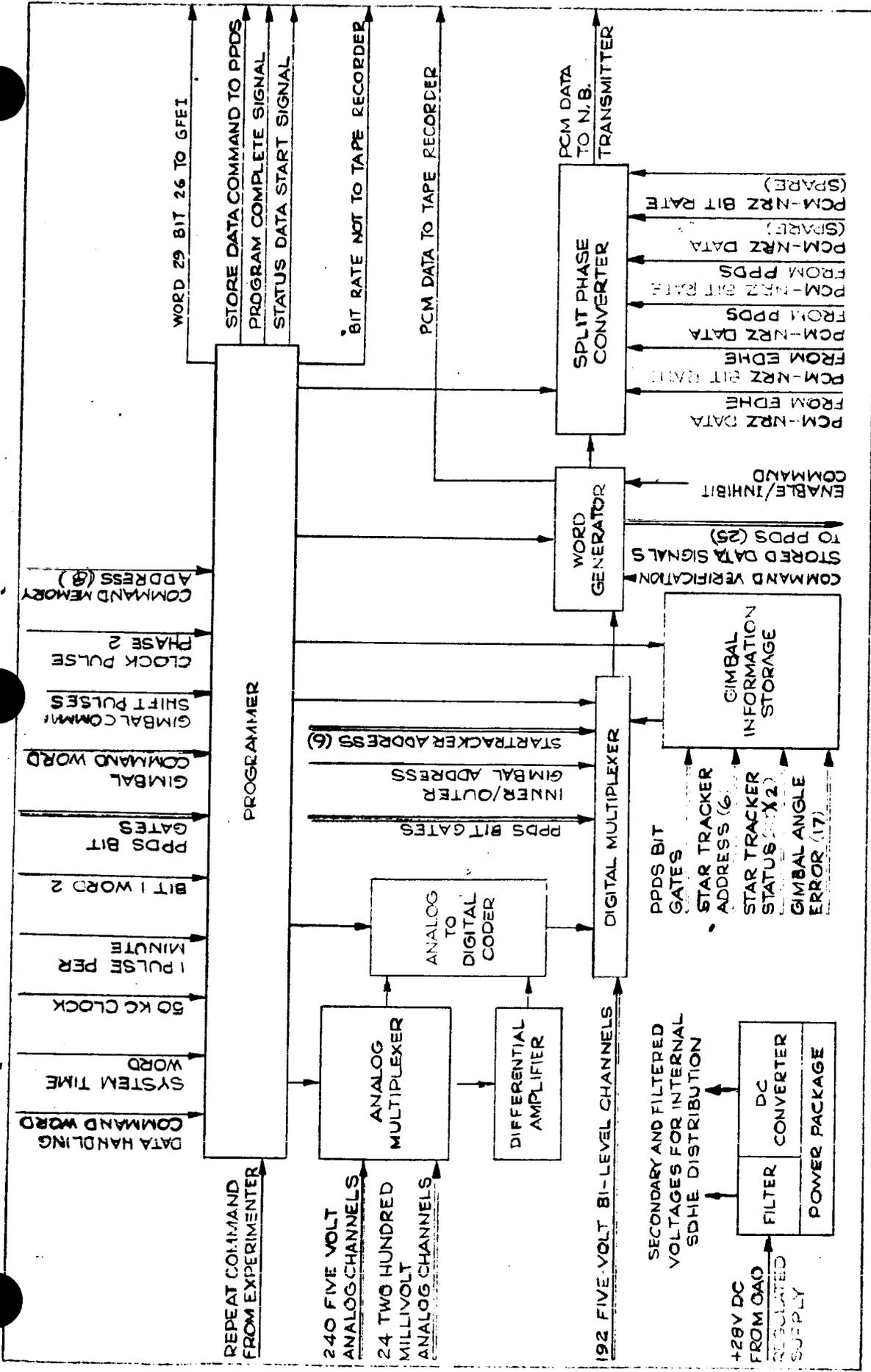## 7.4.6-1   OAO-C SPACECRAFT DATA HANDLING EQUIPMENT

The Spacecraft Data Handling Equipment (SDHE) (Figure 7.4.6-1) organizes, encodes, and transmits data received from all OAO subsystems to earth over the narrow band (NB) transmitter. It also processes data for storage in the tape recorder or primary processor data storage (PPDS).

The SDHE receives and processes four different types of data signals.

1. Digital Data Signals - The SDHE accepts gimbal status data, onboard processor (OBP) status data, command memory address, command verification, and system time as digital input signals. These signals are bi-level groups of information.

2. Bi-level Status Data Signals - The SDHE digital multiplexer accepts data inputs from 192 bi-level status data channels.

3. Analog Data Signals - The SDHE accepts 240 high level (zero to five volts) analog signals and 24 low level (zero to two hundred millivolts) analog signals. The SDHE converts each analog signal into an eight-bit binary coded output.

4. NRZ Data Signal - The SDHE accepts NRZ data together with a synchronizing bit rate signal from the Experimenter's Data Handling Equipment (EDHE) and PPDS. These signals are received at a bit rate of 1.042 KHz, converted to a split-phase signal, and transmitted directly to earth by the narrow band transmitter (NBT).

Command signals from the PPDS are processed as follows:

1. Data Handling Command Word (DHCW) - The SDHE accepts from the PPDS a 32 bit digital command word at a 50 KHz rate. This command controls the start, the mode of operation (except when NRZ signals are being received), the data to be transmitted, and the destination of the transmitted data. A new data handling command word must be issued to place the SDHE into the new mode of operation.

2. Enable/Inhibit Command - This control signal from the PPDS enables or inhibits SDHE data to the NBT.

3. Timing Signals - The SDHE is synchronized by the bit and word time signals from the PPDS. The basic timing signals are the 50 KHz clock and 31 PPDS bit gates.

SPACECRAFT DATA HANDLING EQUIPMENT BLOCK DIAGRAM

Figure 7.4.6-1

Digital, bi-level, and analog data signals are output to the NBT and/or tape recorder in real time, or to the PPDS data storage in a storage mode. The SDHE reads, encodes, and transmits the input digital, bi-level and analog data signals as required by a data handling command word. The SDHE output signals are transmitted either directly to the tape recorder and to earth via the narrow band transmitter (real time mode) in a format of 65 words, each word having 25 data bits plus one odd parity bit (Figure 7.4.6-2) or to the PPDS storage(store mode) in a format of 64 words, each word having 25 bits (the parity bit omitted in this mode). The NRZ input signals to the SDHE are output to the narrow band transmitter only.

The Programmer controls the sampling of data, word formats and output format arrangements. The basic logic consists of a storage register and counters which are synchronized by the PPDS 50 KHz clock. As a data handling command word is received by the Programmer it is stored in a 12 stage storage register. Register state and various counters are gated to provide the necessary pulses at the proper time for organizing the output frame format. When the given command has been executed, the Programmer returns the SDHE to a standby condition.

The 50 KHz clock pulse synchronizes the 50 KHz OSC and counters to the Primary Processor Data Storage 50 KHz master clock frequency. All of the remaining clock pulses are Primary Processor Bit-Time Pulses (PPBT's), (also called Bit Gates). If the 50 KHz clock pulse is lost because of malfunction, the Programmer will continue to operate the SDHE system, except that the gimbal information may be in error. Loss of PPBT's will cause the Programmer to operate in the last mode entered into the DHCW register.
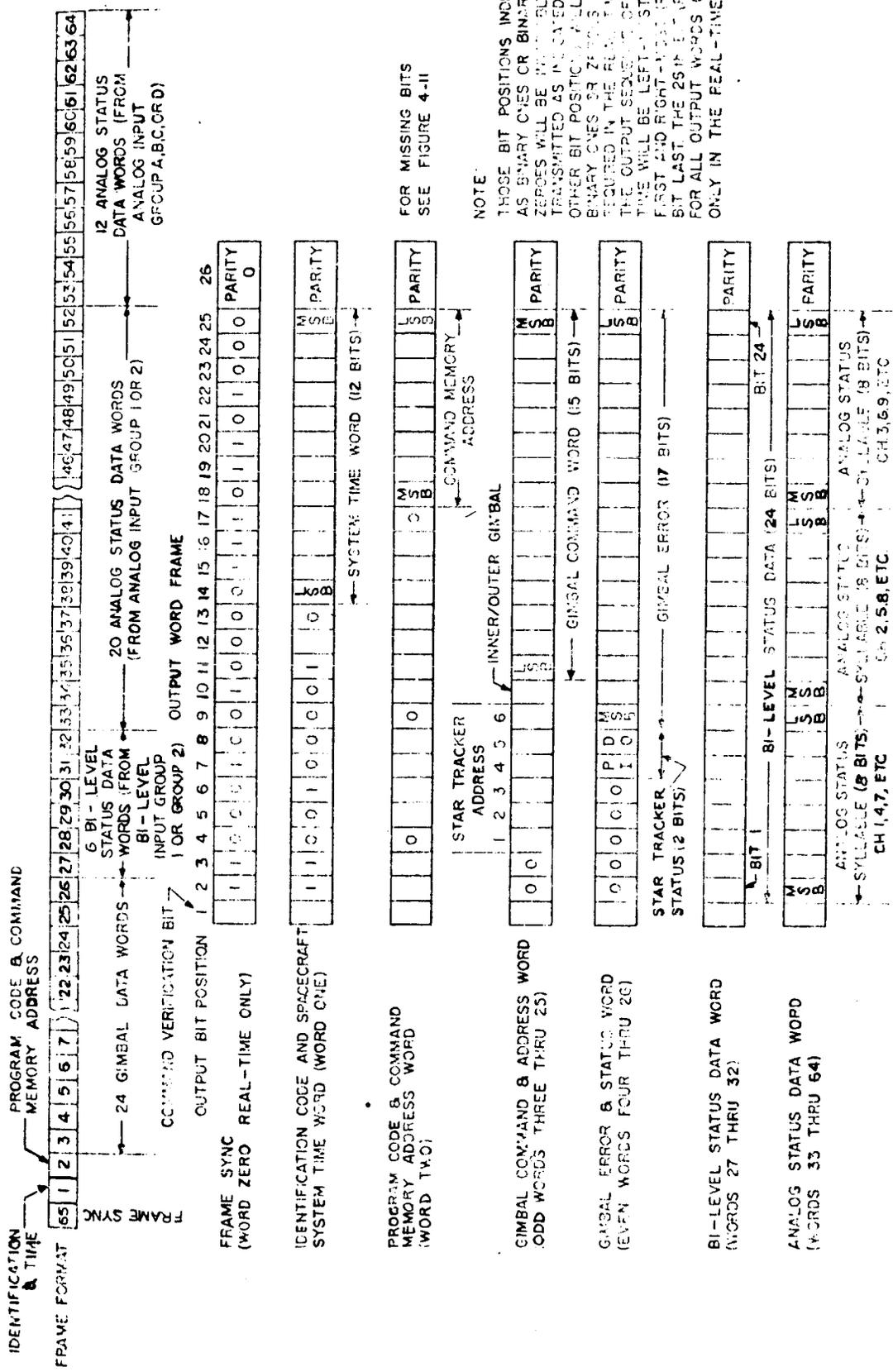
Figure 7.4.6-2. SDHE DATA FRAME AND WORD FORMAT

7.4.6-1   OAO-C SPACECRAFT DATA HANDLING EQUIPMENT

General Description

Program: OAO-C
Vendor: Radiation Inc.
Part Number:

Performance Characteristics

Input Analog Hi Level:	240 channels (A/D converted to 8 bits)
Input Analog Lo Level:	24 channels (A/D converted to 8 bits)
Discretes:	192 bilevel channels
Digital:	1. Sync, ID & Data - see words (0-26) format below
	2. NRZ serial digital from EDHE if present replaces output format below
Master Frame Length:	8 sub frames (12.8 seconds/master frame)
Sub Frame Length:	65 26-bit words/sub frame (1.6 sec/sub frame)
Word Length:	26 bits (25 + parity)

Words: (0-2) sync, identification and time, program code and command memory address.

(3-26) 24 gimbal data words

(27-32) bilevel data (24 channels/word, 192 total bilevel channels)
4 words (96 channels) are sampled each sub frame
2 words (2 groups of 48 channels) are sampled each 2nd sub frame

(33-52) 20 words (each word = three 8-bit analog channels for 60 channels)
2 groups of 60 channels = 120 channels (sampled each 2nd sub frame)

(53-64) 12 words (each word: three 8-bit analog channels for 36 channels)
4 groups of 36 channels = 144 analog channels (sampled each 5th sub frame)
264 analog channels total.

Physical Characteristics

Size:	SDHE logic :15 cm (5.9 in) by 32.3 cm (12.7 in) by 23.9 cm (9.4 in)
	Power pack :12.7 cm (5 in) by 12.7 cm (5 in) by 19.1 cm (7.5 in)
Weight:	SDHE logic 10.5 kg (23 lbs.). Power pack 3.1 kg (6.8 lbs.)

References

OAO Spacecraft Design Manual, Grumman Aircraft Engineering Corp., June 1968

Comments

SDHE contains analog mux, A/D converter, digital mux serial/ parallel shift register and a programmer which controls sampling rates.

Design Status

This component was flown as part of the 1972 OAO-C mission.

7.4.6-2   OAO-C EXPERIMENTERS' DATA HANDLING EQUIPMENT

The Experimenters' Data Handling Equipment (EDHE) assembles analog and digital data from the experiment and places these data in a format suitable for transmission to the ground in the real-time mode or storage in a store mode. Figure 7.4.6.3 is a block diagram of the EDHE.

The EDHE has provisions to accept, as input data, 200 individual bilevel channels and 30 (0 - 5 volt) analog channels. Bilevel inputs are received by the EDHE in one of two voltage bands: ONE (5 to 18 volts) and ZERO (-0.3 to +0.5 volt).

In addition to the above inputs, the EDHE receives 50 KHz clock pulses from the Primary Processor Data Storage (PPDS) to synchronize the 50 KHz EDHE internal clock. The EDHE also receives 24 primary processor bits to perform basic gating.

The major operating modes of EDHE are as follows:

> Real Time Mode: Upon command, the EDHE generates fixed output data frames consisting of 21 words, each word consisting of 26 bits (the 26th bit being an odd parity bit). Data can be transmitted to the WB transmitter at 1042 bps, or to the NB transmitter via the SDHE split-phase converter (also 1042 bps), or to both transmitters simultaneously.
>
> Complete Frame Store Mode: Upon command, the EDHE generates fixed output data frames consisting of 20 words (frame sync is eliminated), each word consisting of 25 bits (the parity bit is not stored). The data are transmitted to data storage (DS) in the PPDS.
>
> Partial Frame Store Mode: Upon command, the EDHE enters either one of two storage modes: store mode lock out or store mode asynchronous. In either of these modes, the EDHE sends data to DS (25 bits at a time in parallel). The parity bit and the frame sync word are not transmitted.
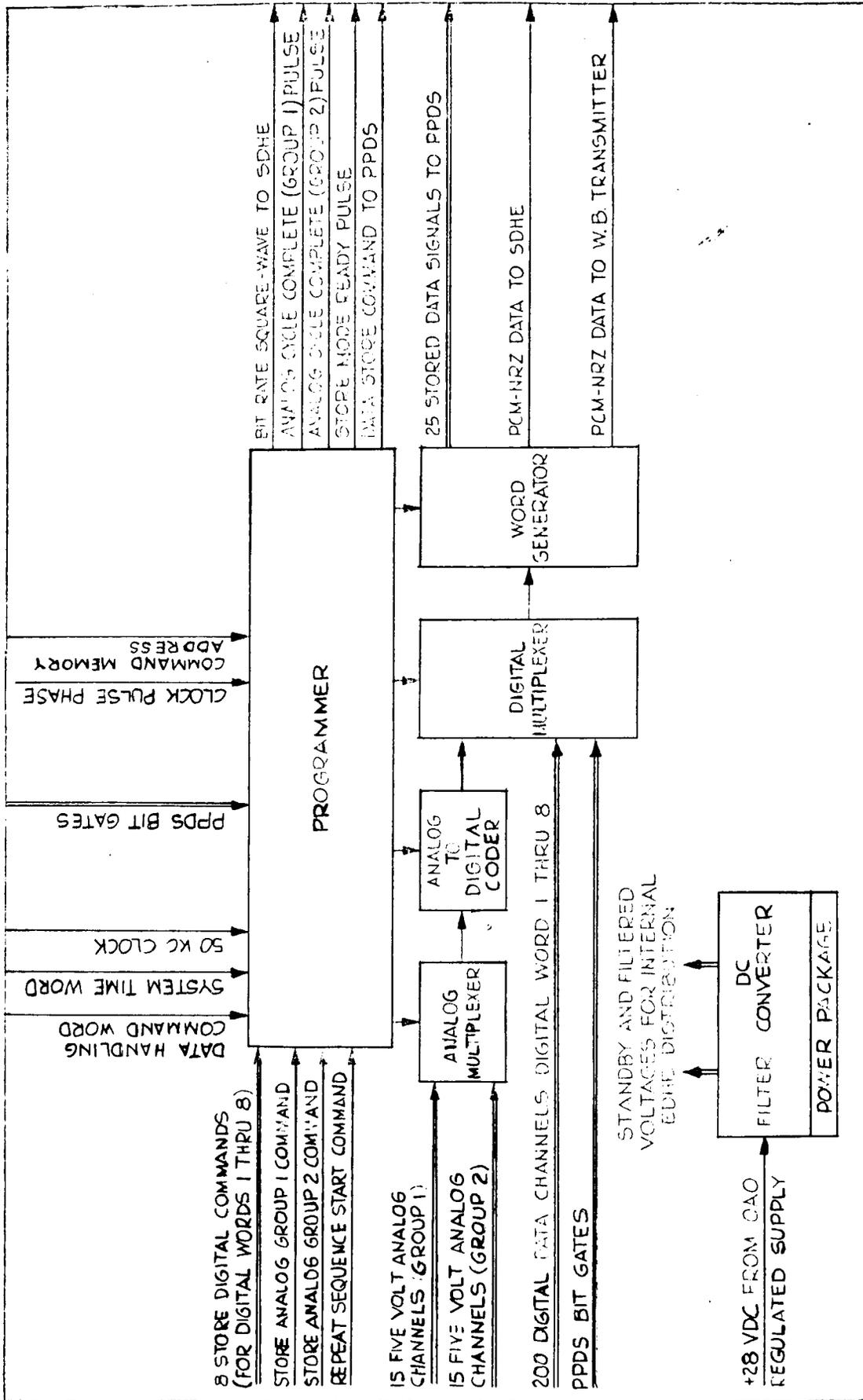
EXPERIMENTER'S DATA HANDLING EQUIPMENT BLOCK DIAGRAM

Figure 7.4.6-3

7.4.6-2 OAO-C EXPERIMENTERS' DATA HANDLING EQUIPMENT

General Description

Program: OAO-C
Vendor: Radiation, Inc.
Part Number:

Performance Characteristics

Input Analog Hi Level:	30 channels
Discretes:	200 bilevel channels
Digital:	See word format below
Master Frame Length:	21 26-bit words. A single 21 word frame or sequences may be transmitted by the narrow band transmitter in place of normal SDHE (PCM-NRZ) data as programmed or ground commanded. (50 KHz bit rate)
Sub Frame Length:	N/A
Word Length:	(25-bit + parity) = 26 bits
Words:	(0-2) Sync, identification and time, program code
	(3-10) 8 digital data words (25 bilevels/word)
	(11-15) 5 analog data groups (15 analog channels, 8-bit each)
	(16-20) 5 analog data groups (15 analog channels, 8-bits each)

Physical Characteristics

Size:	EDHE logic unit:	15cm (5.9 in) by 24.2cm (9.5 in) by 23.7cm (9.3 in)
	Power pack:	12.7cm (5 in) by 12.7cm (5 in) by 19.1cm (7.5 in)
Weight:	EDHE logic unit:	7.5kg (16.5 lbs)
	Power pack:	3.1kg (6.8 lbs)

References

OAO Spacecraft Design Manual, Grumman Aircraft Engineering Corp., June 1968.

Design Status

The component was flown as part of the 1972 OAO-C mission.

7.4.7-1   SKYLAB AM/MDA PROGRAMMER

The programmer (Figure 7.4.7-1) sequentially samples all data signals and puts them into a serial PCM bit stream. All analog channels are time-multiplexed into one serial PAM stream. An analog to digital (A/D) converter encodes each analog signal in the PAM stream into an 8 bit binary coded word. Event channels (bilevel, bilevel pulse, and digital), already in digital form are sampled and time-multiplexed in sets of eight. The 8 bit coded analog measurements and the 8 bit sets of event measurements are sequenced through the output shift register to provide an output serial PCM bit stream. Control is exercised by the programmer through 24 bit master frame synchronization words, 19 bit subframe synchronization words and address count to the output shift register.

The typical analog channel is sampled and time-multiplexed through 1st and 2nd tier switches. If the channel is a 0 to 20 mv low level analog, it is amplified to a proportional 0 to 5 Vdc level. The analog channels are switched through one of the five master tier switches into a high impedance buffer amplifier of the sample and hold circuit. The new stretched 0 to 5 Vdc signal appears at the A/D converter where it is digitized into an 8 bit binary code. Upon completion of the encoding process, 8 bits are gated in parallel to the output shift register. The A/D converter gates are inhibited whenever synchronization, digital time or event channels are being shifted into the output shift register. The 8 bit word is serially shifted out at a 51.2 kbps rate with the most significant bit first. This serial bit stream is filtered and transformer coupled to the transmission subsystem.

The unfiltered 51.2 kbps bit stream also appears at the input of four tape recorder output converters (one in the programmer, three in the interface box). The circuit in the programmer gates only subframe #1 words into the recorder shift register. In a subframe one word occurs for every tenth word of the real time output; thus, the recorder register has its 8 bit word shifted out at a 5.12 kbps rate. This output is transformer coupled to the tape recorders. The tape recorder clock signal is derived from the electronics timing signal.

Direct inserted bilevel and bilevel pulse channel inputs are sequentially sampled in groups of 8 bits and sent via eight parallel lines through insertion gates to the output register. Other bilevel inputs from the interface box as well as digital time data and digital subframe identification data are sequenced through the output register for insertion into the PCM output stream.
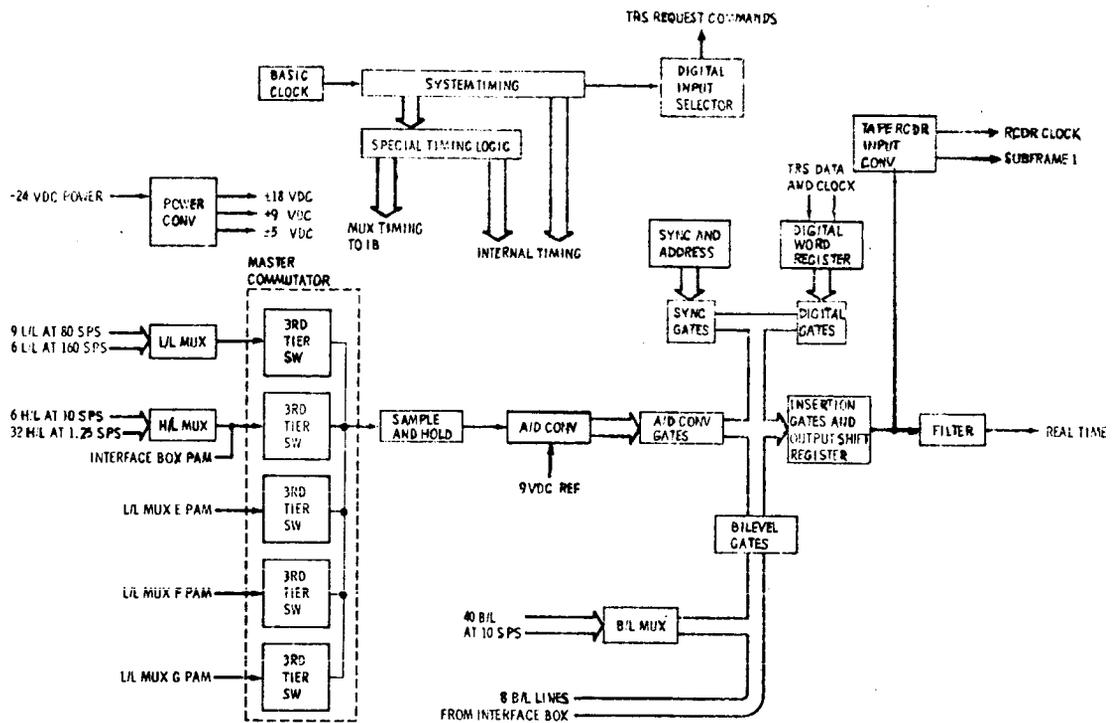
Figure 7.4.7-1   Skylab OWS/AM/MDA Programmer

The digital time channels receive 24 bit digital time words, divided into three 8 bit groups, from the Timer Reference System (TRS). These words represent either elapsed time (Te) or time to go to redundant DCS receiver/decoder (Tr). Both time values are requested by the programmer. The Te request command occurs every 100 milliseconds, the Tr request command occurs once every 2.40 seconds and out of phase with the Te commands. Upon command, the TRS provides a 24 bit serial data output in parallel with 24 clock (shift) pulses at a 8.192 kHz rate. The register in the programmer provides Te and Tr data to subframe #1. The 24 bits of digital Te in the registers are designated as coarse time. The 8 least significant bits (LSB) of these 24 bits are also designated as fine time. At each 100 millisecond update of Te, the eight LSB stages are read to the output shift register as fine time for subframe 1 measurements. Once every 2.40 seconds, the digital register has the Tr time shifted in and at the same time shifts out the remaining Te bits. The output shift register inserts the 24 bit Tr word into the subframe 1 time slots of the PCM stream at the proper time.

7.4.7-1   SKYLAB AM/MDA PROGRAMMER

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Input-Analog Hi Level (0 - 5 V):   6 at 10 sps, 32 at 1.25 sps
    -Analog Lo Level (0 - 20 mv):   9 at 80 sps, 6 at 160 sps,
                                      6 at 10 sps
    -Digital: 24 bit words at 0.416 sps, 8 bit words at 10 sps
Output: - 51.2 Kbps serial NRZ-C at 0.88 ±.04 V p-p (R/T to TM)
         - 5.12 Kbps serial RZ at 5V p-p (+ 1.0, -.5)(subframe 1)
         - 96 master frames per data cycle (2.40 sec), 40 master
           frames per second
         - 4 master frames per subframe
         - 160 words per master frame (0.25 sec)
         - 8 bits per word

Physical Characteristics

Size:
Weight:
Input Power: 24 ±0.5 Vdc,6.3 watts

References

"Skylab Operations Handbook", Volume I, MSC-04727, 20 July 1970,
Revised 24 January 1972.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.4.7-2   SKYLAB AM/MDA INTERFACE BOX

The interface box (Figure 7.4.7-2) includes all the logic to operate and accept multiplexer inputs, provide timing and subframe identification to the programmer for subframes 2, 3, and 4, and accept and output digital time to experiments. Functionally, the interface box is very similar to the programmer. Both accept and process low level and high level analog inputs, digital time inputs, and bilevel inputs. Both process PCM data output for recording. In addition, both exchange data and timing signals with the other.

The interface box's digital register shifts in 24 bits identical to the programmer digital register. The register is read by three sets of output gates that route the bits to the programmer bilevel gates.

Each 100 milliseconds fine time (the 8 least significant bits (LSB) of the Te digital word) is read to the output shift register for subframe 2, 3, and 4 measurements. Once every 2.40 seconds, all 24 bits are read for subframes 2, 3, and 4 coarse time. In addition, each subframe identification word is activated and read into the output shift register once each 2.40 seconds.

The bilevel and bilevel pulse channel outputs are sequentially sampled in sets of 8 bilevel channels or 8 bilevel pulse channels. All high level multiplexer output lines (bilevel and bilevel pulse) are connected to the interface box where they are bused together before being outputted to the programmer. The interface box's digital time and subframe identification words are gated in parallel to the programmer.

Figure 7.4.7-2.   Interface Box Block Diagram

7-123

7.4.7-2   SKYLAB AM/MDA INTERFACE BOX

General Description

Program: Skylab AM/MDA
Vendor:
Part Number:

Performance Characteristics

Inputs: High level analog (0 - 5 Vdc) - 18 at 10 sps; 5 at 20 sps;
          1 at 40 sps; 8 at 40 sps; 5 at 320 sps
          PAM data from external high and low level multiplexers
          51.2 kbps PCM telemetry data stream (from programmer)
Outputs: PAM data and timing signals to programmer
          5.12 kbps serial RZ at 5V p-p (+1, -0.5)   (subframes
          2, 3, or 4) to tape recorder
          24 bit parallel elapsed time word to experiments

Physical Characteristics

Size:
Weight:
Input Power: 18.3 watts at 24 +0.5 vdc
Cooling Method: Cold plate mounting

References

"Skylab Operations Handbook (OWS/AM/MDA)", Volume 1, 20 July 1970,
Revised 24 January 1972.

Design Status

This component was flown as part of the 1973 Skylab mission.

7.4.8   SKYLAB ATM PCM/DDAS TELEMETER MODEL 301

The Model 301 Pulse Code Modulation/Digital Data Acquisition System (PCM/DDAS) Telemeter (Figure 7.4.8-1) is an encoder-multiplexer assembly. It is programmable to accept, encode (when necessary), and time integrate PAM analog signals, discrete signals, and digital signals.

The digital-data output of the Telemeter is in three forms: a serial pulse train, a series of parallel 10 bit words, and a 600 MHz carrier modulated by the serial pulse train.

A master electronic clock included in the PCM/DDAS Telemeter initiates numerous synchronizing signals. These signals synchronize other multiplexers to operate in step with the Telemeter and also synchronize internal circuits of the Telemeter itself.
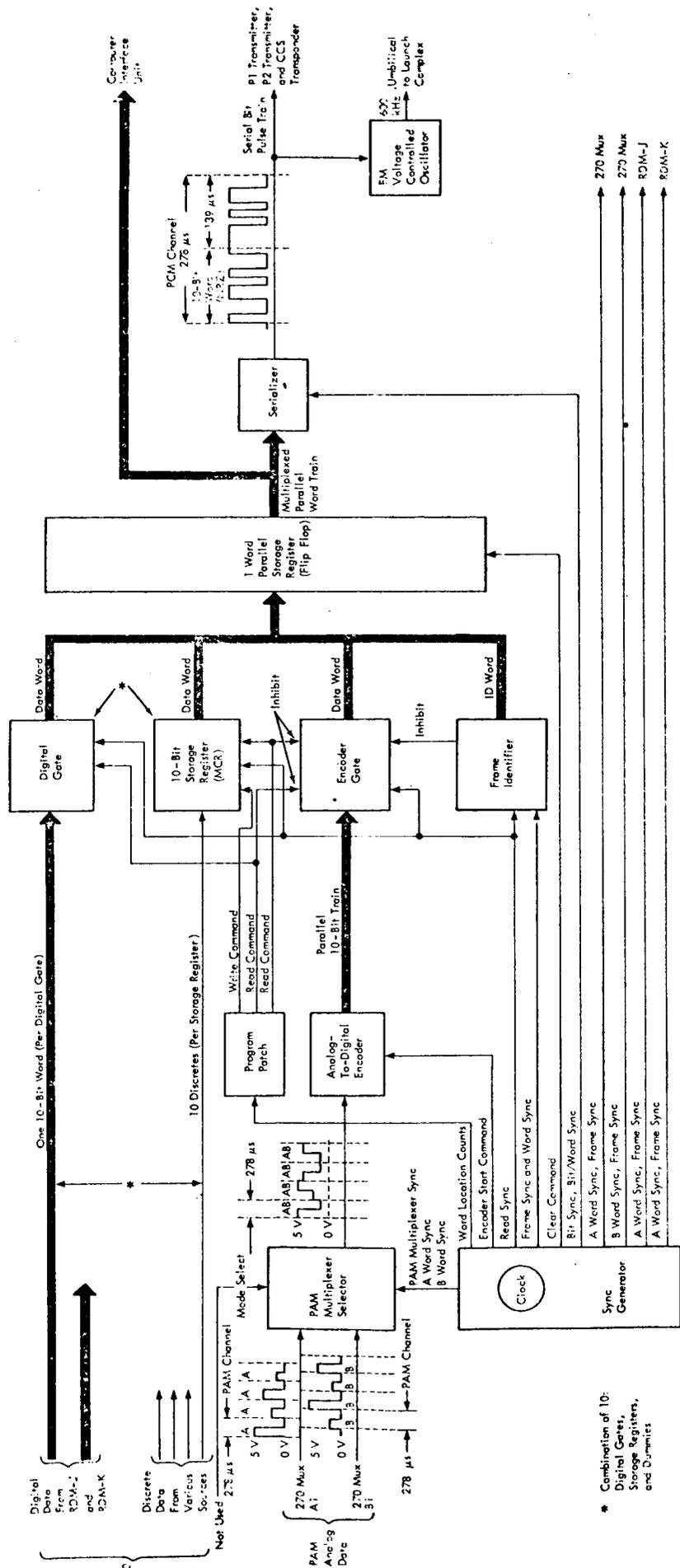
Figure 7.4.8-1.   Model 301 PCM/DDAS Telemeter

7.4.8   SKYLAB ATM PCM/DDAS TELEMETER MODEL 301

General Description

Program: Skylab ATM
Vendor: Brown-Teledyne
P/N:

Performance Characteristics

Input:

Analog: 6 wavetrains; 0 to 5 V; 3600 sps;
impedance > 500 K ohms

Digital: 10 groups of 10 parallel logic levels;
zero   for logic zeros; selectable 5 to
28 V levels for logic ones; optional
temporary storage and dc isolation

Output:

Basic format: 60 10-bit words per frame; 7200
words per second

Serial: digital data NRZ; 6 VPP min.

Parallel: digital data NRZ; 4 VPP min.

DDAS: 600 KHz carrier, frequency modulated
by NRZ serial data; 50 milliwatts
min. into 100 ohms (at 600 KHz)

Synchronization: 3600 Hz square wave, 278 usec
pulse, 4/sec rate, 4 V min.,
2 waveforms offset by 139 usec;
1 waveform 3600 Hz square wave,
120 Hz clock divide by ten counter,
4-6 VPP.

Physical Characteristics

Size: 22.9cm (9in) by 22.9cm (9in) by 33cm
(13in)

Weight: 12.2 Kg (27lbs)

Cooling Method: Cold Plate Mounting

References

"ATM Telemetry System Description" (50M17030)."Measuring and
Telemetry System Description," IBM No. 67-966-0008, MSFC No.
111-5-509-9.

"Digital Data Acquisiton Subsystem, Pulse Code Modulated,
Assembly, Model 301, Specification for", 50M60067, REV A,
21 September 1966

Design Status

This component was flown as part of the 1973 Skylab mission.

7.4.11-1   MARINER MARS 71 PROGRAMMER

Three programmers are used in the Mariner Mars data management system: one for the high speed deck, a second for the medium speed deck, and a third for the low and low-low speed decks. These are shown on Figure 7.4.11-1. Each programmer generates control signals for the digital data conditioner.

The high speed programmer contains a divide by ten counter and decoding gates. It is driven at the word sync rate and generates drive signals for decks 100 and 110. In the homing configuration, the programmer is driven by the homing clock from the Flight Telemetry System (FTS) support electronics.

The medium speed programmer is identical to the high speed programmer except it is driven by word sync divided by twenty. It is updated at the end of each high speed deck cycle and generates the drive signals for the 200, 210, and 220 decks.

The low speed programmer is identical to the high speed programmer, except it is driven by word sync divided by two hundred. It is updated at the end of deck 200 and generates the drive signals for decks 300, 400, 410, 420, and 430.

The 10/11 drive is provided by a flip-flop that is toggled at the end of each high speed programmer cycle, i.e., word sync divided by ten. The outputs of the flip-flop are used to drive switches 10 and 11. Switch 10 is turned on to receive outputs from deck 100 and switch 11 turned on to receive outputs from deck 110.

The 40/41 drive is provided by a flip-flop that is toggled at the end of each low speed programmer cycle, i.e., word sync divided by two hundred. The outputs of the flip-flop are used to turn on switches 40, 41, 42 and 43 to receive outputs from decks 400, 410, 420, and 430, respectively. Table 7.4.11-1 shows the sampling for each deck.

The transfer register selection logic generates the control signals which will gate inputs to the transfer register for subsequent readout to the engineering data multiplexer. The transfer register selection logic also generates control signals which gate inputs to the CC&S mode logic.
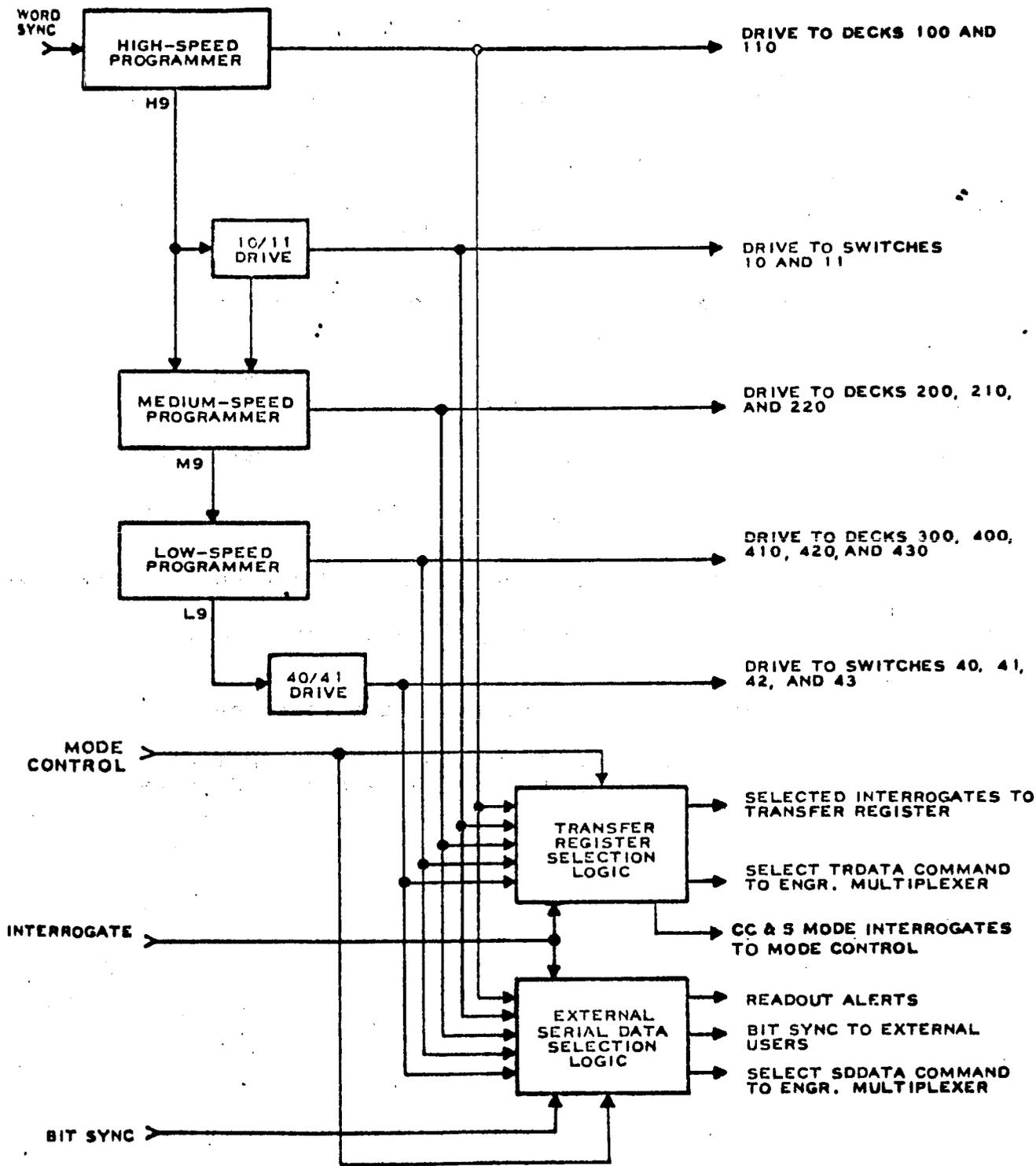
Figure 7.4.11-1. PROGRAMMER BLOCK DIAGRAM (MARINER MARS 71)

Table 7.4.11-1. Deck Sampling Speed

| Deck | Bit Rate (bps) | |
	8-1/3	33-1/3
High Speed Deck 100 Series	16.8 seconds	4.2 seconds
Medium Speed Deck 200 Series	2.8 minutes	42.0 seconds
Low Speed Deck 300 Series	28.0 minutes 28.0 minutes	7.0 minutes
Low-Low Speed Deck 400 Series	56.0 minutes	14.0 minutes

The external serial data selection logic performs three functions:

a. Generate readout alert pulses for spacecraft users.

b. Buffer the FTS bit sync to spacecraft users.

c. Generate enable commands to allow selections of serial digital data by the engineering data multiplexer.

7.4.11-2   MARINER MARS 71 FORMATTER

Data is formatted in the data processor as shown in Figure 7.4.11-2. The data processor is standby redundant with the outputs of both processors tied together and fed to the Radio Frequency Subsystem (RFS). The processor is capable of formatting analog-to-digital converter (ADC) data, transfer register (TR) data, serial digital data, Central Computer and Sequencer (CC&S) data, Data Automation Subsystem (DAS) data, and block coded (BC) data.

The engineering data multiplexer handles the ADC, TR, CC&S and serial digital data. It uses control inputs from the programmer to enable the proper multiplexing of engineering data to pass to the synchronizer. The synchronizer is a flip-flop, clocked by bit sync. This assures that an engineering data transition occurs at the same time as a bit sync transition. The transition generator modulo-two adds the engineering data with an alternating "1" – "0" pattern clocked at the data rate. The engineering data modulator modulo-two adds the engineering data with the engineering channel subcarrier S_B. S_B is a 24 kHz square wave with a 50 $\pm$1 percent duty cycle.

The DAS data modulator modulo-two adds the DAS low rate data and the science channel subcarrier S_A. S_A is a 34.286 kHz square wave with a 50 $\pm$1 percent cuty cycle. The BC data modulator modulo-two adds the BC data and the BC subcarrier S_C. S_C is a 259.2 kHz square wave with 50 $\pm$1 percent duty cycle. The data selection logic controls which data is presented to the mixer. The gating is enabled with mode control signals from the mode and rate control subassembly.

The mixer amplifier is designed as an inverting operational amplifier. The mixer amplifier combines the outputs of the modulator, according to the mode of operation, and outputs them to the RFS. The SE (support electronics) amplifier is designed as a unity gain inverting operational amplifier, and supplies the mixed signal to the SE.
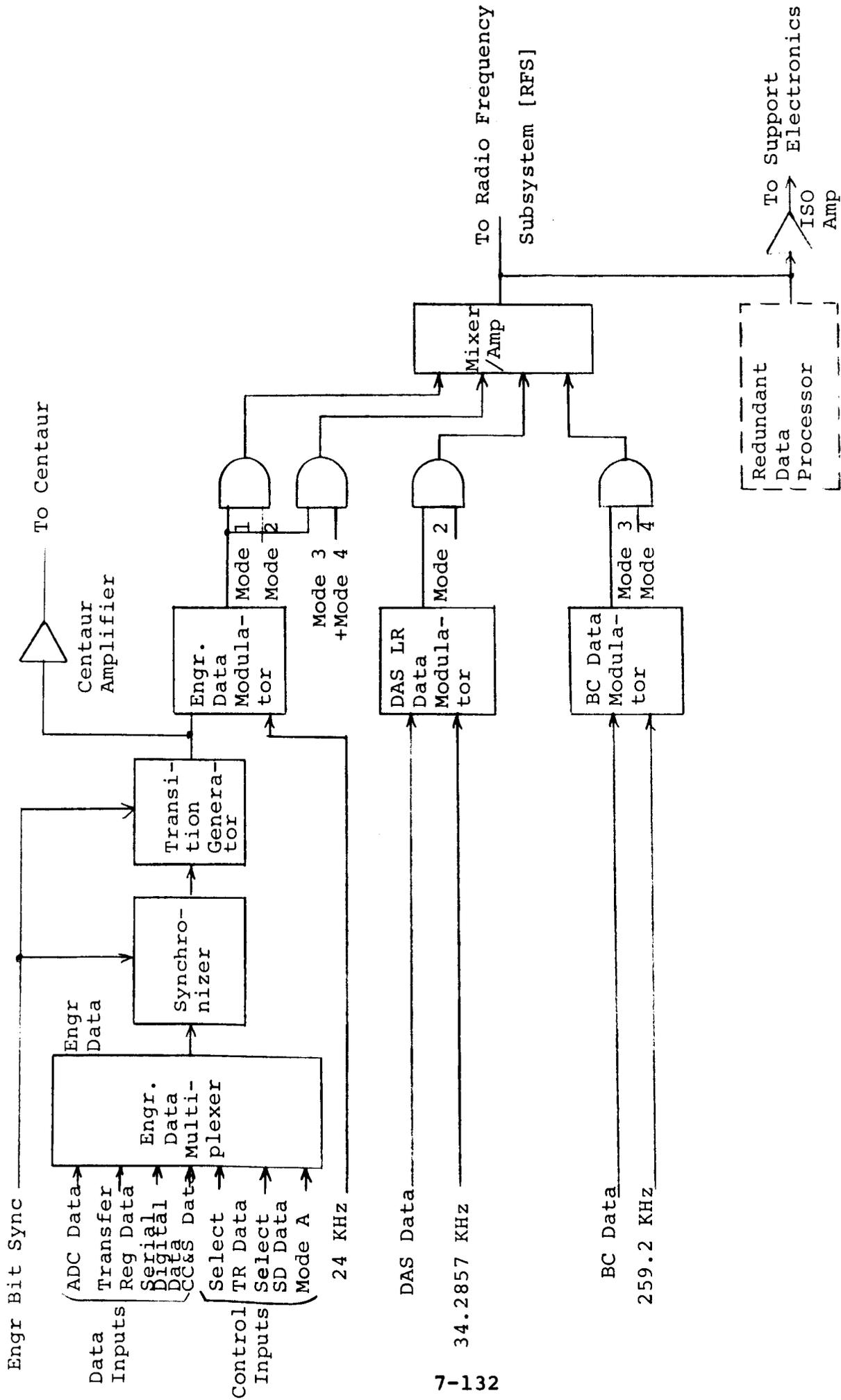
Figure 7.4.11-2. Data Processor Block Diagram