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OSO SPACECRAFT MANUAL

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GODDARD SPACE FLIGHT CENTER

GREENBELT, MD.

X-440-66-346

OSO SPACECRAFT MANUAL

July 1966

Goddard Space Flight Center
Greenbelt, Maryland

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OSO SPACECRAFT MANUAL

Section 1

INTRODUCTION

1.1 GENERAL

The Orbiting Solar Observatory (OSO) is an earth-orbiting satellite designed primarily as a stabilized platform for solar-oriented instruments – searching out and reporting information about the sun. The expected minimum useful life-time is 6 months. Progressive change in the attitude of the observatory permits observation of most of the celestial sphere as well as portions of the earth's surface. The spacecraft design provides for orientation of the prime experiments to within 1 arc-minute of the center of the sun throughout the uneclipsed portion of the observatory orbit. Additional experiments are contained in the wheel, which rotates once every 2 seconds.

The number and type of experiments can be interchanged and increased from mission to mission with little change in configuration of the structure. OSO, as a basic carrier, provides the scientist great flexibility in experiment configuration and mission objective.

1.2 PURPOSE OF MANUAL

This manual is a spacecraft handbook prepared for groups such as the experimenters and sub-contractors to use in preparing hardware for the spacecraft. The handbook will also supply needed information to such groups as Goddard Space Flight Center, Delta Vehicle Group, Tracking and Data Acquisition Personnel and Data Processing Personnel and others.

1.2.1 References

Publications that may be used as references in association with this manual are listed in Table 1-1.

Table 1-1
References

Title	Date or Number
GSFC Experimenter's Manual for the OSO	February 1965
GSFC Experimenter's Manual for the OSO Supplement #1	June 1965
BRRC Experiment/Spacecraft Interface Specification	A18480
BRRC Model Specification for OSO D Spacecraft	A17408
BRRC Test Specification for OSO D Spacecraft	A17409
OSO Project Development Plan, Revision 3.	July 1966
GSFC Environmental Test Specification	S-320-D-2
AVCO VHF Command Receiver	1 September 1964
BBRC OSO Aspect System Manual TM65-1	15 July 1965

1.2.2 List of Abbreviations

To facilitate the usage of this manual, certain terms are abbreviated; these terms and the abbreviations used are listed in Table 1-2.

Table 1-2
Abbreviated Terminology

Nomenclature	Abbreviation
Analog Subcommutator	ASC
Ball Brothers Research Corporation	BBRC
Digital Multiplexer & Encoder	DME
Electron Volts	ev
Goddard Space Flight Center	GSFC
Inside Diameter	ID
Orbiting Solar Observatory	OSO
Outside Diameter	OD
Pressure Per Square Inch	psi
Pressure Per Square Inch Absolute	psia
Pressure Per Square Inch Gauge	psig
Pulse Code Modulation	PCM
Pulse Duration Modulation	PDM
Revolutions Per Minute	rpm
Revolutions Per Second	rps
Spin Orientation & Rate Electronics	SORE
True Inside Radius	TIR

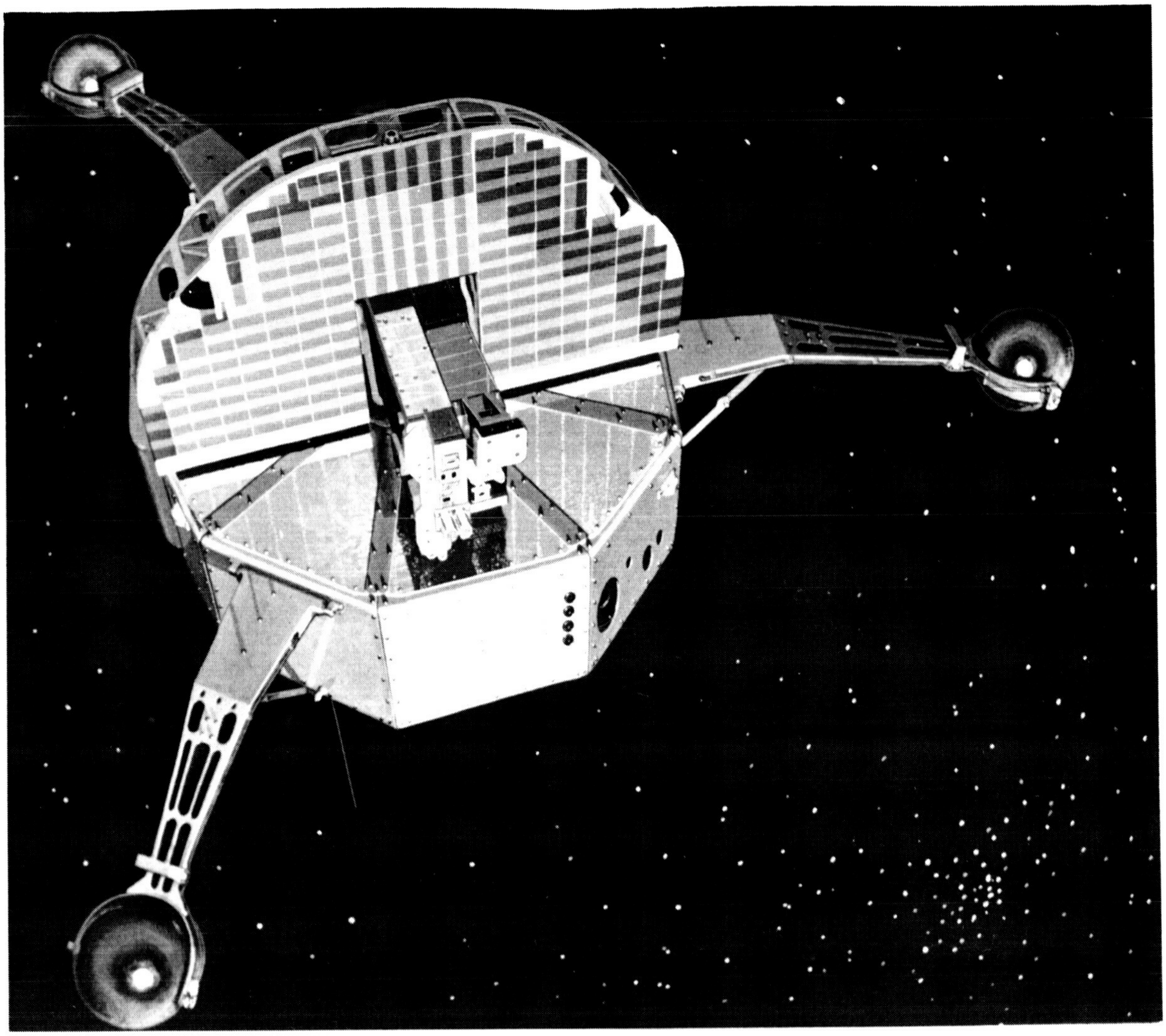


Figure 1-1—Orbiting Solar Observatory

Section 2

GENERAL DESCRIPTION

2.1 INTRODUCTION

The Orbiting Solar Observatory consists of an upper structure and a gyroscopic spinning lower structure. The upper structure, which is termed the sail, contains both the pointing experiment instruments and the solar cells. The lower portion, known as the wheel, is built around a central hub casting containing bearings which support the sail shaft. This aluminum shaft runs from the base of the sail through the center of the wheel, ending in a support ring structure on the underside of the wheel. Mounted on the shaft between the top and lower wheel bearings is a high-pressure nitrogen gas tank for the pitch precession jets which are mounted on the sail structure. A torque motor mounted at the top of the shaft controls the pointed section in azimuth. On the base of the shaft is a slip ring assembly which provides the electrical and communication contacts between the upper and lower structures.

Figure 2-1 shows the entire spacecraft; the semicircular sail towards the top, the pointing instruments which are the rectangular cases near the bottom center of the sail, and the nine-sided wheel underneath the sail. (See also Figs. 2-2 and 2-3).

In addition, it shows the three extendable arms. Spreading these arms improves the gyroscopic stability of the craft. The circular vessels on the ends of the arms contain a gas supply for adjusting the rotation rate of the wheel. The weight of the spacecraft alone is approximately 350 pounds; the complete observatory about 600 pounds.

Tables 2-1 through 2-4 list the materials used in the spacecraft and their application.

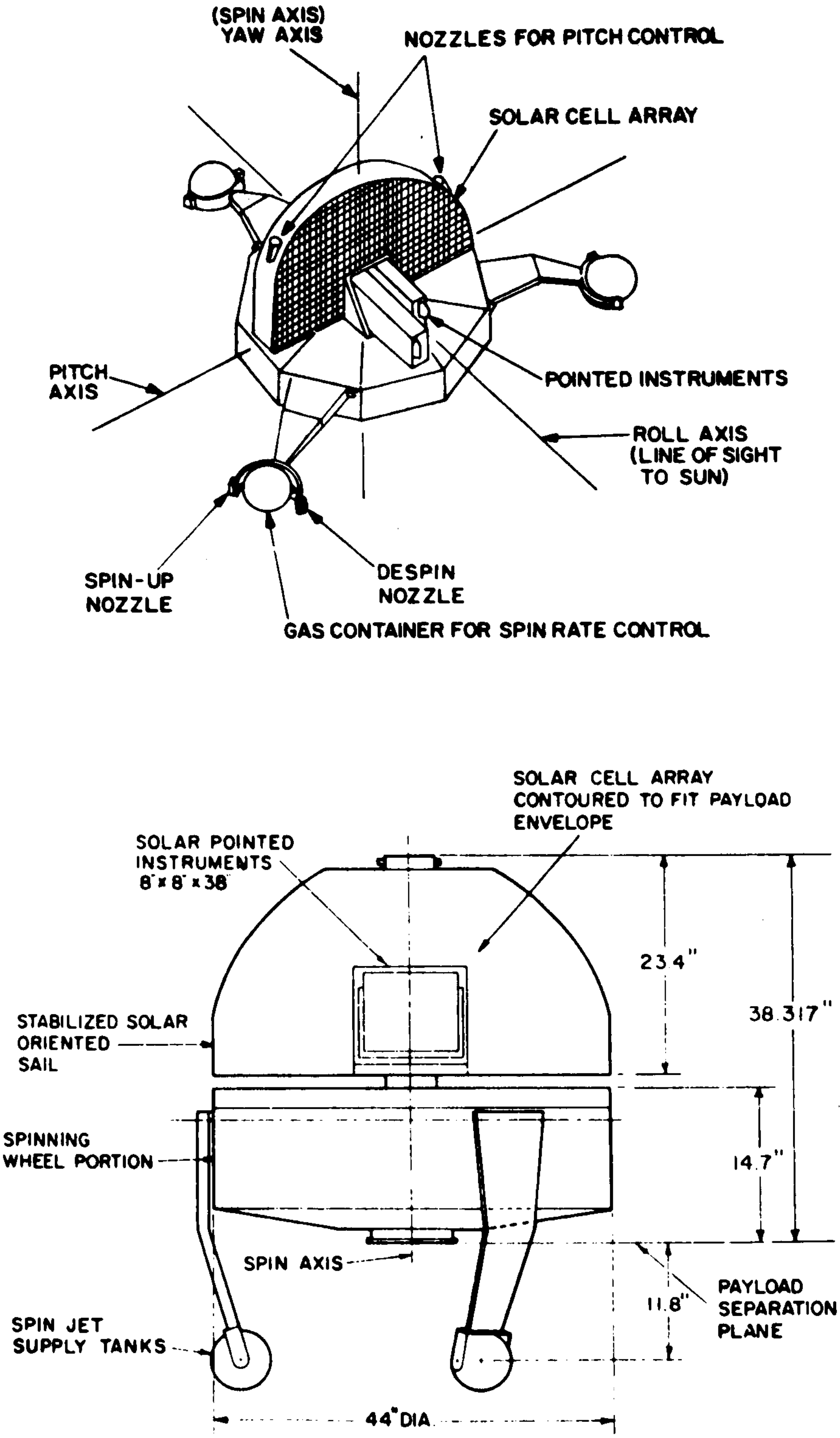


Figure 2-1—OSO Spacecraft Arrangement and Dimensions

Table 2-1
Aluminum Alloys

Material Designation	Specification	Design Applications
2024-T-351	QQ-A-268-T351	Miscellaneous rigid structural parts such as: arms, blocks, brackets, mounting strips, covers, housings, retainers, etc.
2024-T-351	QQ-A-355-T351	Miscellaneous rigid structural parts such as: mounting plates, gussets, panel angles, arms, holders, spacers, etc.
2024-T-351	QQ-A-267-T351	Channel stiffener
2024-T-3	QQ-A-355-T3	Rigid structural parts such as: latch links, follower links, stiffener angles, brackets, sail skin, cases, covers, etc.
2024-T4	QQ-A-355-T4	Mounting plate and bracket
2024-T4	QQ-A-268-T4	Plug and spacer connector
2024-TO-T42	QQ-A-355-TO HT to T42 MIL-H-6088	Bracket, sail rib and panel
A356-T6	QQ-A-356-T6	Castings, main structural parts such as: center wheel and sail frames
6061-0 HT to T6	QQ-A-327-TO MIL-H-6088 (Heat Treat)	Rigid structural parts from machined, formed, and heat-treated sheets such as: wheel compartment panels, rib panels, covers, etc.
6061-0	QQ-A-327-TO	Spun sheet cover
6061-T6	QQ-A-327-T6	Channels and straps
6061-T651	QQ-A-325-T651	Battery housing
5052-H34	QQ-A-318-H34	Small structural brackets, covers, etc.
1100-H14	QQ-A-411-H14	Shear pins and deep drawn parts
3003-H14	QQ-A-359d-H14	Cover
7075-T6	QQ-A-282-T6	Shaft

Table 2-2
Ferrous and Other Metals Except Aluminum

Material Designation	Specification	Design Applications
Type 302 Stainless Steel	MIL-S-7720-302Af	Tubing fitting
Type 302 Stainless Steel	MIL-A-8675	Valve poppet
Type 302 Stainless Steel	MIL-S-7720-302A Cb	Tubing manifold
Type 303 Stainless Steel	QQ-763-303A	Structural parts of small components such as: valve case, bushing cylinder covers, arm lock follower, etc.
Type 303 Stainless Steel	MIL-S-7720-303 Ac	Small parts such as: lock block, rotor key, stud, etc.
Type 303 Stainless Steel	MIL-S-7720-303 AC-b	Tubing manifold
Type 303 Stainless Steel	MIL-S-7720-303Af	Washers, retainers, tubing fitrings, slip ring, etc.
Type 303 Stainless Steel	MIL-S-7720-303 Bc	Retainers, nuts, bolts, etc.
Type 304 Stainless Steel	QQ-S-763B-304A	Tubing fitting
Type 18-8 Stainless Steel	MIL-Y-6845	Seamless tubing
Type 18-8 Stainless Steel		Sintered filter
Type 416 Stainless Steel	QQ-A-763 C1 416A MIL-S-6857 (Heat Treat)	Pivot screw, arm latch pins
Type 4140 Carbon Steel	MIL-S-5626 MIL-C-76074 C1 I (Electroless Ni Plate)	Hinge pins
Coin Silver	90% Ag, 10% Cu, Brinell	Electrical contact
Silver Braze	MIL-B-7883 QQ-S-561 Filler Material	Pressure tubing and slip rings
Solder	QQ-S-571-SN63-W-AR-P3 QQ-S-571C	Electrical Soldering

Table 2-3
Non-Metals

Material Designation	Specification	Design Applications
Epoxy Glass Laminate	MIL-P-18177 Type GFE or GEB	Circuit boards, insulating spacers, etc.
Epoxy Glass Laminate (copper clad)	MIL-P-13949B	Printed circuit boards
Epocy Glass Laminate (tubing)	MIL-P-79C Form TR GR164	Housing for electronic components
Diallylphthalate	MIL-M-14F (SDG Type I)	Electrical connectors
Melamine, Mineral Filled		Electrical connectors
Ceramic, Silicone Impregnated	MIL-E-5400	Electrical connectors
Alkyd Putty No. 413		Electrical connectors
Nylon	MIL-M-20693A, Ty I	Insulating spacers
Nylon	MIL-P-17091	Insulating spacers
Nylasint	64HV	Lubricant reservoirs
Teflon	MIL-I-22129	Insulating sleeves and wire insulation
Glass, Borosilicate	Fish Shurman BK-7G	Optical
Glass	Corning X-260-JL	Optical filter
Glass	Corning No. 2600	Optical filter
Glass, Quartz	GE-102	Cover-glass
Epoxy	Paraline	Bonding
Epoxy	Epoxy Products No. 3022 Resin No. 18 Hardener	Thermally conducting

Table 2-3
Non-Metals (cont.)

Material Designation	Specification	Design Application
Epoxy	Shell Epon 828, Shell V-25 or Versamid V-125 Curing Agent	Potting, bonding, conformal coating
Epoxy	Armstrong C-7, with Activator and LD-20 Pearlite	Potting compound
Epoxy	Hysol 4238, Versamid 125 Curing Agent	Thermally conductive bonding
Silicone Elastomer	GE RTV-11, Thermo-lite 12 Calalyst	Potting and conformal coating
Silicone Elastomer	GE LTV-602, SRC-05, Catalyst	Potting and conformal coating
Polyolefin (Irradiated)	Rayclad-RNF-100 Ty II	Insulating Sleeves and wire insulation
Phenolic	MIL-P-15035 NEMA LE	Insulating spacer
Aluminum Honeycomb Phenolic Sandwich	Goodyear Bondalite-Z	Cover panels
Silicone Rubber	3M No. 70 Electrical Tape	Electrical wrapping
Buna-N Rubber	Parker N-183-9 or N-109-7	"O" ring
Silicone Rubber	Lord Mfg. Co. No. J-6449-10 RTV Damped	Bumper
Fluorinated Polymer	Rulon A	Rigid Mount

Table 2-3
Non-Metals (cont.)

Material Designation	Specification	Design Applications
Red Fiber Sheet (vulcanized)	MIL-F-1148 Ty CH	
Mylar		Electrical shield and flex-print wiring
Polystyrene "Q" Dope		Inductor coating
Beryllium Oxide		Heat Sink
Silicone Foam	3M Scotch Cast No. XR-5017	Potting compound
Urethane Foam	Nopco Lock Foam	Potting compound
Silicone Adhesive	Dow Dorning Silastic 140	Bonding
Apiezon L		Lubricant

Table 2-4
Coatings and Finishes

Material Designation	Specification	Design Applications
Gold Plate	MIL-G-45204 Ty II C1 4	Electrical contacts
Gold Iridite		Electrical connectors
Silver Plate	QQ-S-365 Ty I Gr A	Electrical components
Silver Plate	MIL-F-14072	Coaxial relay
Silver Electropolish		Slip rings
Nickel Plate	MIL-C-76074 C1 I	Protective finish on carbon steel
Chromium Plate		Protective finish on carbon steel
Copper Plate	MIL-C-14550	Printed circuit boards
Tin Plate	MIL-T-10727 Ty I	Electrical connectors
Solder Plate	MIL-T-55155	Electrical components
Solder Plate	Electro-deposit, QQ-S-571 Solder	Electrical components
Aluminum coating	Vacuum deposited	Optical light shield
Aluminum Anodize	MIL-A-8625	Surface passivation
Aluminum Black Anodize	MIL-A-8625 Ty II	Surface passivation and optical black
Aluminum Hard Anodize	AMS 2468	Surface passivation
Aluminum Chromicoat	Oakite Chromicoat	Surface passivation
Aluminum Photo Anodize	Fed Spec 595 No. 36492	Lettering
Black Velvet	3M Black Velvet Paint	Optical Black
Aluminum Paint	Komac XR-630 Silicone Resin, MD5100 Powdered Aluminum Pigment (Metals Disintegrating Co.)	Satellite thermal control
White Paint	Domac XR-630 Silicone Resin, Komac KM 6212 TiO_2 Pigment	Satellite thermal control
Polished Aluminum		Satellite thermal control

2.2 SAIL STRUCTURE

The sail structure (Figure 2-2) is a semicircular framework attached to a casting called the azimuth. Solar cells cover the entire sun-facing surface, except the part occupied by the pointed instruments. Behind the solar cells are the electronic and mechanical components necessary for operation of the sail-mounted equipment. Included are the coarse and pitch control eyes, nutation damper, elevation servo motor and pneumatic gas control components.

The pointed instruments are mounted in the elevation frame which in turn is mounted in the azimuth frame. Space is provided for two pointed instruments each 4 inches wide by 8 inches high by 36 inches long. The pointed instruments are independently adjusted to one another so that their optical axes are parallel. Located on the front of each pointed instrument are the sun sensor eye blocks of the solar pointing control system. The weight of each pointed instrument including balance weights and attaching hardware is 40 pounds.

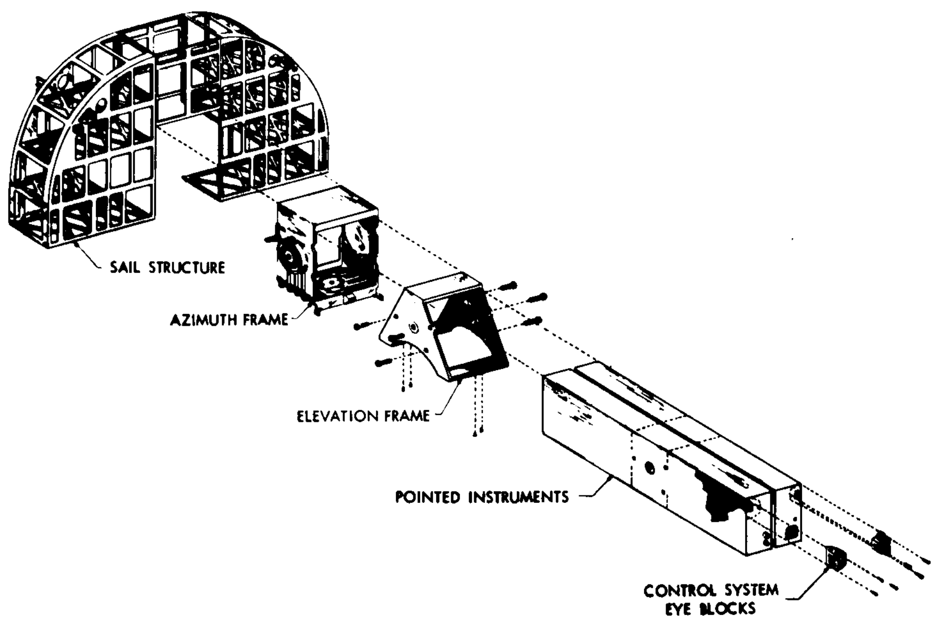


Figure 2-2–Major Features of Sail Structure

2.3 WHEEL STRUCTURE

The wheel structure (Figure 2-3) is a nine-sided cylinder made up of nine wedge-shaped compartments. Each compartment can contain instrumentation occupying up to 1000 cubic inches of volume. Its overall diameter is 44 inches, and the height of the cylinder is 9.9 inches. Attached to three of the wedge-shaped sections are the extendable arms carrying the spin-control gas vessels. After injection into orbit, these arms extend into the plane of the wheel, increasing the effective diameter of the wheel to 92 inches.

An antenna array is located at the base of the wheel. It consists of three V shaped monopoles spaced 120 degrees apart; two are active, and the third is parasitic. One half of each monopole is the supporting element for the extending arms.

2.3.1 Wheel Experiments

Five of the compartments contain experiments. No experiments are housed in wheel sections to which the extendable arms are attached. Of the total experiment weight, about 150 pounds is allocated to the wheel experiments. Prorating this weight equally to five compartments gives an average of 30 pounds per experiment compartment, not to exceed 45 pounds in any one compartment. Experiment instrumentation in each compartment is not expected to weigh exactly 30 pounds, and all the centers of mass are not expected to be located in the same place. In general, however, the center of mass of all experiment assemblies in one compartment are on the radial center line of the compartment about 4 inches above the deck.

2.3.2 Wheel Electronic System Compartments

Four of the wheel compartments house the control systems components, telemetry equipment, and radio command equipment. These compartments are numbers 1, 4, 7, and 8. (See Figure 2-4.) Compartments 2, 3, 5, 6 and 9 house the experiments.

2.4 STRUCTURAL BALANCE, STATIC AND DYNAMIC

For proper performance during launch and in orbit, the OSO spacecraft must be balanced statically and dynamically. Since a large portion of the mass is experiment instrumentation, restrictions are placed on the weight distribution of each instrument.

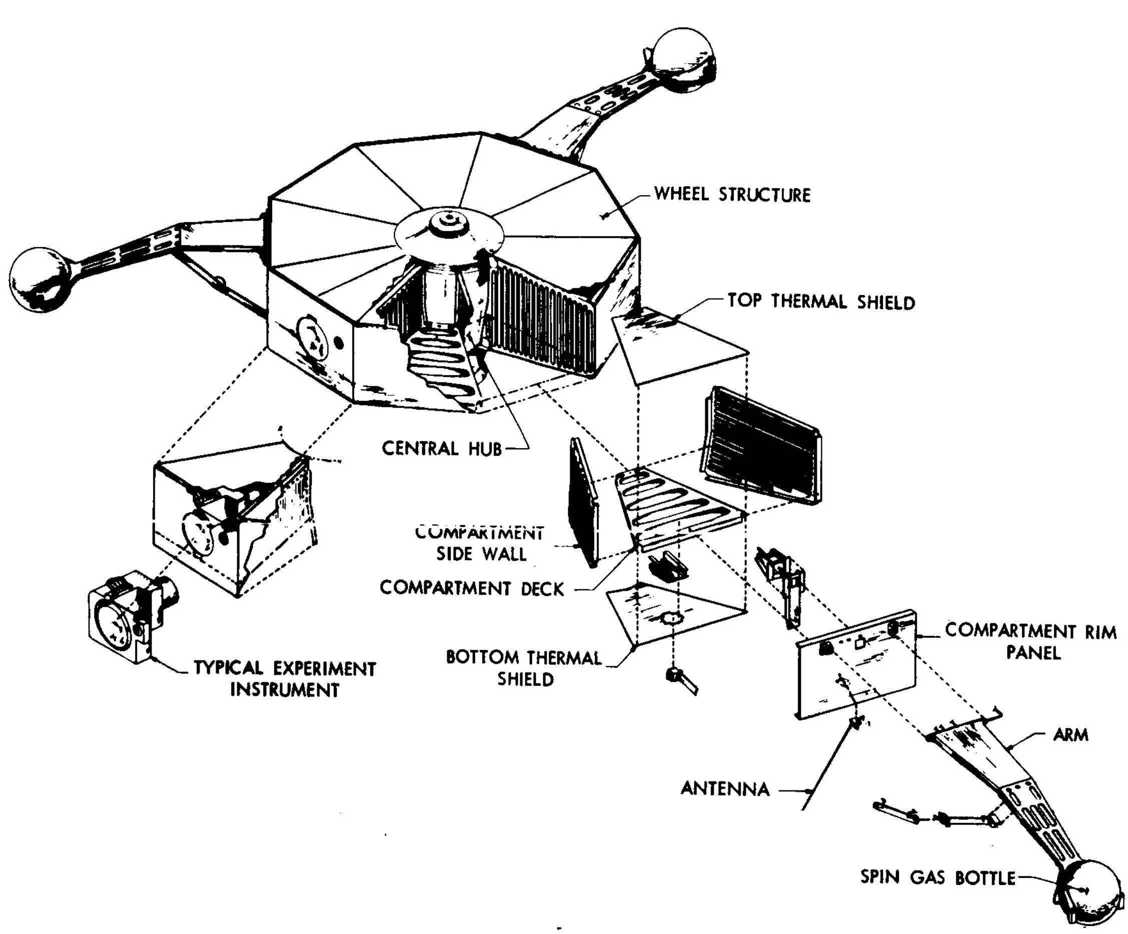


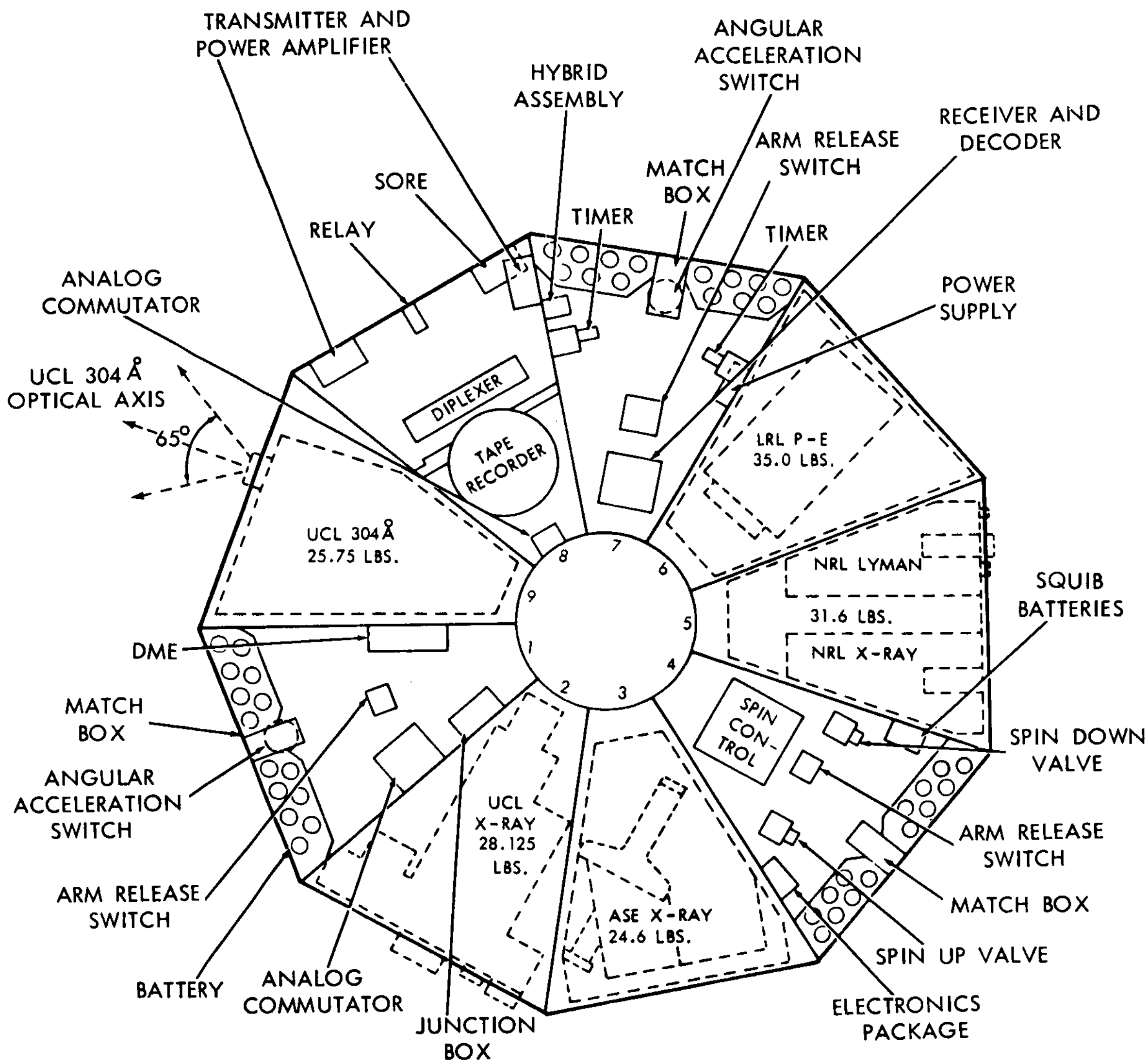
Figure 2-3—Major Features of Wheel Structure

2.4.1 Alignment Requirements

The alignment of the bearing axis of the spacecraft to the bearing axis of the balancing machine spin table is sufficient to cause less than 0.002 TIR at the indicator collar when the sail is held stationary and the wheel is rotated. The indicator collar must be concentric within 0.002 TIR of a line through the center of the attached fitting and perpendicular to the attached (separation) plane.

2.4.2 Balance Requirements

With the three arms that are attached to the wheel structure fully extended, the wheel is balanced within 10 ounce-inches static, and within 140 ounces-inches^2 dynamic balance.



1. ALL PLUMBING COMPONENTS FOR WHEEL ARE IN COMPARTMENT 4.
2. ARM DAMPER SYSTEM LINE IS IN EACH COMPARTMENT ROUTED WITH PLUMBING LINES OR CO-AX LEADS.
3. OSO-D CONFIGURATION

Figure 2-4—Wheel Layout of Major Components

While the arms remain extended, and the pointed experiments are locked in the launch position, the sail is then balanced to provide observatory balance within 10 ounce-inches static, and 300 ounce-inches ^{2} dynamic balance. With the pointed instruments in the orbit state, the sail is balanced to provide observatory balance within 10 ounce-inches static and 300 ounce-inches ^{2} dynamic balance.

The observatory is balanced within 20 ounce-inches static and 1000 ounce-inches^2 dynamic balance with the arms placed in the stow position and the pointed experiments locked in the launch position.

2.4.3 Machine Alignment

Before mounting the spacecraft on the balancing machine pedestal, the pedestal table is aligned perpendicular to the true bearing axis of its spindle with a dial indicator. This indicator is set up to measure vertical motion 4.5 inches from the center of the table. When this is accomplished the table is aligned within 0.12 minutes of arc. The upper structure is statically balanced about the elevation axis within the effect of a 5 gram weight. This is done in the fore, aft, top and bottom directions.

2.5 MAGNETIC BALANCE

A permanent magnet or a bar of soft iron tends to align itself with the earth's magnetic field as does a compass. The strength of this tendency is determined by a property of the object called the magnetic dipole moment. If the spacecraft had a significant magnetic dipole moment, the geomagnetic field would exert a torque on it that could only be counteracted by the gas jets. Since no needless gas expenditure can be afforded, the magnetic torque must be eliminated by reducing the dipole moment to an insignificant value.

2.5.1 Torque Measurement

The spacecraft is hung on a frictionless suspension in a region of uniform geomagnetic field, and the torque that is exerted by its attempt to line up with the field is measured on a torque meter. This is done at three mutually perpendicular positions. Then permanent magnets are installed with the same moment but opposite orientation, making the net moment very small. The measurements are then repeated to make sure that the torques are negligible.

In order to properly perform magnetic balancing, a torque must be measured with a resolution of at most 100 dyne-cm. To accomplish this, the spacecraft is hung in such a way that the suspension friction and all stray disturbances (such as those due to breezes) add up to well under 100 dyne-cm. The work must be done where the earth's magnetic field is not distorted by extraneous magnetic materials. A wooden building is used.

2.5.1.1 Magnetotropometer

The magnetrotropometer is an instrument that can handle test specimens up to 1300 pounds, and measure torque with a resolution of 10 cyne-cm. It consists of a tub about 5 feet in diameter and 2-1/2 feet deep with a core up the middle, nearly filled by a donut-shaped object which floats in silicone oil. A shaft hanging from this float extends down the core of the tub and through the floor into a chamber on the floor below. The test specimen hangs on this shaft and is protected from drafts by the sealed and insulated chamber. Another shaft extends upward from the float through the tub cover. This shaft is fitted with a "chain carrier," which can be slid up and down and rotated on the shaft, and can be locked to the shaft with a set screw. Three very light chains are attached to the chain carrier 120 degrees apart, and droop radially outward to stationary anchor points. These chains hold the float and spacecraft centered in the apparatus.

If the float rotates slightly, the horizontal force of the chains no longer acts through the center of the shaft. Therefore, this force causes a restoring torque on the float. The torque due to the chains is a nearly linear function of float angle for small float rotations.

There is a mirror mounted on the chain carrier. This, with a conventional galvanometer telescope and scale, allows any small angular deflections of the float to be read.

2.6 PRELAUNCH TESTS

To ensure that the OSO is in an operational readiness state, a series of tests are conducted. All subsystems and experiment instrumentation must be capable of surviving the launch environment and operating in the thermal-vacuum environment at orbital altitudes. For detailed information concerning these tests, refer to the Experimenters' Manual for the OSO, Supplement number 1, Section 9, and GSFC Environmental Test Specification, S-320-D2.

Section 3

CONTROL SYSTEMS

3.1 INTRODUCTION

Like many other spacecraft, the OSO-D uses the gyroscopic properties of a spinning body for stability. After the launch sequence has been completed and the arms have been extended, the control systems are activated. The sensors acquire the sun, use it as a reference, and feed information to the electronic control systems which in turn actuate the spin and pitch pneumatic systems to stabilize the spacecraft.

The entire spacecraft is utilized as the controlled platform. The spin rate around the spin axis is maintained by jets in the arms. These jets either increase (spin up) or decrease (spin down) the spin rate to maintain a spin rate of about 30 rpm (or 0.45 to 0.66 rps). Pitch angle, the tangential relationship of the sail to the sun, is maintained by two jets which are on the rim of the sail. Since the sail is attached to the wheel through the shaft, the entire spacecraft precesses about the pitch axis. Azimuth alignment of the sail is controlled by the servo motor which is mounted at the top of the shaft. This motor holds the sail fixed while the wheel rotates. A servo motor, mounted near the pointed experiments, maintains accurate elevation alignment. The motor drives the pointed instruments in elevation from signals supplied by the fine eyes. The control systems location is shown in Figure 3-1.

A magnetic bias coil has been placed around the base of the spacecraft as a supplement to the pneumatic system used to control the pitch angle. This magnetic bias coil is primarily intended as a mode of pitch control but is also capable of correcting or adjusting roll attitude.

On previous OSO spacecraft it was realized that there is a necessity to determine the aspect, or orientation, of the spacecraft. This is necessary to determine the orientation of the scan pattern on a picture of the sun and to determine the great circle on the celestial sphere which the line of sight of a wheel instrument describes as the wheel makes a revolution.

Therefore an Aspect Measuring System has been included in the OSO-D spacecraft; this system consists of a magnetometer, a solar detector, and a timer. The outputs of these are transmitted to a ground station where the data is fed into a computer for calculation of the roll angle.

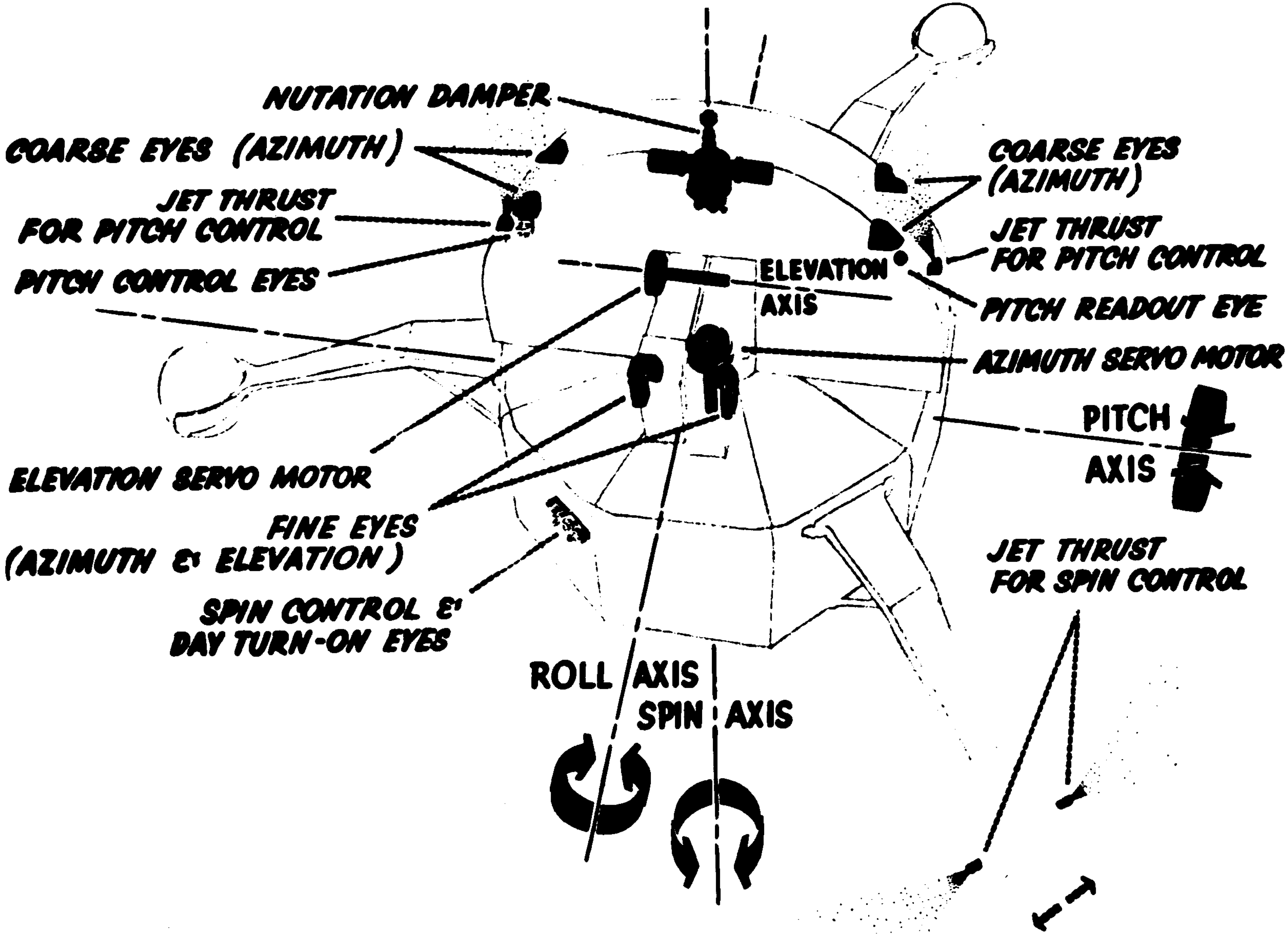


Figure 3-1—Control Systems

The spacecraft can also be operated in a scanning mode. The mode of operation is initiated by a scan "on" command, and the spacecraft will revert to the pointing mode when the scan "off" command is sent. In the scan mode, the azimuth and elevation servo systems are made to scan the solar disc and part of its corona in a pattern similar to that of a television system. This mode of operation enables the pointed experiments to present one complete data picture of the solar disc and its immediate corona every 307.2 seconds.

The spin control and the pitch control systems are backed up by the command system which will allow manual control of the spacecraft spin and pitch by command.

3.2 SPIN CONTROL SYSTEMS

There are two modes of controlling the spin rate of the spacecraft: (1) the automatic mode which senses the period of spacecraft rotation and actuates a pneumatic system to either spin-up or spin-down the spacecraft, and (2) a command backup system which can adjust the spin rate by signals from the ground. A block diagram of the spin control systems is shown in Figure 3-2.

3.2.1 Automatic Spin Control System

Because the nutation frequency is directly proportional to the spin rate, the spin rate of the spacecraft must be maintained between 27.0 and 39.6 rpm, with an ideal spin rate of 30 rpm, so that the nutation damper will work effectively.

As the spacecraft rotates, the spin rate sensors see the sun each revolution and generate a pulse. These pulses are used to trigger electronic circuits that measure the period of spacecraft rotation. When the period of rotation, spin rate, exceeds the prescribed limits, a signal is sent to the pneumatic system to open one of two solenoid valves. One solenoid valve expells compressed gas through the spin-up nozzles; the other expells compressed gas through the spin-down nozzles.

3.2.1.1 Sensors

Two spin control sensors are mounted on the spin eye assembly (Figure 3-3). A redundant spin eye assembly is mounted on the edge of compartment 8.

The assembly consists of four identical photovoltaic detectors. The output of each detector is ideally a fixed current between 1 and 2 ma when the sun is in the detector's field of view, and zero when the sun is outside the field of view. The field of view is 3 degrees in azimuth and 24 degrees in elevation.

With $\theta = 0$, a typical output current of each detector in the assembly as a function of azimuth angle Φ is shown in Figure 3-4. The off-axis characteristic ($\theta \neq 0$) has the same general shape as the on-axis curve but with the amplitudes diminished. The peak outputs are as follows:

$\theta = 0$ The peak on-axis output amplitude is greater than 1000 ua and less than 2000 ua

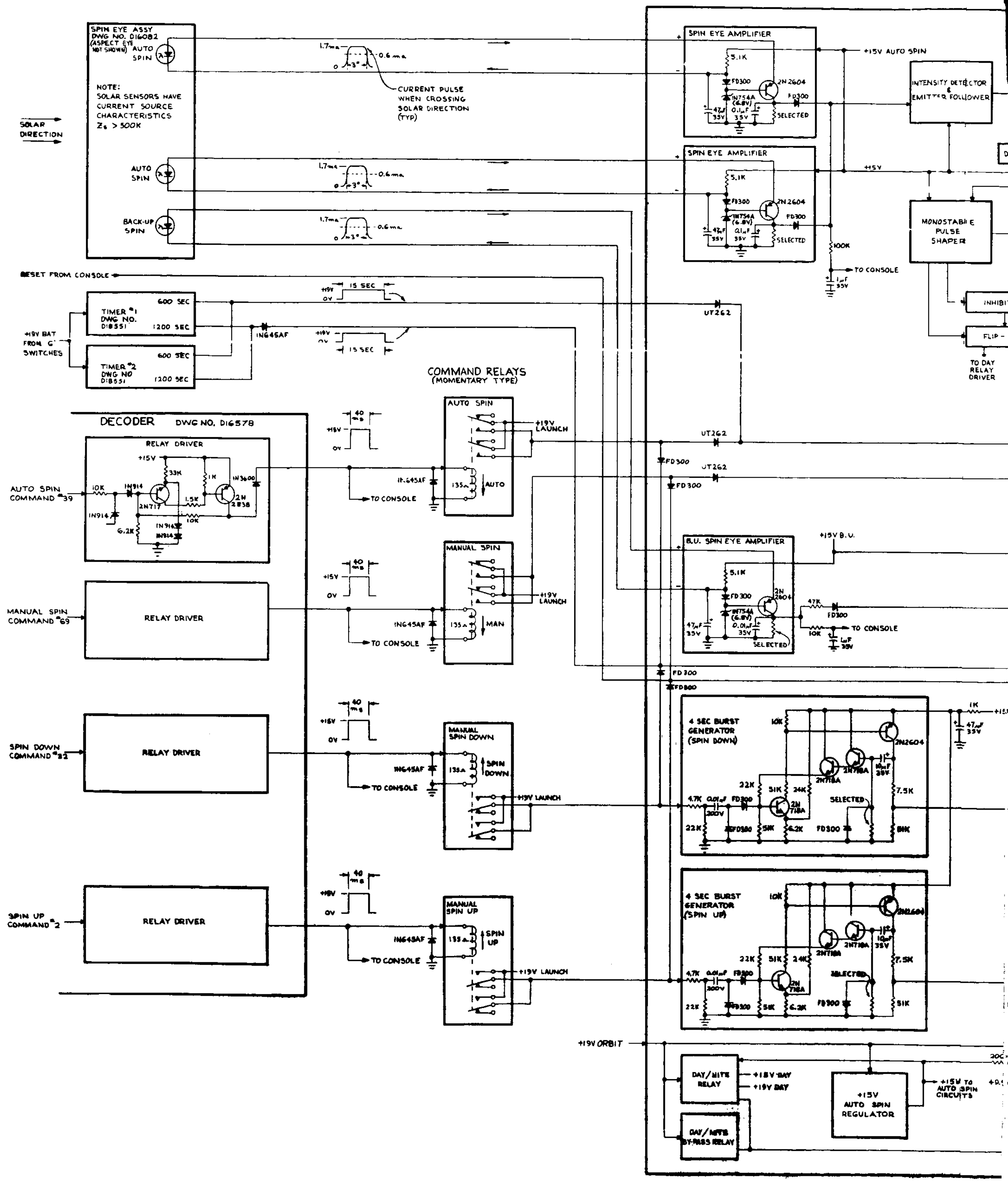
$\theta = \pm 12$ degrees
The peak 12-degrees off-axis output amplitude is greater than 800 ua and less than 2000 ua.

3.2.1.2 Electronics

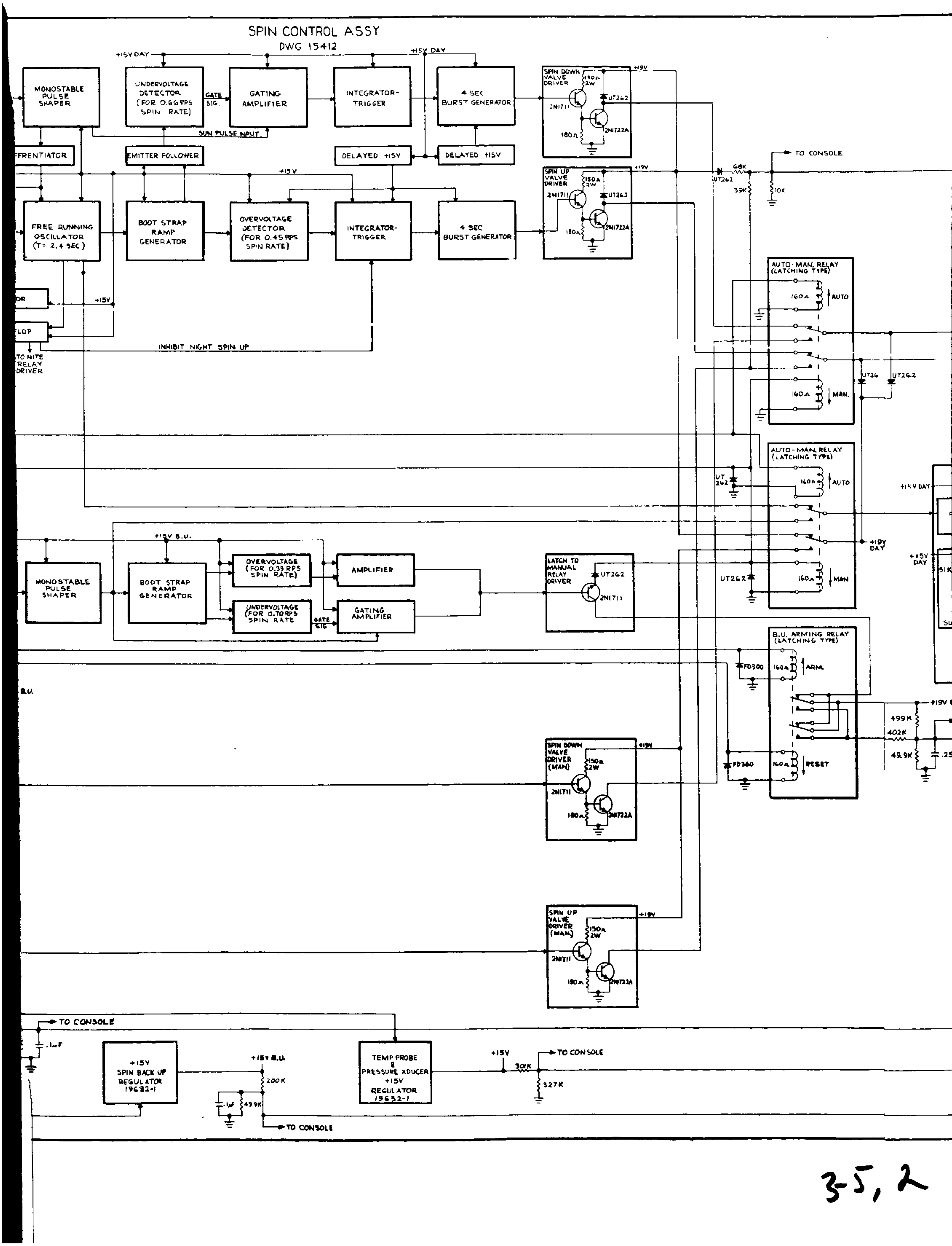
An electronics package in compartment 4 contains the electronic circuitry that converts the pulses from the spin eyes into signals to operate solenoid valves. The spin control assembly controls the wheel spin rate by operating the wheel spin-up gas jets if the spin rate drops below approximately 0.45 rps or increases above approximately 0.66 rps. This circuit is also used for the spacecraft despin during launch sequence operations. The weight of the spin control assembly is 4 pounds 12 ounces.

A diagram of the spin control system is shown in Figure 3-2. As the wheel rotates, the spin eye senses the sun once each rotation, giving a pulse each time. These periodic current pulses provide the proper base-emitter bias to the PNP transistor located in the spin eye amplifier. The output from this amplifier is then shaped and applied to a flip-flop. The output of the flip-flop is fed to an integrator which generates a rising ramp function. When the flip-flop changes from the low state to a high state the integrator is reset. The ramp is interrupted after it has been rising for the period of rotation. If the period of rotation is 5 percent too long, the ramp rises above a critical level determined by a voltage comparator. When this occurs, a burst generator operates and applies power to a solenoid valve for four seconds.

Several problems associated with this technique are not immediately apparent. As the spacecraft comes into the sunlight, it passes through the penumbral shadow where only part of the sun is visible. If, during this time, the turn-on circuitry applies power to the spin-up system before the spin eyes are giving out pulses of sufficient amplitude, a call for spin-up gas would occur. This problem is solved in two ways. First, the spin eyes are made sensitive enough to give satisfactory



SPIN EYE ASSY
DWG NO. D16082
(ASPECT EYE NOT SHOWN)
AUTO SPIN
NOTE:
SOLAR SENSORS HAVE CURRENT SOURCE CHARACTERISTICS
Z_s > 500K
SOLAR DIRECTION
AUTO SPIN
BACK-UP SPIN
CURRENT PULSE WHEN CROSSING SOLAR DIRECTION (TYP)
RESET FROM CONSOLE
TIMER #1 DWG NO. D18551
600 SEC
1200 SEC
TIMER #2 DWG NO D18551
+19V BAT FROM G' SWITCHES
15 SEC
IN645AF
UT262
COMMAND RELAYS (MOMENTARY TYPE)
AUTO SPIN
+19V LAUNCH
DECODER DWG NO. D16578
RELAY DRIVER
AUTO SPIN COMMAND #39
MANUAL SPIN
MANUAL SPIN COMMAND #69
TO CONSOLE
MANUAL SPIN DOWN
SPIN DOWN COMMAND #32
MANUAL SPIN UP
SPIN UP COMMAND #2
SPIN EYE AMPLIFIER
+15V AUTO SPIN
INTENSITY DETECTOR & EMITTER FOLLOWER
MONOSTABLE PULSE SHAPER
INHIBIT
FLIP-
TO DAY RELAY DRIVER
B.U. SPIN EYE AMPLIFIER
+15V B.U.
4 SEC BURST GENERATOR (SPIN DOWN)
4 SEC BURST GENERATOR (SPIN UP)
SELECTED
+19V ORBIT
DAY/NITE RELAY
+19V DAY
DAY/NITE BY-PASS RELAY
+15V AUTO SPIN REGULATOR
+15V TO AUTO SPIN CIRCUITS


SPIN CONTROL ASSY
DWG 15412
MONOSTABLE PULSE SHAPER
UNDERVOLTAGE DETECTOR (FOR 0.66 RPS SPIN RATE)
GATE SIG.
GATING AMPLIFIER
INTEGRATOR-TRIGGER
4 SEC BURST GENERATOR
SPIN DOWN VALVE DRIVER
SUN PULSE INPUT
EMITTER FOLLOWER
DELAYED +15V
TO CONSOLE
SPIN UP VALVE DRIVER
FREE RUNNING OSCILLATOR (T= 2.4 SEC)
BOOT STRAP RAMP GENERATOR
OVERVOLTAGE DETECTOR (FOR 0.45 RPS SPIN RATE)
AUTO-MAN. RELAY (LATCHING TYPE)
INHIBIT NIGHT SPIN UP
TO NITE RELAY DRIVER
OVERVOLTAGE (FOR 0.39 RPS SPIN RATE)
AMPLIFIER
UNDERVOLTAGE (FOR 0.70 RPS SPIN RATE
LATCH TO MANUAL RELAY DRIVER
B.U. ARMING RELAY (LATCHING TYPE)
SPIN DOWN VALVE DRIVER (MAN)
SPIN UP VALVE DRIVER (MAN)
+15V SPIN BACK UP REGULATOR 19632-1
TEMP PROBE & PRESSURE XDUCER +15V REGULATOR 19632-1

3-5, 2

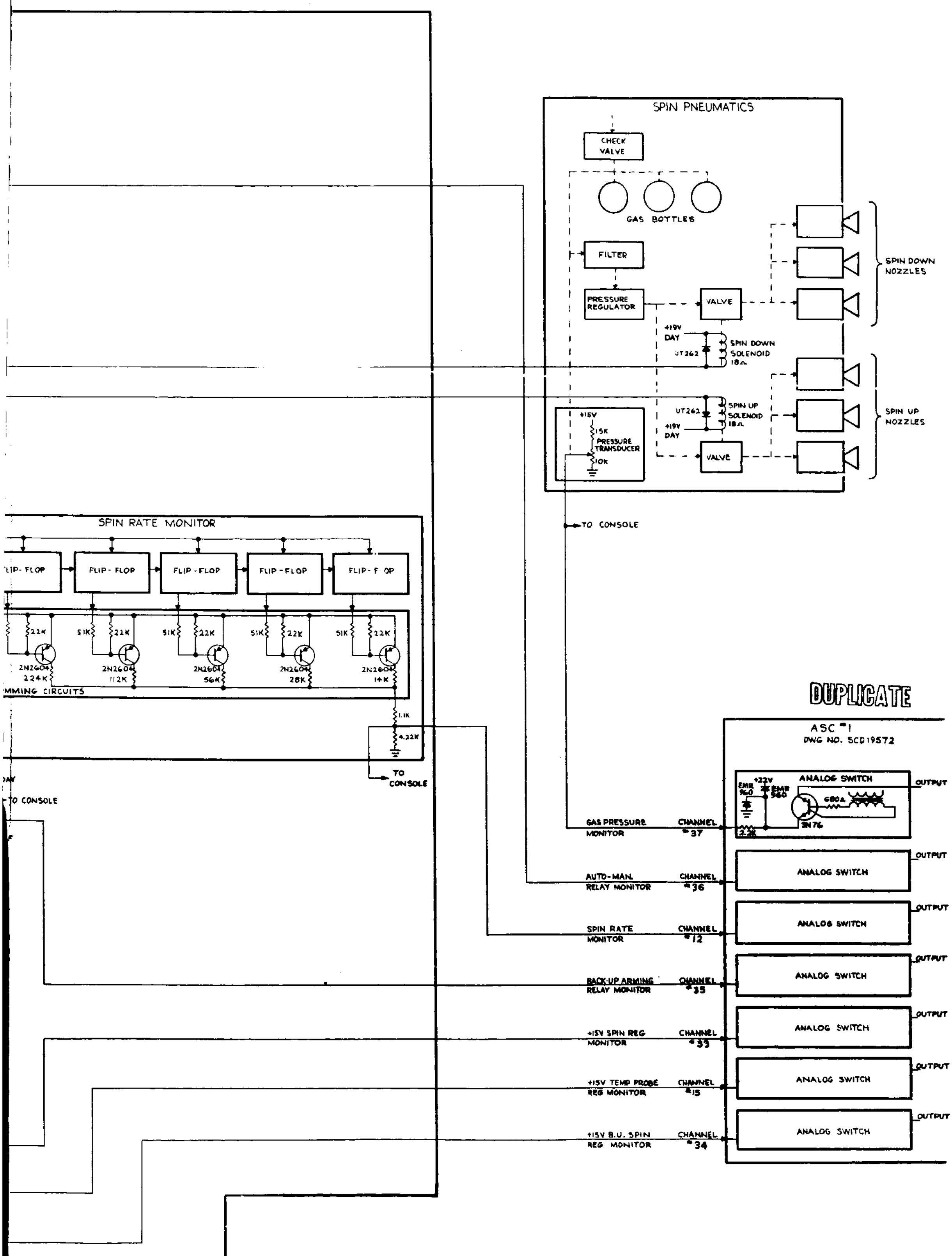
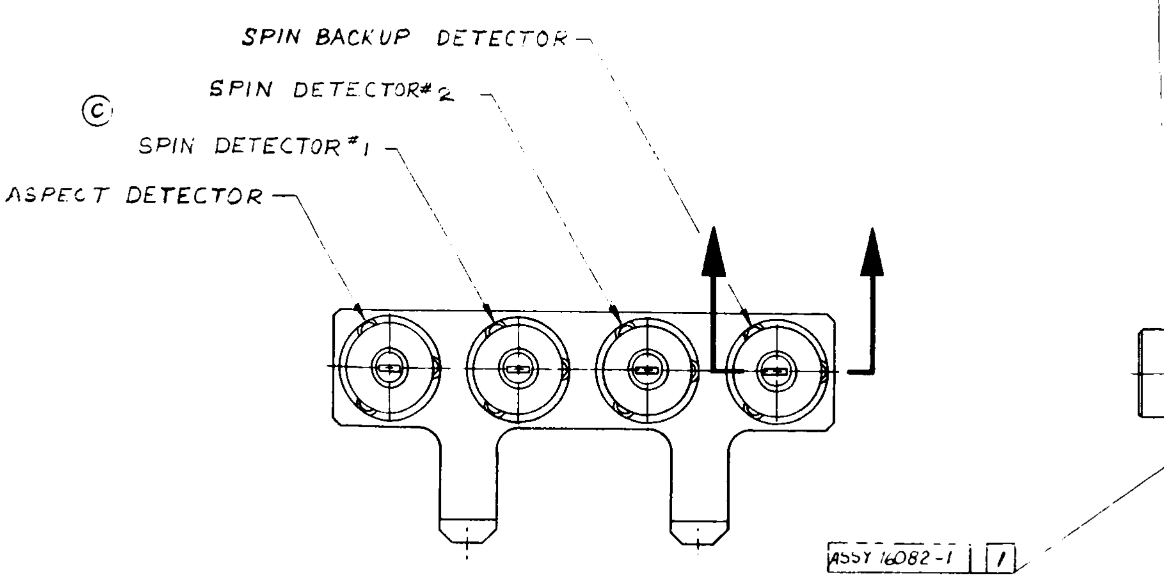
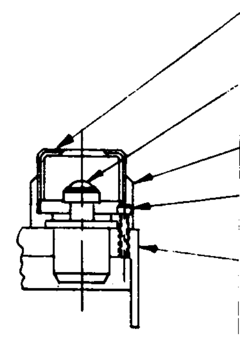
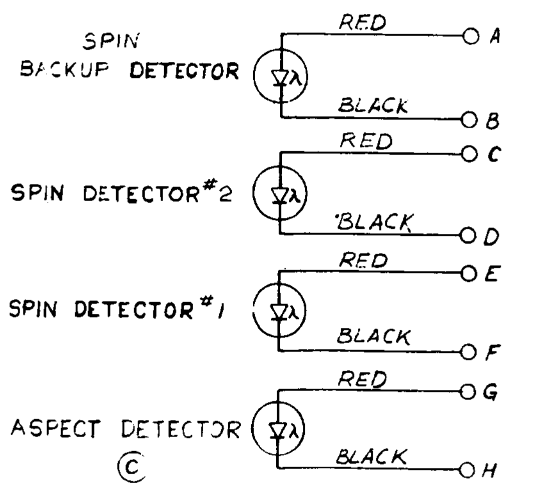


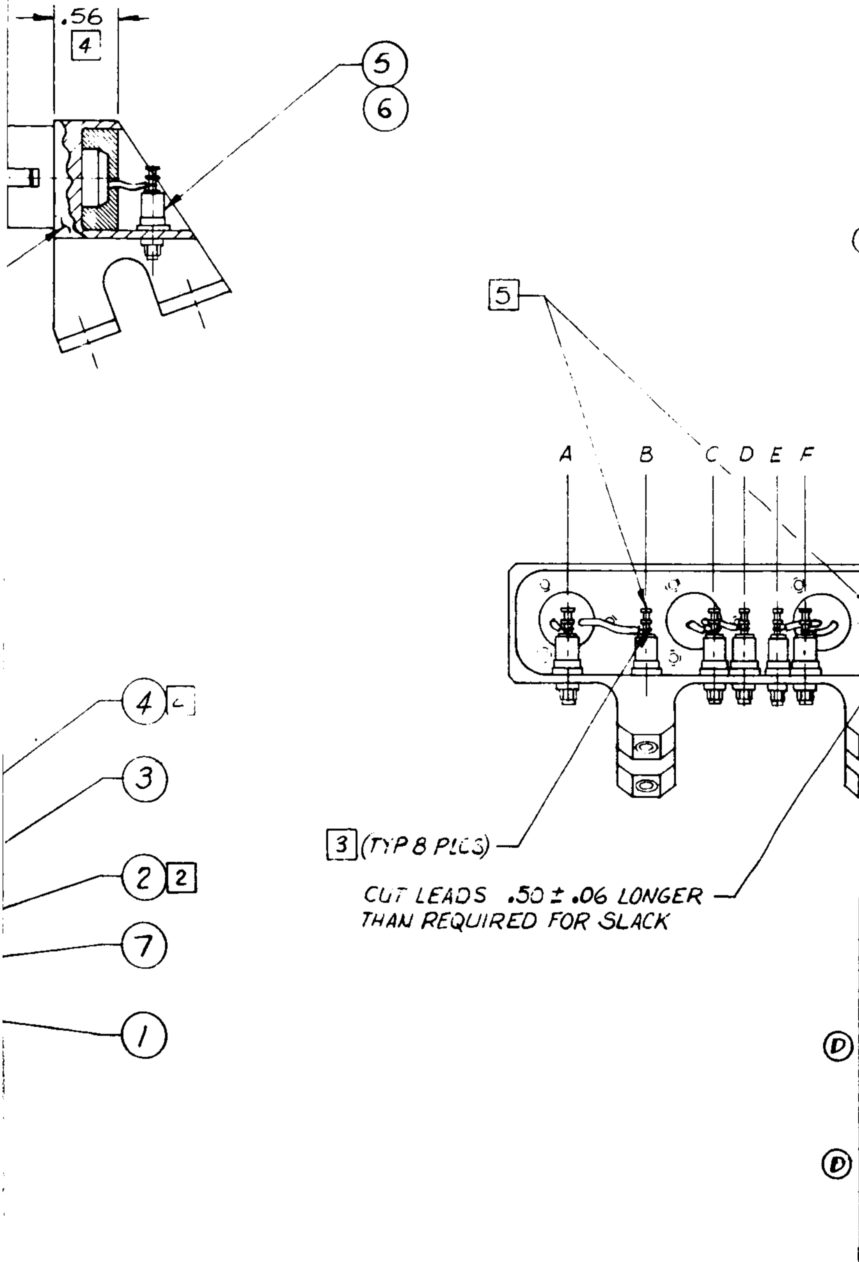
Figure 3-2–Spin Control System Diagram







SCHEMATIC DIAGRAM



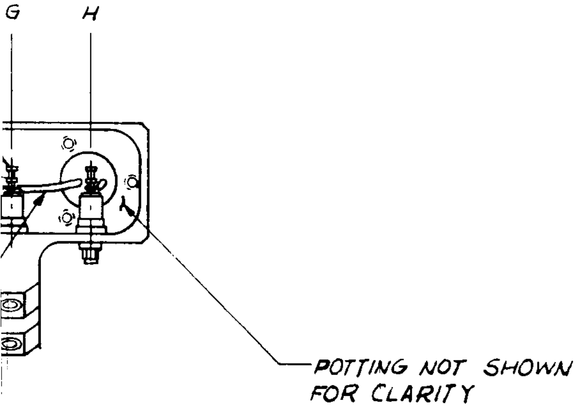
.56
4
5
6
5
A
B
C
D
E
F
4
3
2
2
7
1
3 (TYP 8 PLCS)
CUT LEADS .50 ± .06 LONGER
THAN REQUIRED FOR SLACK
D
D

37-2

GEN. NOTES UNLESS OTHERWISE SPECIFIED:

1. MARK PER BPS 19.00-1-12
2. BOND ITEM (4) IN ITEM (2) PER BPS 11.00
3. SOLDER PER BPS 2.00
4. FILL CAVITY OF ITEM (1) AS SHOWN WITH POTTING COMPOUND PER BPS 12.00 - AFTER ALIGNMENT AND ELECTRICAL CHECKOUT IS COMPLETE
5. APPLY BMS 9.01 TO THREADS

(D) 6. REFERENCE MODEL SPEC 18818



					12	NAS1351-01-6	SCREW	
					6	NAS1291A04M	NUT	
					8	SP0052-1	TERMINAL	
					4	C17910-1	COVER	
					4	C15929-503	DETECTOR ASSY, TARGET	
					4	C5263-3	RETAINER	
					1	D16083-1	HOLDER	
					-1	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	STOCK SIZE
QUANTITY REQ'D PER ASSEMBLY						ODD DASH NUMBERS SHOWN		LIST OF M

Figure 3-3–Spin Eye Assembly

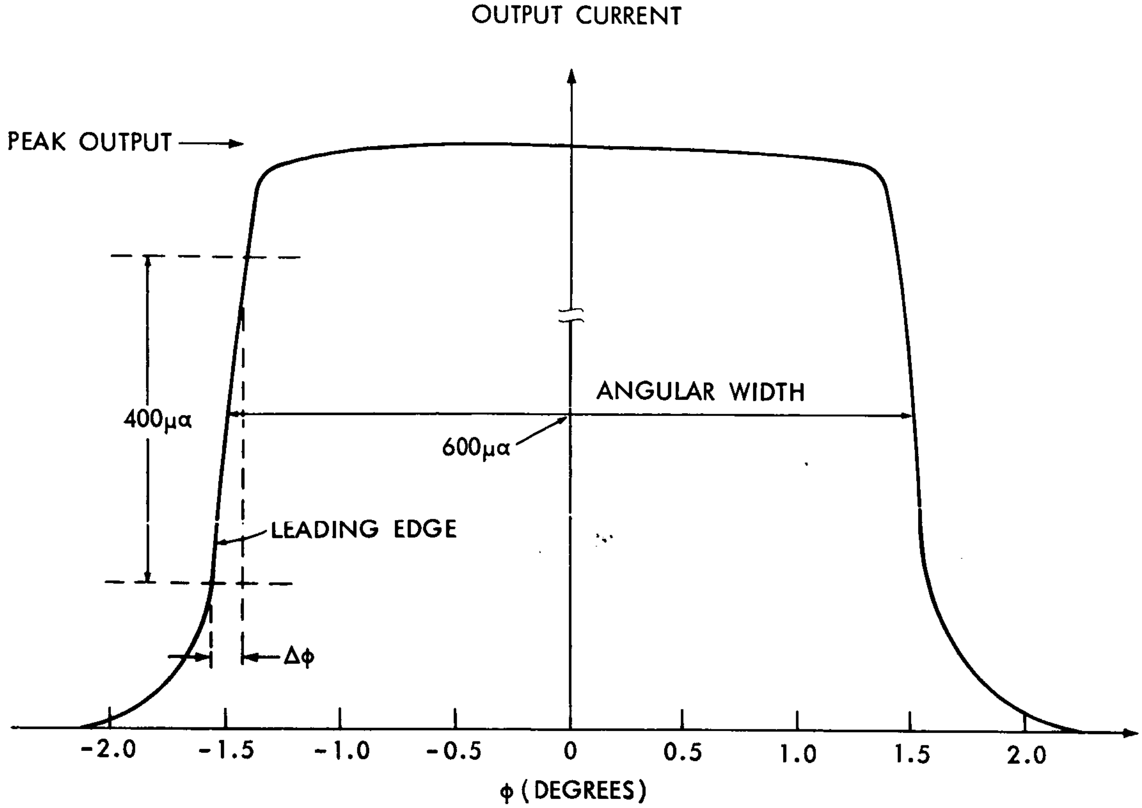


Figure 3-4—Typical Angular Response Curve of a Spin Control Detector

pulses on less light than is required to turn on the spacecraft. As a further precaution, power to the regenerative trigger is delayed by about 5 seconds. During this interval the sun rises far enough to show a nearly full disc, before the gas system is required to operate. It takes approximately 9 seconds for the spacecraft to pass through the penumbral shadow.

3.2.1.3 Pneumatics

The spin pneumatic system uses compressed nitrogen flowing through nozzles located at the ends of the extended arms to produce a torque to either increase or decrease the spin rate. See Figures 3-5 and 3-6.

The system consists of three storage bottles, one on the extremity of each arm of the spacecraft. These storage bottles are filled with nitrogen at initial pressure of 3000 psi. A quick disconnect fitting, an inline filter, and a check valve on the input line provide assurance that the nitrogen supply is pure and that it will not leak when the high pressure source is removed. The three storage bottles and the fill-line all feed into a common manifold. This manifold and

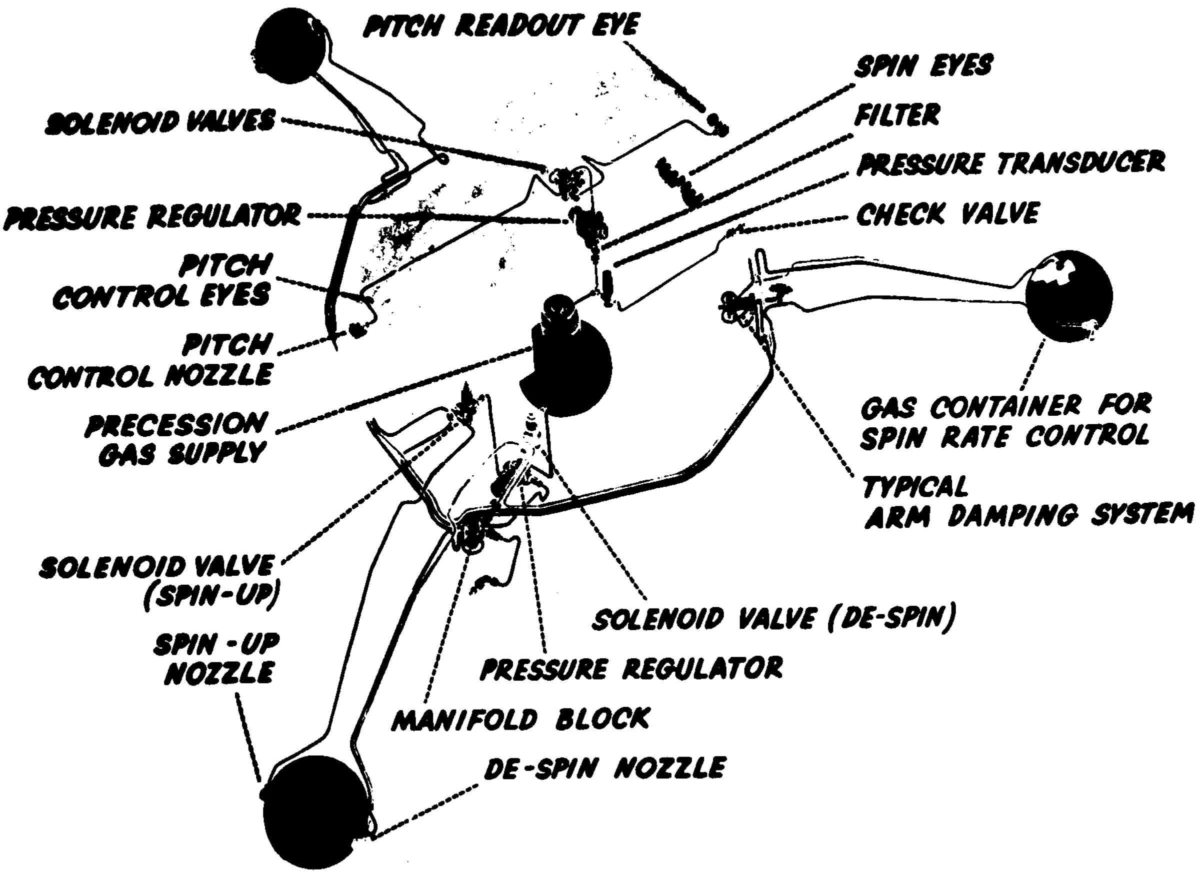
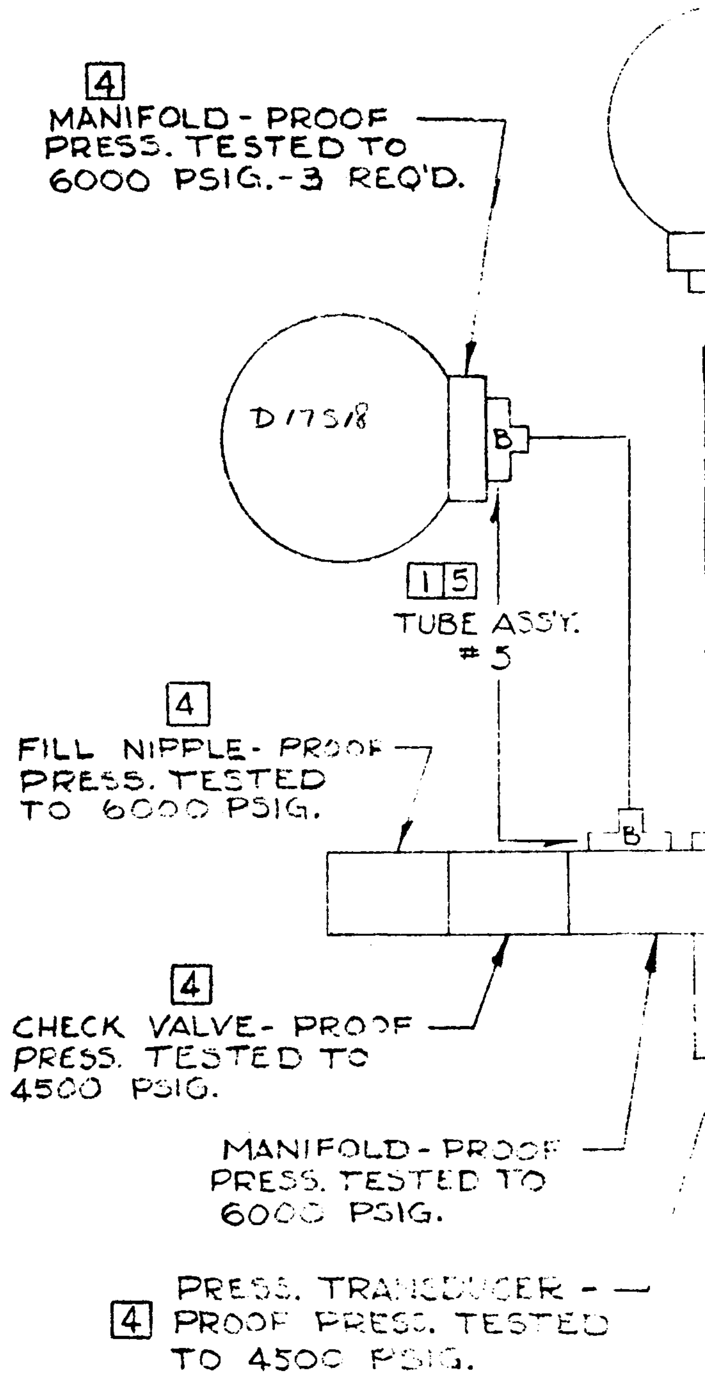


Figure 3-5–Gas Control Systems

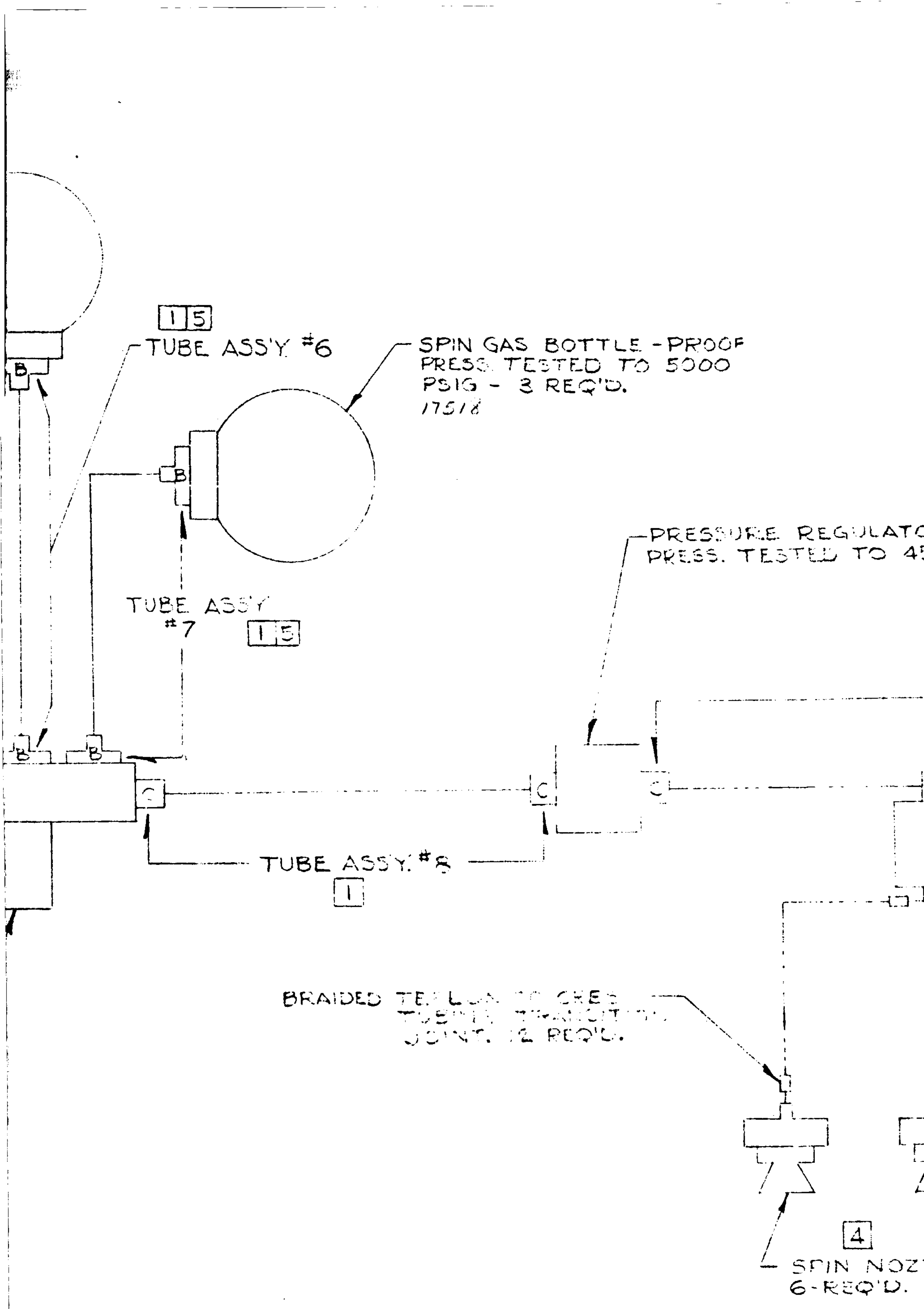
the pressure transducer are mounted on the skin of the spacecraft in compartment 4. The pressure transducer (Figure 3-7) converts the pressure to an electrical signal which is used as an input on channel 37 of ASC number 1.

A pressure regulator, the spin-up solenoid valve, and the spin-down solenoid valve are mounted on a plate in compartment 4. The pressure regulator (Figure 3-8) decreases the 3000 psi system pressure to 60 psi. This reduced pressure is delivered to both solenoid valves. When a signal (ground) is received from the spin electronics package by one of these solenoids, the valve opens and discharges the nitrogen through the three nozzles on the spacecraft arms. However, the solenoid working voltage is supplied by the +19 volt day circuit and if this circuit is not energized, the solenoids will not operate. The thrust of each nozzle is 0.1 pound at a distance of 3.8 feet from the center of gravity; so the total torque applied is approximately 1.14 pound-feet. The solenoid valves can also be actuated by the Command Backup System; refer to paragraph 3.2.2.



4
MANIFOLD - PROOF
PRESS. TESTED TO
6000 PSIG.-3 REQ'D.
D175/8
B
1 5
TUBE ASSY.
5
4
FILL NIPPLE - PROOF
PRESS. TESTED
TO 6000 PSIG.
B
4
CHECK VALVE - PROOF
PRESS. TESTED TO
4500 PSIG.
MANIFOLD - PROOF
PRESS. TESTED TO
6000 PSIG.
PRESS. TRANSDUCER -
4
PROOF PRESS. TESTED
TO 4500 PSIG.

341, 1



1 5
TUBE ASS'Y #6
B
SPIN GAS BOTTLE - PROOF PRESS. TESTED TO 5000 PSIG - 3 REQ'D.
17518
B
PRESSURE REGUL
PRESS. TESTED TO
TUBE ASS'Y #7
1 5
B
B
C
C
C
TUBE ASS'Y #8
1
BRAIDED
4
6-REQ'D.

3-11, 2

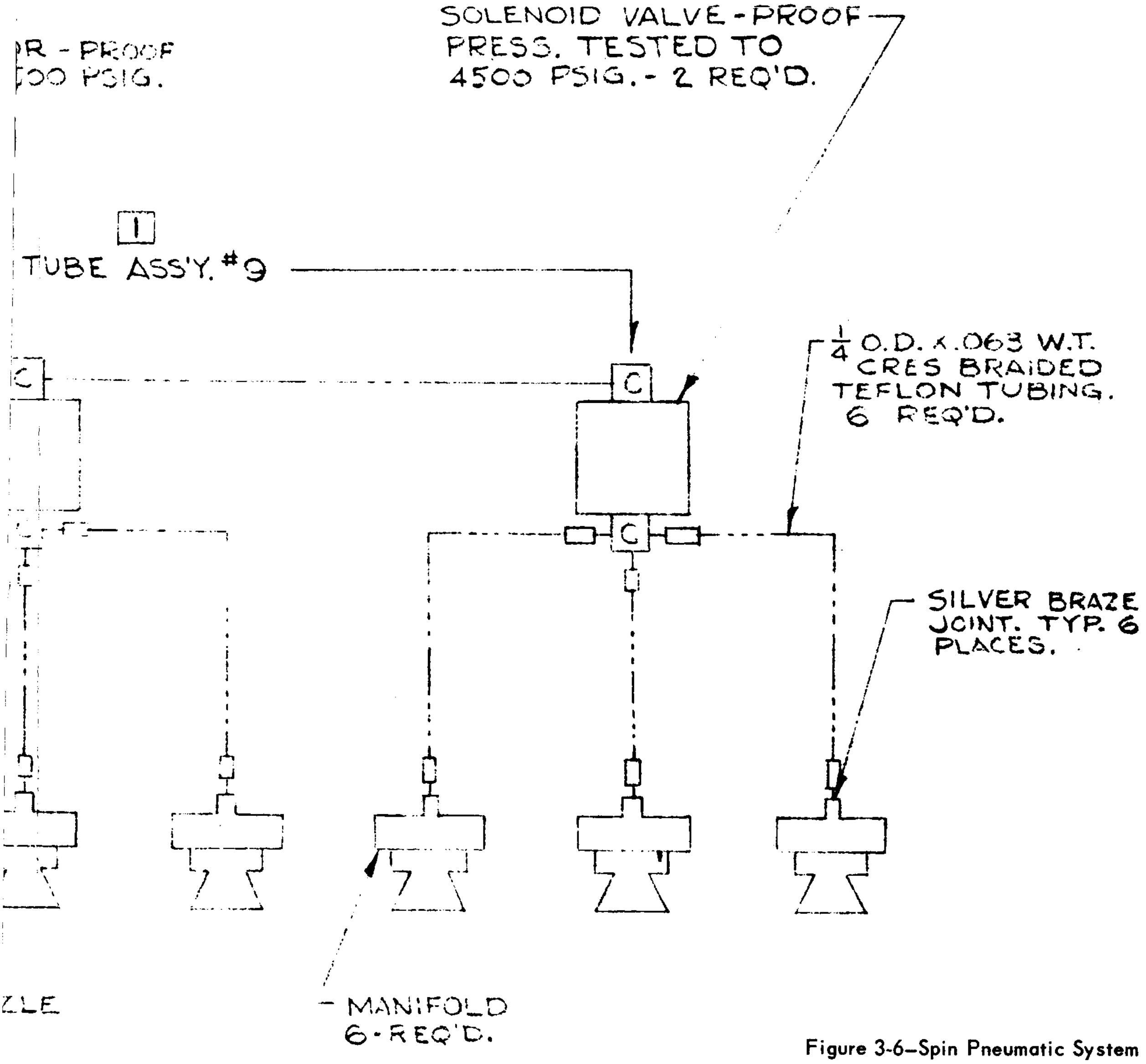


Figure 3-6–Spin Pneumatic System

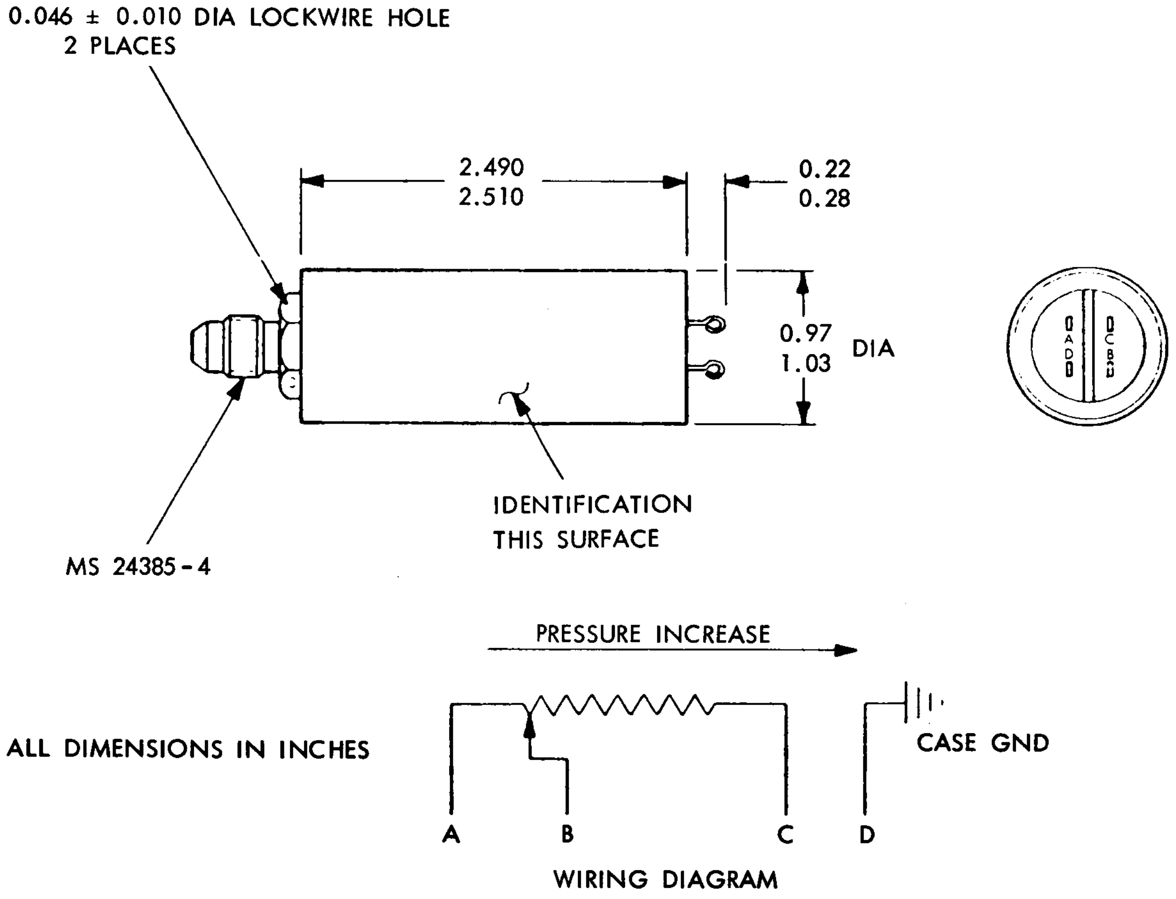


Figure 3-7–Pressure Transducer

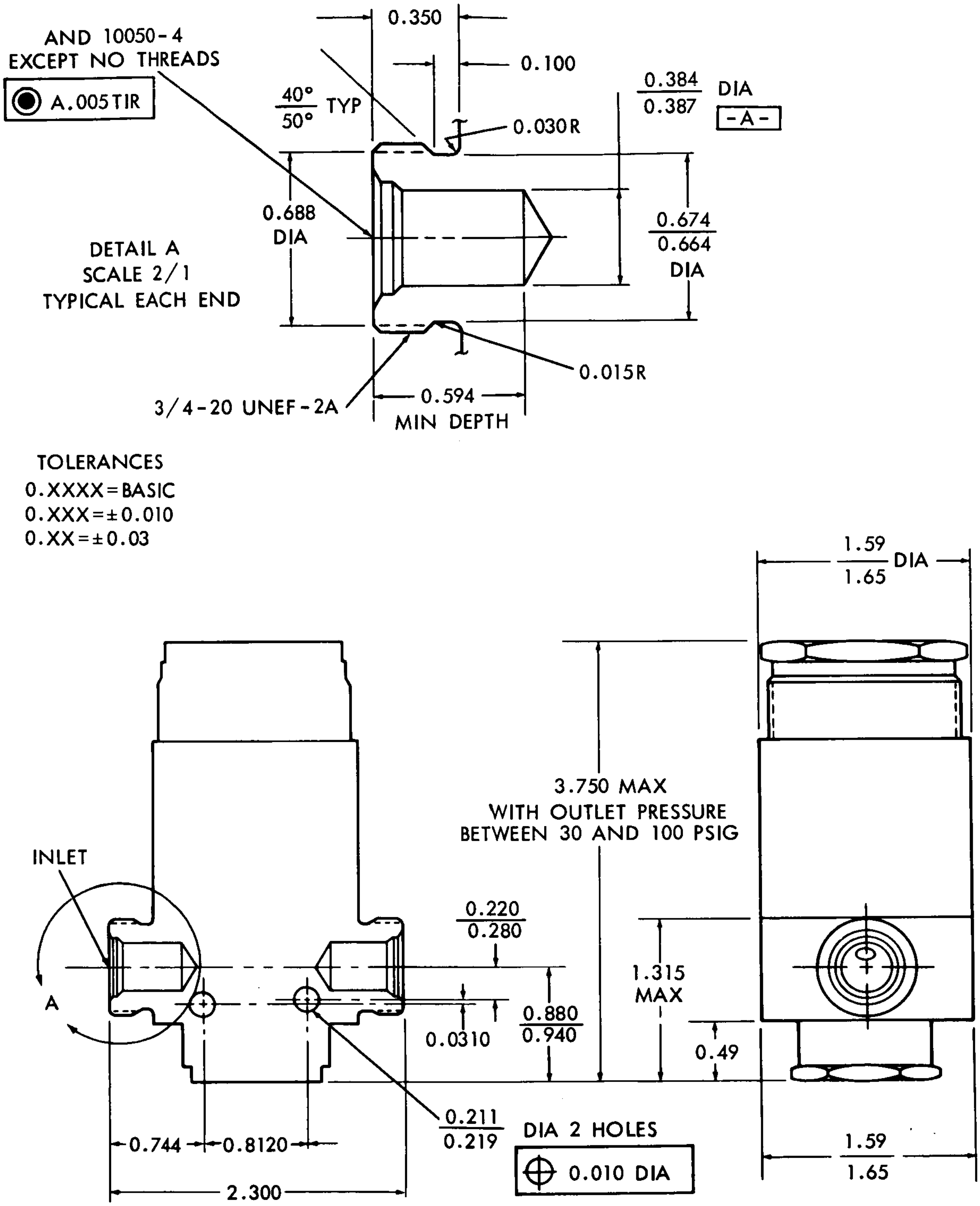


Figure 3-8–Pressure Regulator

3.2.1.3.1 Pneumatic System Components

All pneumatic components within the pneumatic system are tested to determine if the system meets the spacecraft requirements.

3.2.1.3.2 Tubing

Three types of tubing are used.

a. 1/4 OD stainless steel braid covered, 1/8 ID which meets MIL-P-5518.

b. 3/16 OD × 0.030 wall, copper which meets MIL-P-5518.

c. 1/8 OD × 0.030 wall, copper which does not meet MIL-P-5518. Chase Copper Alloy Handbook, Copyright 1948, for this tubing gives a burst pressure of 22,000 psi and working pressure of 3600 psi. All connections to this copper tubing are made by silver brazing it inside the 3/16 OD copper tubing.

3.2.1.3.3 Fittings

All tubing fittings are standard MS flareless type, aluminum, rated for 3000 psi service and meet MIL-P-5518.

3.2.1.3.4 Storage Bottles

Each of the three open storage bottles has a 157 cubic inch volume for a system total of 471 cubic inches. All bottles are made of titanium alloy and have the following ratings:

a. Operating Pressure	3000 psig
b. Proof Pressure	5000 psig minimum
c. Burst Pressure	6667 psig minimum

3.2.1.3.5 Check Valves, Filters, Pressure Regulators and Solenoid Valves

All these components are rated at a minimum of 3000 psia service pressure and a minimum of 7500 psig burst pressure. All have been proof tested at a minimum of 4500 psig.

The solenoid valves are downstream of the pressure regulators so are not actually part of the high pressure system. However, a leaky regulator could apply 3000 psi to them; therefore, they have been considered as high pressure components.

3.2.1.3.6 Pressure Transducers

The pressure transducers have a service pressure of 3500 psig and have been proof tested at 4500 psig. The output of the pressure is telemetered on Channel 37 of the analog telemetry system.

3.2.2 Command Backup Spin Control System

The function of the command spin backup is to automatically switch out the automatic spin control systems if the wheel spin rate decreases below about 0.39 rps, or increases about 0.70 rps, and to switch in circuits which can use ground commands to actuate the spin-up and spin-down gas jets. A spin backup arming relay is provided which allows the automatic "switch to manual" feature to be made operational or nonoperational by bround command. This relay also inhibits switch to backup during launch sequence spin down.

3.2.2.1 Sensors

The spin backup sensor is mounted on the spin eye assembly (Figure 3-3). This sensor is identical to the automatic system sensors. The output pulse generated by the eye is connected to the backup sin eye amplifier in the spin control electronics package.

3.2.2.2 Electronics

Pulses from the backup spin sensor (Figure 3-5) are applied to the backup spin amplifier. This amplifier is identical to the spin eye amplifier. The base of the amplifier is clamped by a 6.8 volt zener diode and the collector resistor is selected for the proper gain. The output from the amplifier is applied to a pulse shaper and then to the ramp generator. Depending upon the signal received from the ramp generator, the overvoltage or undervoltage circuit will be energized. After passing through an amplifier stage, the signal is then applied to the relay driver turning it on, and energizing the manual coil of the auto-man relays. The spin backup circuitry is basically the same as the automatic circuit.

With the auto-man relay in the manual position, 19 volts power is then applied to the manual circuits. A spin-up or spin-down command can then be applied. This signal will energize a relay which applies an input signal to the four second burst generator. The generator will conduct until it is turned off by a negative pulse applied to the base of the input transistor. The four second time constant is controlled by a r-c network. The output from the generator is applied to the manual valve driver, saturating its output stage. This will place one side of the solenoid coil at ground potential, causing it to energize.

The spin rate monitor supplies a quantized analog voltage to the telemetry system from which the wheel spin rate can be computed. The spin rate is monitored on channel number 12 of ASC number 1.

3.3 COARSE AZIMUTH CONTROL SYSTEM

The coarse azimuth control system is used to acquire the sun each spacecraft day. At the end of the spacecraft day, when the earth is between the spacecraft and the sun, the azimuth control system is inoperative and the sail rotates with the wheel. As the spacecraft enters the field of view of the sun, it is the function of the coarse azimuth control system to acquire the sun and orient the sail so that the pointing control system can align the pointed experiments toward the sun. A schematic diagram of this system is shown in Figure 3-9.

3.3.1 Sensors

There are two types of sensors used in the control circuit for the coarse azimuth control system; the acquisition eye and the target eye.

3.3.1.1 Coarse Eyes

The coarse eyes each have a characteristic curve that approximates a cosine curve. Four coarse eyes are arranged as shown in Figure 3-10, using shadowing masks to modify the cosine curve. This arrangement gives an error signal with a stable null looking toward the sun and an unstable null in the antisolar direction. In addition, the arrangement is specifically designed to aid in the acquisition problem. At the spacecraft's dawn, the oriented section is spinning along with the wheel section. Because of this, the sun must be acquired each morning by stopping the oriented upper section. There is insufficient torque to stop the rotating oriented section in a half revolution, therefore, a signal is needed that will provide a stopping drive for a large portion of a rotation. A rate gyro would, of course, be an ideal type of device for generating such a signal, but the power consumed and the reliability problem with such a device would not allow its use. By shaping the coarse eye curves and using error rate damping (lead network), signals are developed to stop the rotation for all orientations except in those narrow regions where sensing switches from rear eyes to front eyes. The field of view of each coarse eye is 90 degrees in azimuth and 30 degrees in elevation. The viewing field is reduced in elevation so the earth will not be acquired during initial acquisition.

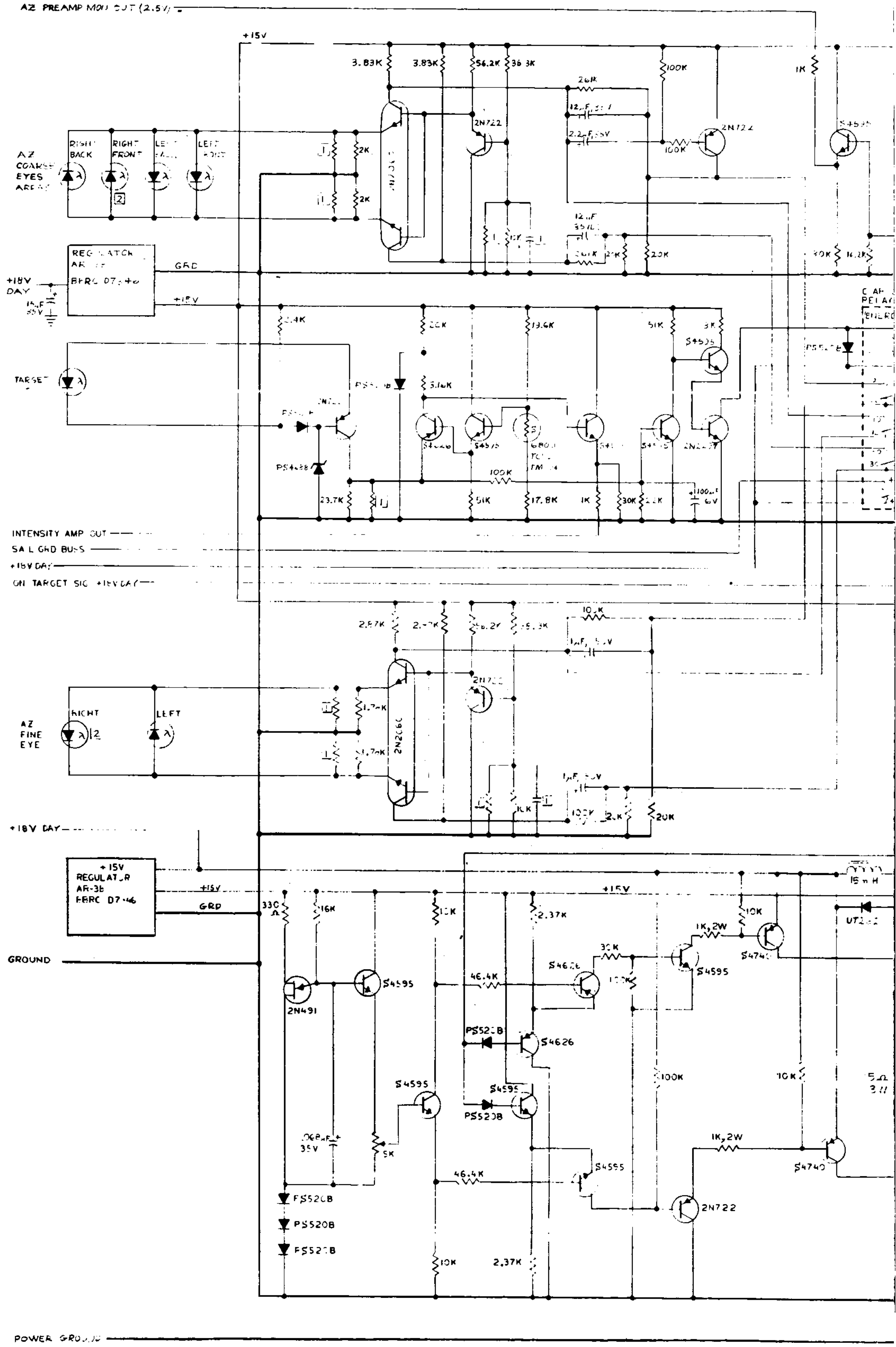
The coarse eye array will orient the upper section to the sun within 3 degrees. When this is done, the upper section is stopped and coarsely oriented. The fine eyes now are able to see the sun.

3.3.1.2 Target Eye

When the servo has settled down in the fine-eye region, the coarse eyes are no longer necessary and would contribute to errors in the pointing due to their picking up stray light from the earth. A target eye actuates the switch which disconnects the coarse eyes from the circuit when they are no longer needed. The target eye is identical to a fine eye except that the reticle is a rectangular aperture which permits an 8 degree square viewing field. The angular characteristics of a target eye are shown in Figure 3-19. A time delay of 6 to 10 seconds is associated with the switch so switching does not continually take place during the initial acquisition. The target eye is mounted on a pointed instrument.

3.3.2 Electronics

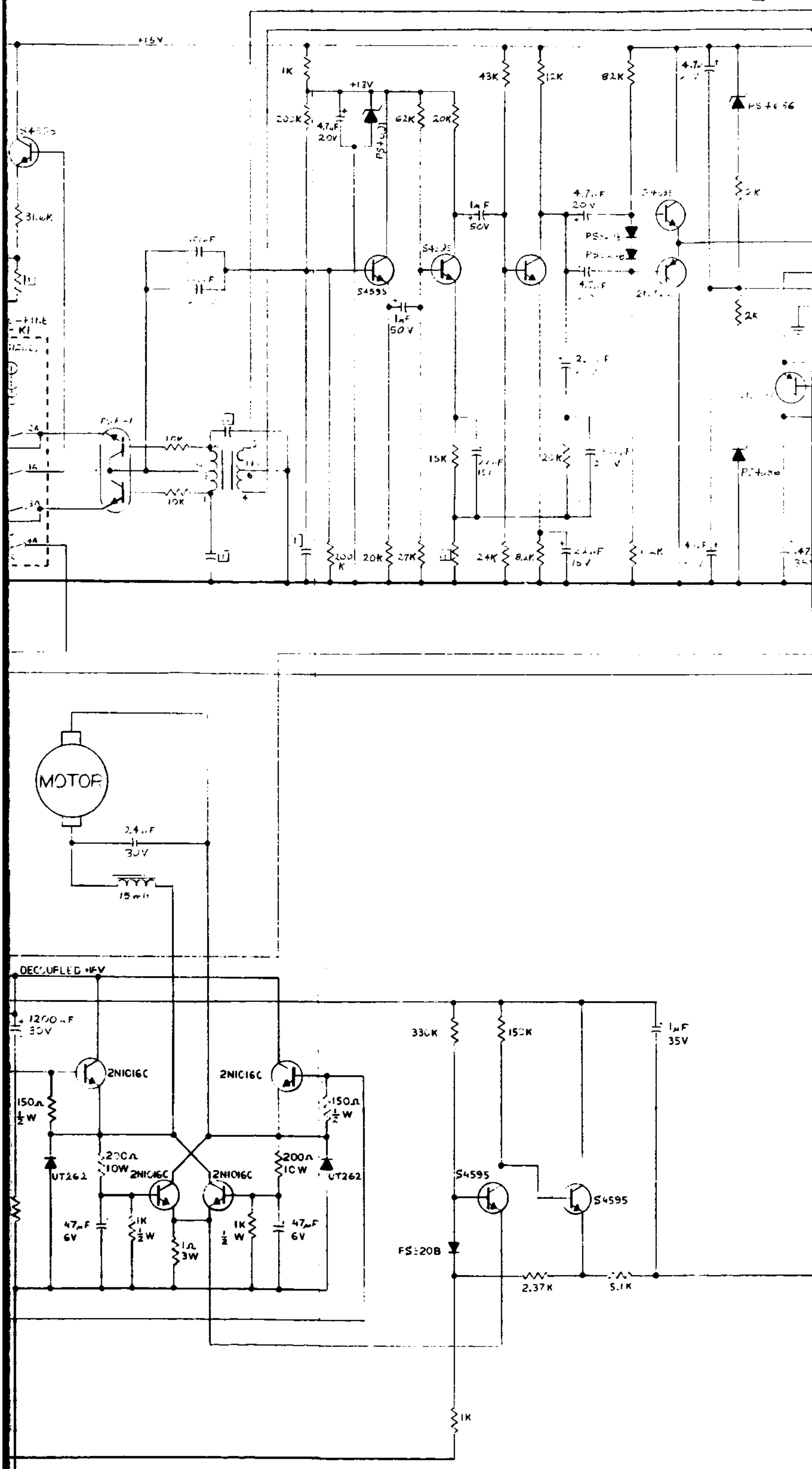
Error signals produced by the coarse eye array are applied to a preamplifier located in the servo box. The maximum normal current produced by the coarse eye array is plus or minus 1.9 ma. The preamplifier provides a short circuit load for the sensor. The sensor currents are converted to dc voltages and fed to a rate network for servo damping. The pulse is also inverted before being modulated. The rate network signal is modulated by a 1 to 2 kc square


AZ PREAMP MOD OUT (2.5V)
+15V
3.83K
3.83K
56.2K
36.3K
26K
100K
2N722
2N722
100K
1K
AZ COARSE EYES ARRAY
RIGHT BACK
RIGHT FRONT
LEFT BACK
LEFT FRONT
2K
2K
20K
+18V DAY
GRD
+15V
TARGET
100K
17.8K
1K
30K
23.7K
51K
INTENSITY AMP OUT
SA L GRD BUSS
+18V DAY
ON TARGET SIG +18V DAY
2.87K
10K
2N722
AZ FINE EYE
RIGHT
LEFT
2N2060
1K
20K
+18V DAY
+15V REGULATOR AR-36 FBRC D7-46
+15V
GRD
GROUND
330 Ω
16K
10K
2.37K
10K
1K, 2W
S4740
S4595
30K
S4626
46.4K
2N491
PS520B
S4626
S4595
100K
10K
PS520B
S4595
.068μF 35V
5K
46.4K
S4595
1K, 2W
S4740
2N722
PS520B
PS520B
PS520B
10K
2.37K
POWER GROUND

GEN. NOT

[1] VALUES

[2] EYE THA



3-20 0

S UNLESS OTHERWISE SPECIFIED
TO BE DETERMINED BY TEST.
SEES WHEN SAIL IS PULLED LEFT OF POINT.

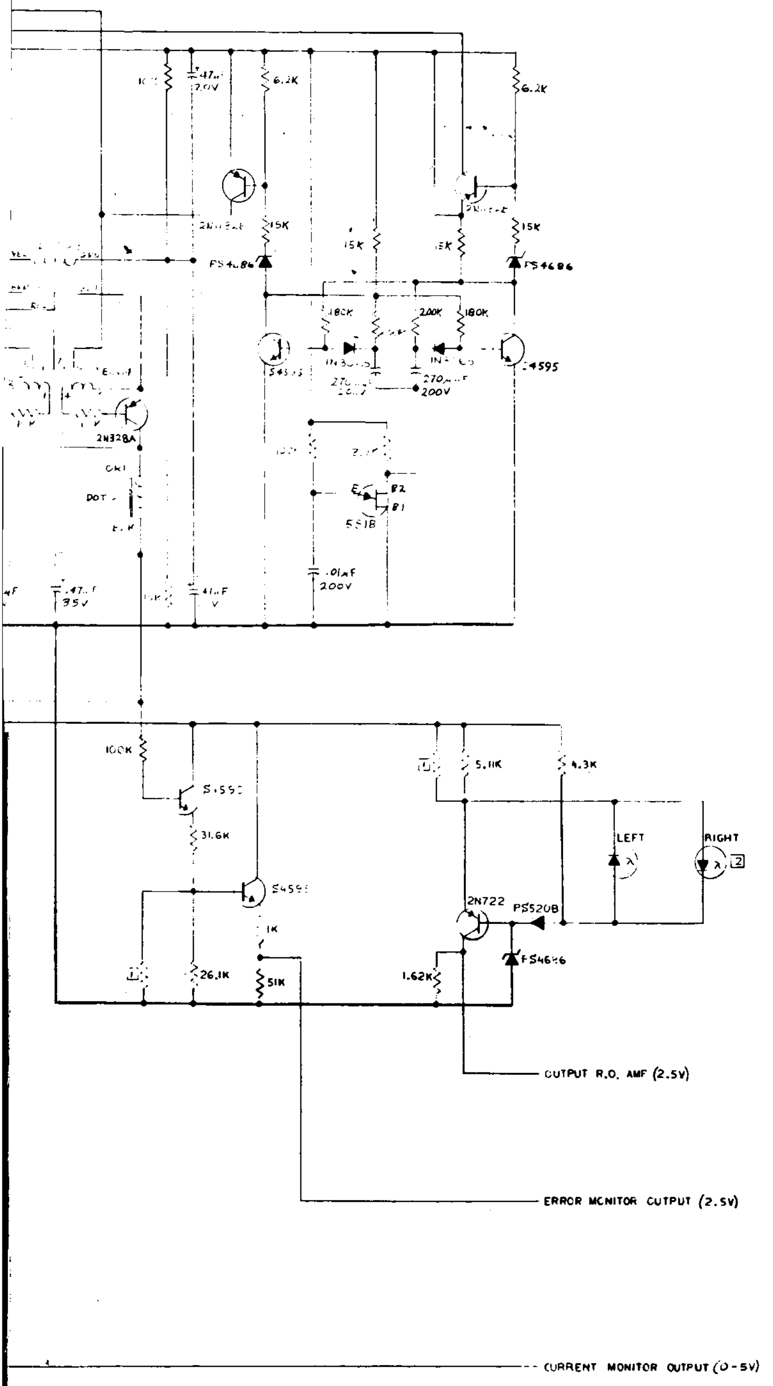
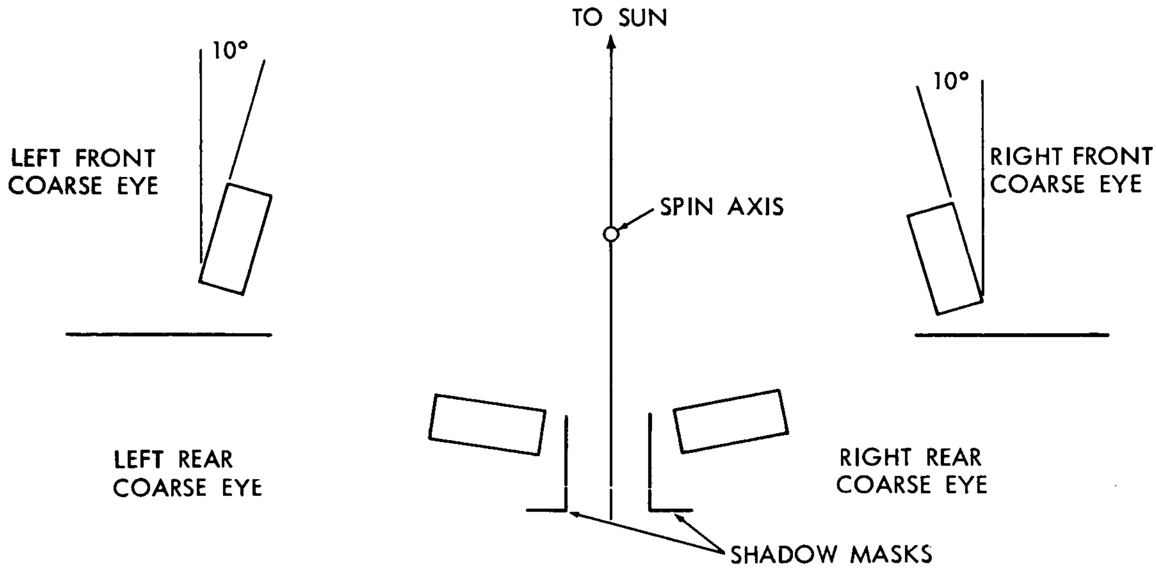
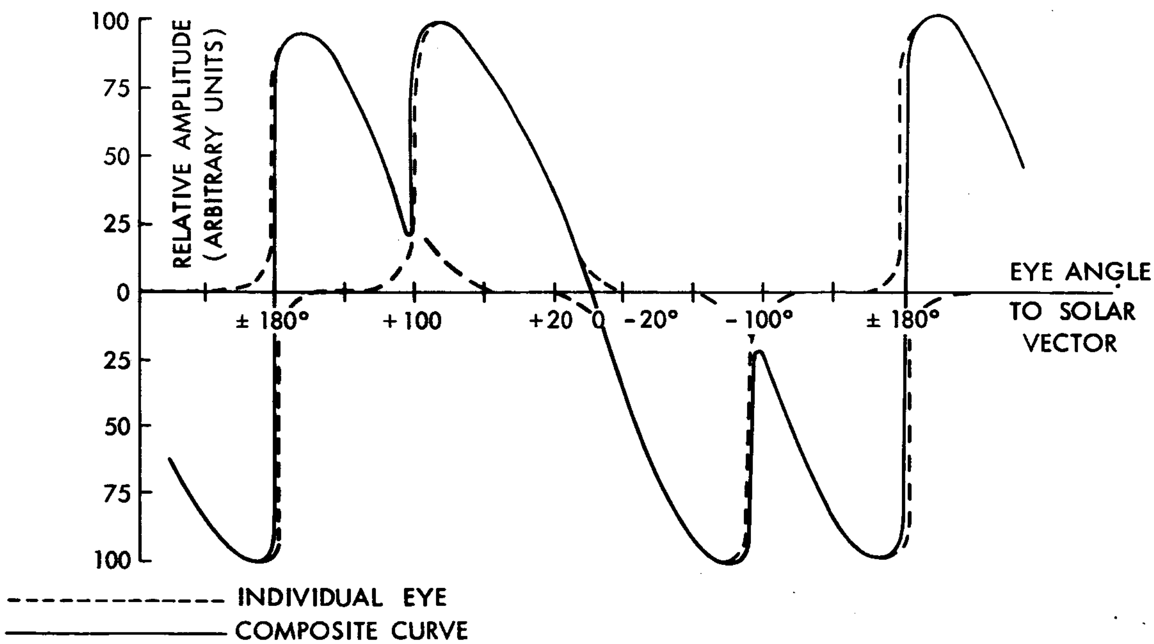


Figure 3-9—Azimuth Control System Diagram



ARRANGEMENT OF AZIMUTH COARSE EYE



ANGLUAR CHARACTERISTICS OF COARSE EYE

Figure 3-10–Arrangement and Angular Characteristics for Coarse Eyes wave and then sent to the ac amplifier. The ac amplifier amplifies and demodulates the error signal. The resulting dc error voltages are fed to the pulse width demodulator. A block diagram of the pointing system is shown in Figure 3-21.

The pulse width modulator converts the dc error voltages to a constant amplitude signal having a duration proportional to the error voltages. The repetition rate of the pulses from the modulators are approximately 1,000 pps. The pulses from the modulators are used to drive power bridge circuits which in turn drive the azimuth torque motor.

The azimuth power amplifier located in the power box provides the driving power to the azimuth torque motor. The amplifier operates as a saturated switch to obtain maximum power efficiency.

When the target sensor receives the proper amount of illumination the target eye amplifier will receive a signal, amplify the signal and apply it to the intensity monitor. The intensity monitor will then produce and output voltage proportional to solar intensity. This signal is monitored on channel number 22, ASC number 2.

The target eye amplifier also applies a signal to the on target relay driver which operates the coarse-fine relay after a 6 to 10 second delay. This relay switches out the azimuth coarse detector (sensor) and preamplifier, leaving only the fine sensor and preamplifier, when the target sensor receives the proper amount of illumination.

3.3.3 Servomotor

The servomotor in the azimuth control system is the same motor described in the pointing control system. Refer to paragraph 3.5.3.

3.4 PITCH CONTROL SYSTEMS

The pitch control gas system is an on/off device using photo-cells as detectors to sense when the jets should be turned on and off. The detectors are mounted on the sail oriented toward the sun. Two different modes of operation are possible; the automatic mode and the command pitch backup mode.

3.4.1 Automatic Pitch Control System

The automatic pitch control system keeps the spin axis of the spacecraft normal to the solar vector so that the elevation servo system is within operating range. The sensors monitor the pitch angle and, when the pitch axis is more than 3 degrees from the perpendicular, a signal is sent to the pitch controllers which operate jets to precess the spacecraft until the spin axis is approximately 1 degree beyond the perpendicular. The overshoot is to accommodate the scanning requirements of an instrument located in the sail.

Outputs from the pitch control eyes (sensors) actuate electronic switches that operate solenoid valves. The valves control the flow of nitrogen to the nozzles. The exhaust of the gas applies a torque to the spacecraft to precess the spin axis in the desired direction. The electronic switches are arranged so that both of the up or down outputs must be high to actuate the switch and both must be low to turn it off. A system diagram of the pitch control system is shown in Figure 3-11.

3.4.1.1 Sensors, Pitch Control

The pitch control sensor provides the angular pitch error signal to the pitch control subsystem.

Four solar sensors are used for automatic pitch control activation. One sensor is mounted with its optical axis tilted about 11 degrees above a line normal to the sail. The field of view of this sensor (A) extends to within 4 degrees of normal. A second sensor is mounted so that its optical axis is tilted about 7 degrees above normal and its field of view extends below normal by about one degree. The second pair is mounted with the same offset angles below normal. These sensors operate in pairs to provide the pitch-up or pitch-down correction (Figure 3-12).

The logic of pitch correction is as follows:

a. One point, ± approximately one degree of the solar direction, both the (B) sensors are activated.

b. As pitch drift begins to exceed one degree, but is less than 3 degrees, the appropriate (B) detector will be active, the other (B) detector will be inactive.

c. As pitch error reaches threshold of the appropriate (A) detector, both the (A) and (B) sensors will then be activated.

d. A true pitch error is recorded and pitch correction is initiated.

e. Pitch correction continues until both the (A) and (B) detectors are deactivated which, it can be seen, is about one degree past the zero error point.

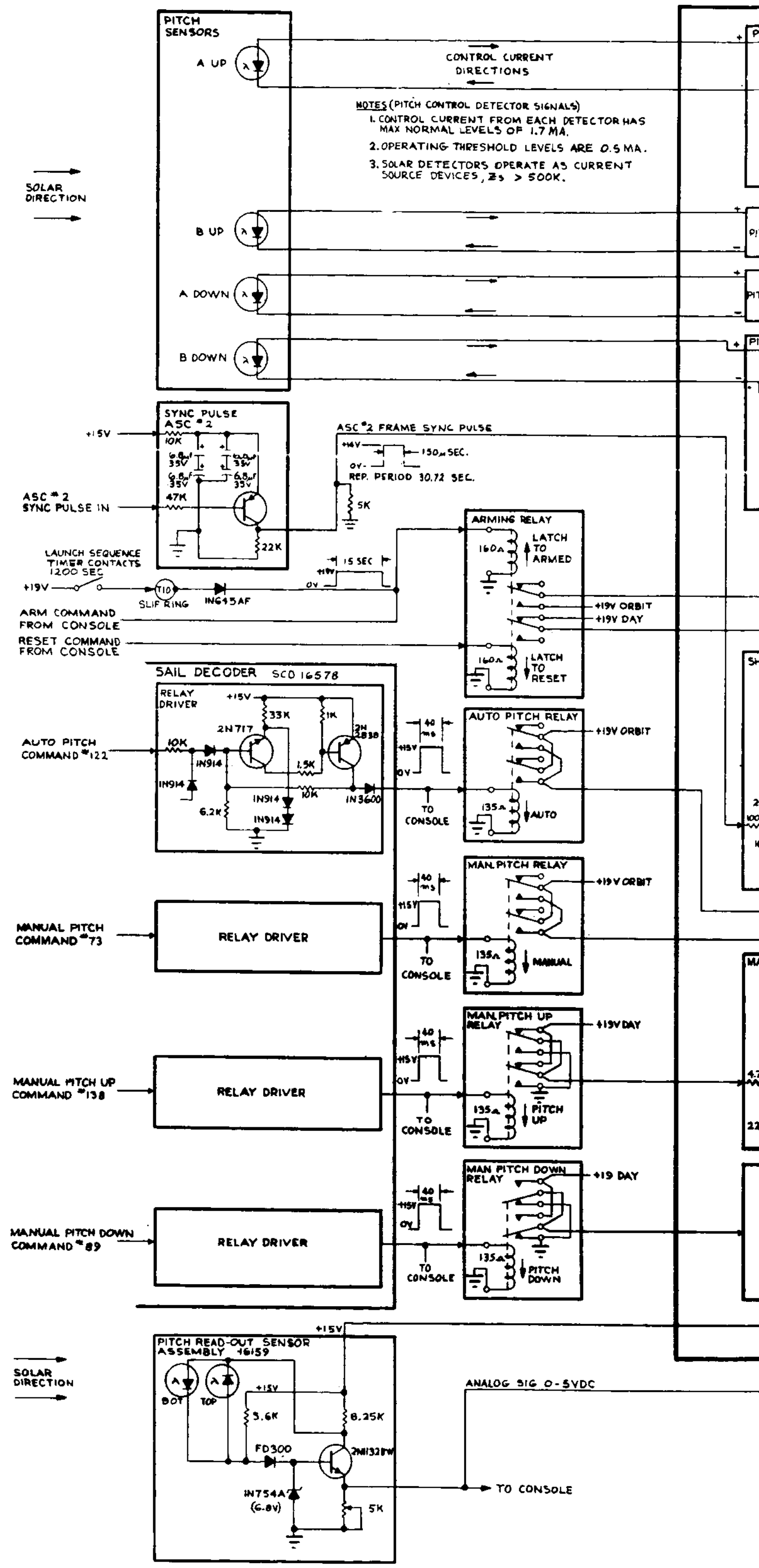
When the pitch axis is zero, the spin axis is normal to the solar direction. Now consider a pitch-up drift of the spacecraft in which the spin axis is tilted away from the solar direction. As the A-down detector reaches its turn-on threshold, the detector amplifier, after a delay of about 8 seconds, changes the state of the pitch-down bistable flip-flop to its on condition. The flip-flop change occurs, however, only if the B-down detector signal also is operative; that is, a 4 degree pitch-up error, the B-down detector is 4 degrees to 5 degrees past its turn-on threshold. With only the B detector on, the flip-flop state will be held in its off position until the A detector threshold signal is received. The flip-flop off state is likewise a controlled condition when neither A nor B detectors are on.

Downward precession of the spacecraft results as gas is released from the pitch-down jet and continues until a one degree pitch-down error is reached. At this angle, the B detector signal falls below its on threshold and the pitch-down valve closes as the flip-flop returns to its off state. Automatic correction of a 4 degree pitch-down error occurs in the same manner as for the error correction just presented, except that for down-error the elements of the pitch-up control are employed. The time to make a 4 degree automatic pitch correction is about 64 seconds. A nutation of the spin axis results when a pitch correction is made.

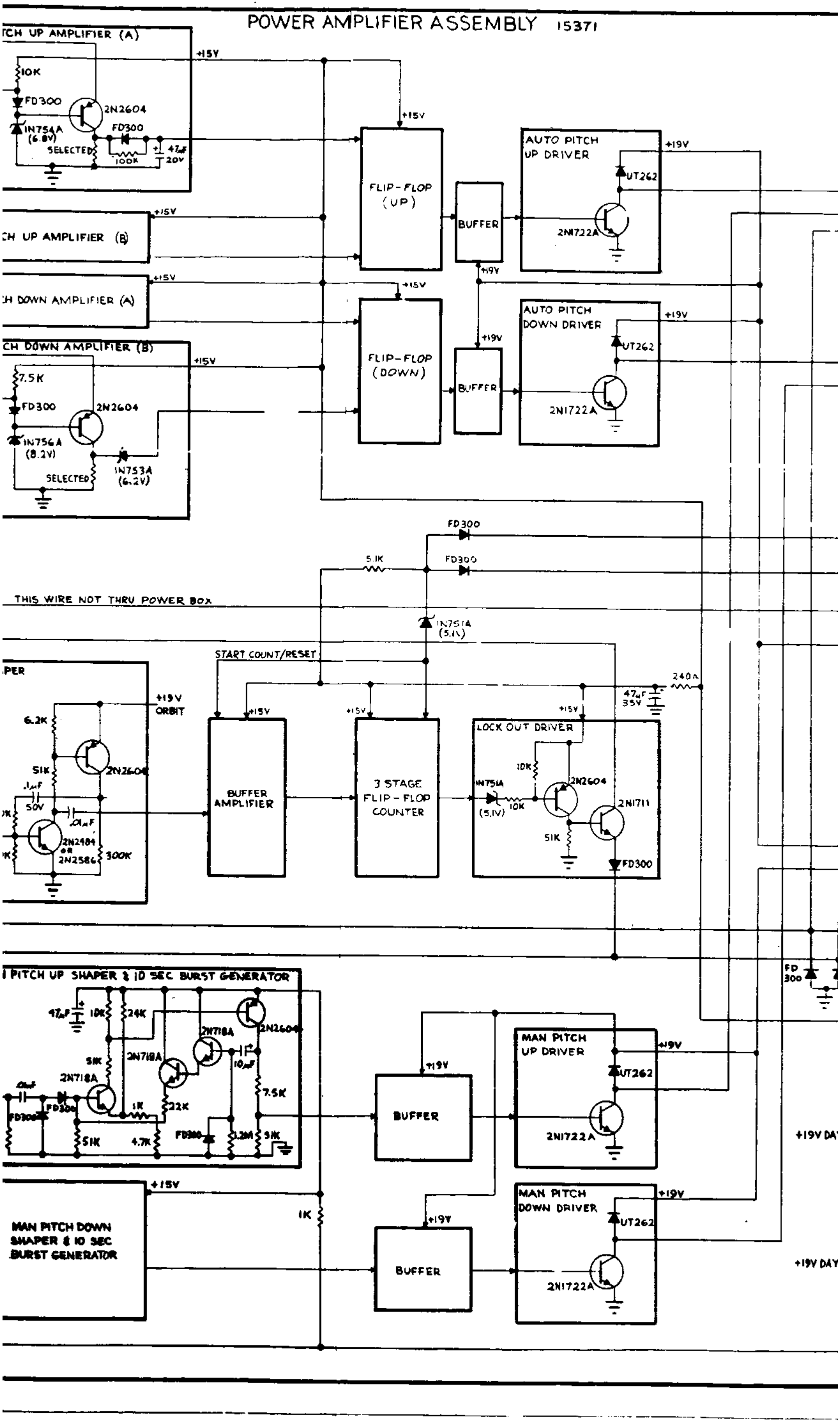
3.4.1.2 Electronics

The error signals are applied from the pitch sensors to the pitch-up or pitch-down amplifiers (Figure 3-11). The pitch-up and pitch-down circuits are identical. The signal is then amplified and applied to the flip-flop, placing it in the up state. This signal is then applied to the driver circuit through a buffer amplifier. The driver output transistor is turned on full, placing the negative side of the solenoid at ground potential and energizing the solenoid.

The pitch-up gas jet shall actuate 3.0 to 10.0 seconds after the pitch angle reaches its negative correction threshold of -3.5 degrees and will remain actuate until the pitch angle is +1 degree. The pitch-down gas jet will actuate 3.0 to 10.0 seconds after the pitch angle reaches its positive correction threshold of +3.5 degrees and will remain actuated until the pitch angle is -1.0 degree. These +1 degree and -1 degree signals received from the sensors will enable the flip-flop.



PITCH SENSORS
A UP
B UP
A DOWN
B DOWN
CONTROL CURRENT DIRECTIONS
NOTES (PITCH CONTROL DETECTOR SIGNALS)
1. CONTROL CURRENT FROM EACH DETECTOR HAS MAX NORMAL LEVELS OF 1.7 MA.
2. OPERATING THRESHOLD LEVELS ARE 0.5 MA.
3. SOLAR DETECTORS OPERATE AS CURRENT SOURCE DEVICES, Zs > 500K.
SOLAR DIRECTION
SYNC PULSE ASC #2
ASC #2 SYNC PULSE IN
ASC #2 FRAME SYNC PULSE
REP. PERIOD 30.72 SEC.
LAUNCH SEQUENCE TIMER CONTACTS 1200 SEC
SLIP RING
IN645AF
ARM COMMAND FROM CONSOLE
RESET COMMAND FROM CONSOLE
ARMING RELAY
LATCH TO ARMED
LATCH TO RESET
+19V ORBIT
+19V DAY
SAIL DECODER SCD 16578
RELAY DRIVER
AUTO PITCH COMMAND #122
AUTO PITCH RELAY
TO CONSOLE
AUTO
MANUAL PITCH COMMAND #73
RELAY DRIVER
MAN. PITCH RELAY
MANUAL
MANUAL PITCH UP COMMAND #138
MAN. PITCH UP RELAY
PITCH UP
+19V DAY
MANUAL PITCH DOWN COMMAND #89
MAN PITCH DOWN RELAY
PITCH DOWN
+19 DAY
PITCH READ-OUT SENSOR ASSEMBLY 46159
BOT
TOP
FD300
IN754A (6.8V)
ANALOG SIG 0-5VDC
TO CONSOLE


POWER AMPLIFIER ASSEMBLY 15371
PITCH UP AMPLIFIER (A)
PITCH UP AMPLIFIER (B)
PITCH DOWN AMPLIFIER (A)
PITCH DOWN AMPLIFIER (B)
FLIP-FLOP (UP)
FLIP-FLOP (DOWN)
BUFFER
AUTO PITCH UP DRIVER
AUTO PITCH DOWN DRIVER
THIS WIRE NOT THRU POWER BOX
START COUNT/RESET
BUFFER AMPLIFIER
3 STAGE FLIP-FLOP COUNTER
LOCK OUT DRIVER
ORBIT
MAN PITCH UP SHAPER & 10 SEC BURST GENERATOR
MAN PITCH DOWN SHAPER & 10 SEC BURST GENERATOR
MAN PITCH UP DRIVER
MAN PITCH DOWN DRIVER
+19V DAY
2N2604
2N1722A
2N1711
2N718A
UT262
FD300
1N754A (6.8V)
1N756A (8.2V)
1N753A (6.2V)
1N751A (5.1V)
SELECTED
3-26 a

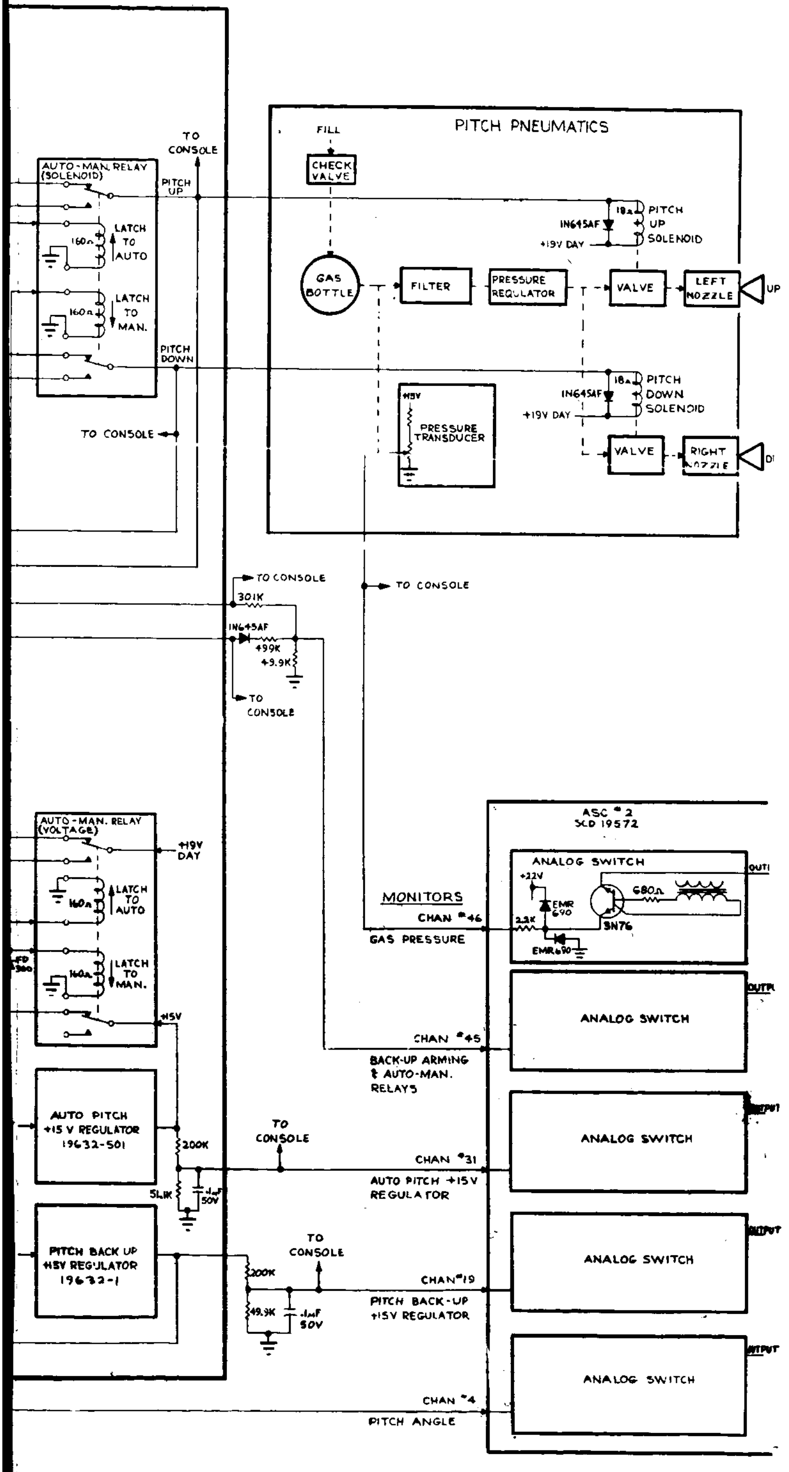


Figure 3-11—Pitch Control System Diagram

(2)

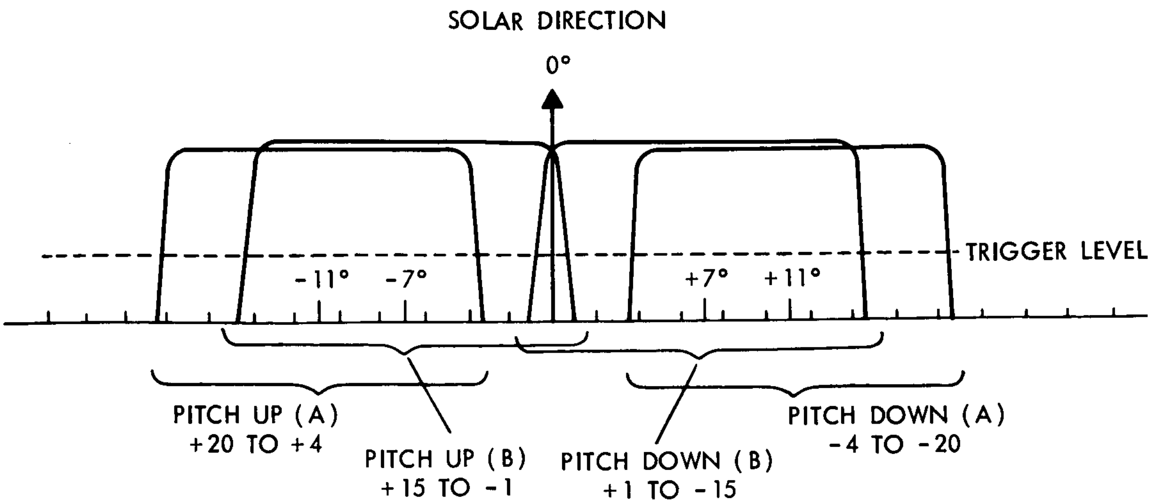


Figure 3-12–Fields of View for Pitch Control Sensors

Either pitch gas valve will remain actuated for a duration of approximately 10 seconds for each signal received. Error signals received while a pitch valve is actuated will have no effect.

The pitch control system will remain in the automatic control mode during the launch sequence until the 1200 second launch sequence time signal occurs. This lockout is necessary during launch to avoid having the pitch system switch to manual during initial pitch acquisition. Automatic correction of pitch errors up to 18 degrees is possible during the lockout period.

3.4.1.3 Pneumatics

The pitch pneumatic system (Figure 3-13) forces compressed nitrogen through the nozzles located on the rim of the sail to produce a torque to change the pitch attitude of the spacecraft.

The system consists of a nitrogen storage bottle, pressure transducer, pressure regulator, solenoid valves, and hardware. The storage bottle is mounted on the azimuth shaft and is, therefore, an integral part of the sail. The other components are mounted around the edge of the pointed experiments. The storage bottle is filled with nitrogen at a pressure of 3000 psi. A quick disconnect fitting, several inline filters, and a check valve of the input line provide assurance that the nitrogen supply is pure and that it will not leak when the high pressure source is removed. The storage bottle and the fill line connect to the same manifold. This pressure transducer is mounted on the manifold. The pressure transducer converts the system pressure to an electrical signal which is used as an input on channel 46 of ASC number 2.

The pressure regulator decreases the 3000 psi system pressure to 30 psi; this reduced pressure is applied to both the pitch-up and pitch-down solenoid valves. When a signal (ground) is applied from the power amplifier assembly to one of the solenoid valves, the valve opens and discharges nitrogen through the valve to its corresponding nozzle (pitch-up or pitch-down). However, the solenoid working voltage is supplied by the +19 volt day circuit and if this circuit is not energized, the solenoids will not operate. The thrust of each nozzle is 0.05 pound at a distance of 1.9 feet from the center of gravity; so the torque applied by either nozzle is 0.095 pound-feet which causes the spacecraft to precess at a rate of 0.064 degree per second. The solenoid valves can also be operated by the command backup system; refer to paragraph 3.4.2.

3.4.1.3.1 Storage Bottle

The storage bottle internal volume is 480 cubic inches minimum capacity at ambient temperature.

3.4.1.3.2 Pressure Regulator

The pressure regulator reduces the system pressure from 3000 psi to 30 psi.

3.4.1.3.3 Pressure Transducer

The pressure transducer has a service pressure of 3500 psi and have been proof tested at 4500 psi. The output of the pressure transducer is telemetered on channel 46 of ASC number 2.

3.4.1.3.4 Other Components

All other components of the pitch system are similar to those used in the spin system. Refer to paragraph 3.2.1.3.

3.4.2 Command Backup Pitch Control System

The command backup pitch control provides the means for switching out the automatic pitch control system if the automatic system continues to provide pitch error correction for 107 ± 15 seconds or the system may be commanded by ground control. When the automatic pitch control circuits are switched out, driver circuits are switched in which can be operated by ground commands to control the

NOTES:

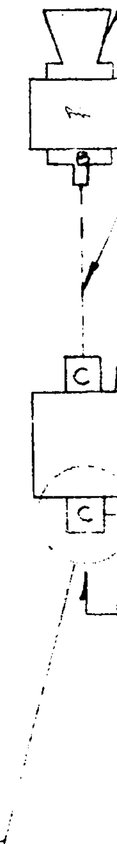
1. [boxed] PROOF PRESS. TESTED AS A SUB-ASS'Y. TO 6000 PSIG. BURST PRESS. TESTED TO 12,000 PSIG.
2. ALL TUBING 3/16 O.D. X .028 W.T. CRES SEAMLESS TYPE 18-8 (MIL-T-6845), UNLESS OTHERWISE SPECIFIED.
3. VARIFICATION OF ALL TESTS ON FILE AT BBRC.
4. [boxed] THREADED INTO ADJACENT COMPONENT WITH O-RING SEAL.
5. [boxed] 1/8 O.D. x .030 W.T. CU. TUBE TYPE DHP ASTM B-280-58T.
6. ALL BRAZED JOINTS PER MIL-B-7883 W/FILLER METAL PER QQ-S-561.
7. DESIGN PRESSURES: (EXCEPT TUBE ASS'YS. FROM SOLENOID VALVES TO NOZZLES)
   GAS BOTTLES - 6667 PSI (ULTIMATE)
   LINES; FITTINGS; MAIFOLDS - 12,000 PSI (ULTIMATE)
   COMPONENTS - 7500 PSI (ULTIMATE)

LEGEND:

——————— 3000 PSI OPERATING PRESS.

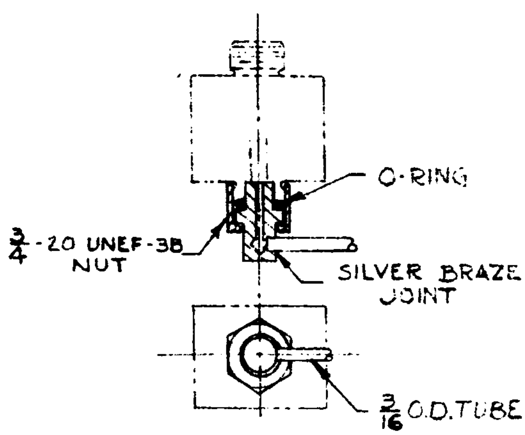
– – – – – – – – 30 PSI OPERATING PRESS.

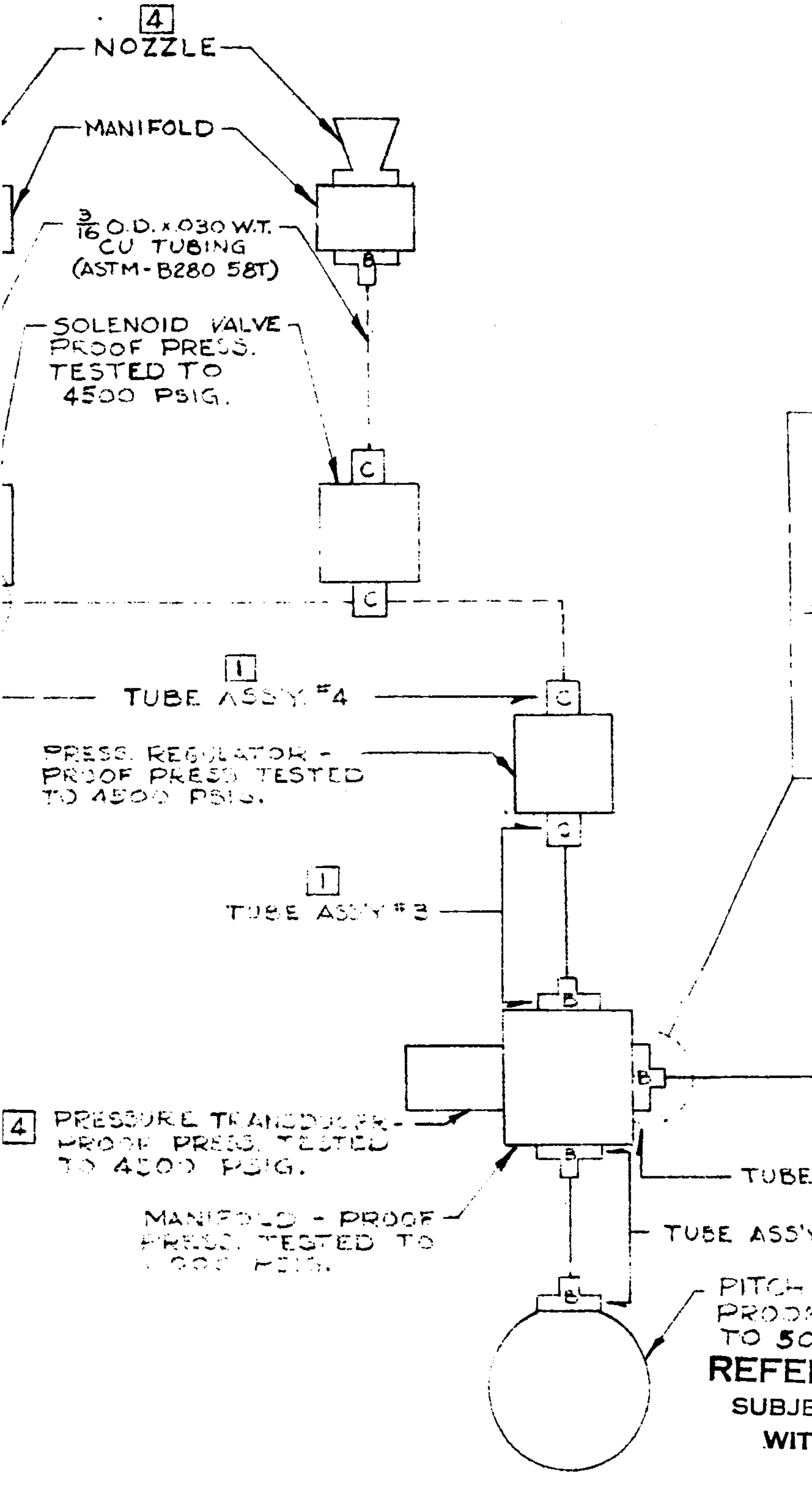
——- - -——- - -—— 60 PSI OPERATING PRESS.



TUBE FITTING-TYPE "C"

TYP. 13 PLACES




4
NOZZLE
MANIFOLD
3/16 O.D. x .030 W.T. CU TUBING (ASTM-B280 58T)
B
SOLENOID VALVE PROOF PRESS. TESTED TO 4500 PSIG.
C
C
1
TUBE ASS'Y #4
C
PRESS. REGULATOR - PROOF PRESS TESTED TO 4500 PSIG.
C
1
TUBE ASS'Y #3
B
B
4
PRESSURE TRANSDUCER - PROOF PRESS. TESTED TO 4500 PSIG.
B
MANIFOLD - PROOF PRESS. TESTED TO
TUBE
TUBE ASS'Y
B
PITCH
TO 5C
REFE
SUBJE
WIT

3-30

0

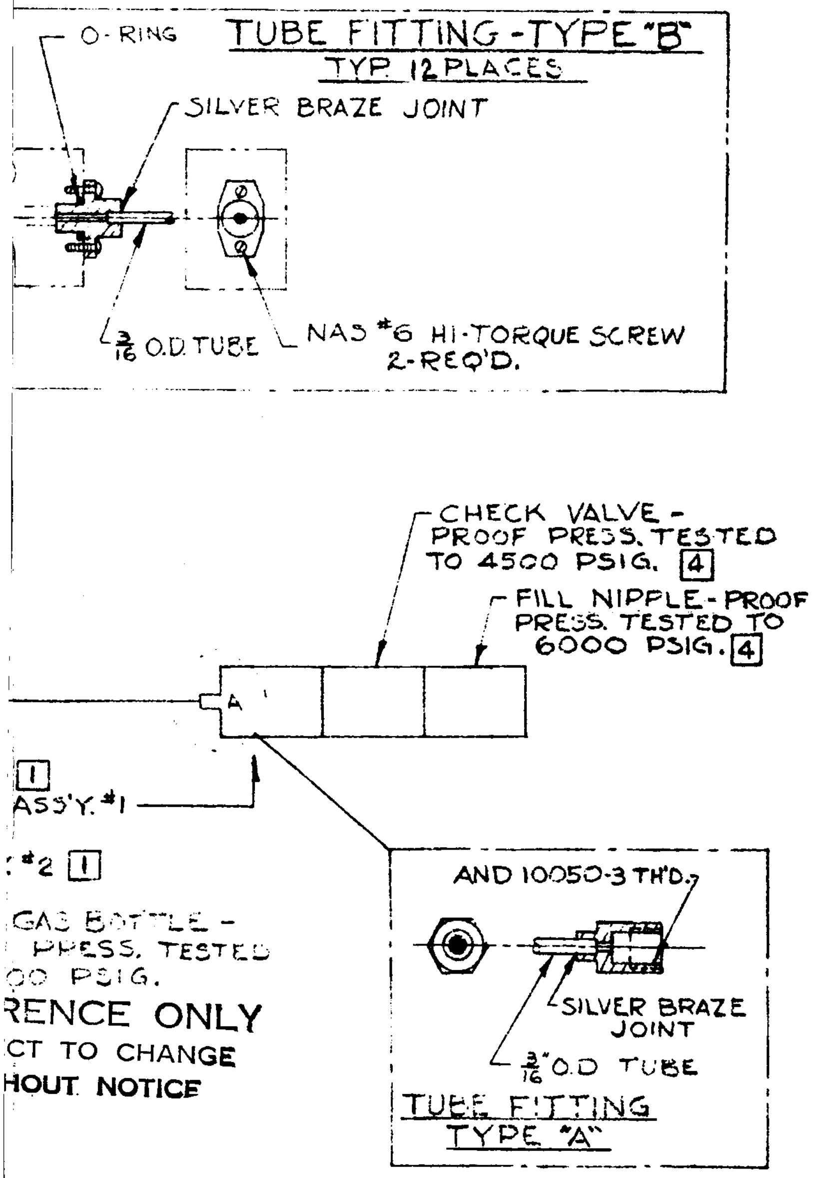


Figure 3-13–Pitch Pneumatic System

pitch angle. The command circuits provide a solenoid drive duration for approximately 10 seconds for each pitch command. The backup pitch control is locked out during the launch sequence.

3.4.2.1 Sensor, Pitch Readout

This assembly provides to the spacecraft data handling system a 0 to 5 volt signal proportional to the pitch angle. The pitch angle is defined as the angle between the spacecraft spin axis and the normal to the solar direction in the plane formed by the solar direction and the spacecraft spin axis. The pitch angle data are used to monitor the pitch control servo and in determining the spacecraft orientation. The output of the pitch readout sensor is monitored on channel 4 of ASC number 2.

The x, y, z coordinate system is fixed in the body of the assembly and is shown in Figure 3-14. The y axis is perpendicular to the axis of the cylindrical housing of the sensor and parallel to the line connecting the centers of the two holes on either side of the front aperture. The x axis is defined as the direction in this plane which results in an output of 2.5 volts from the sensor assembly when it is made to coincide with the X axis.

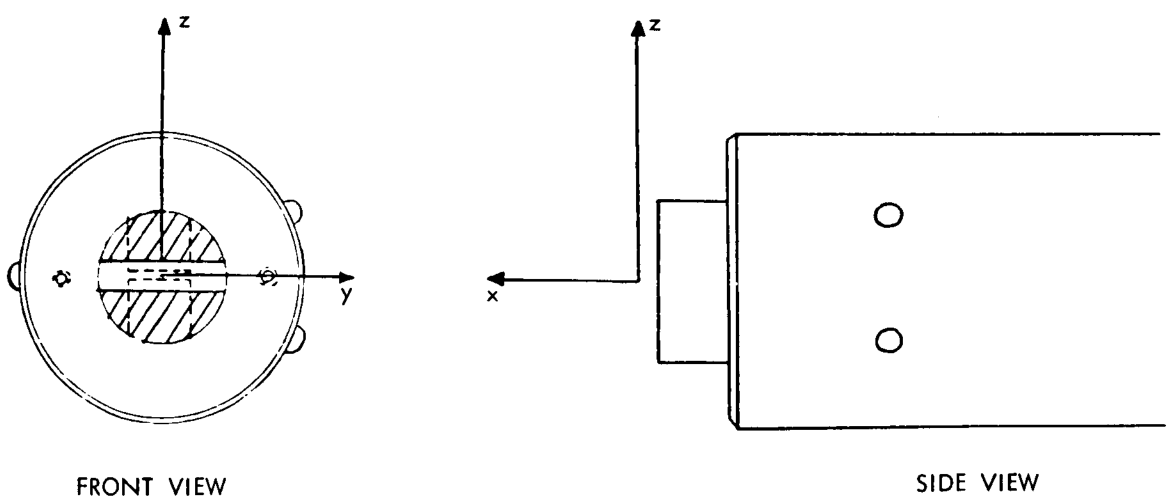


Figure 3-14–Pitch Angle Readout Axis Definition

The solar direction is defined as the line of sight from the position of the assembly to the center of the sun. The X axis is coincident with the solar direction and the Y axis is normal to it in the y-X plane. Note that the x, y, z coordinate system coincides with the X, Y, Z system whenever the assembly is oriented in the solar direction (see Figure 3-15).

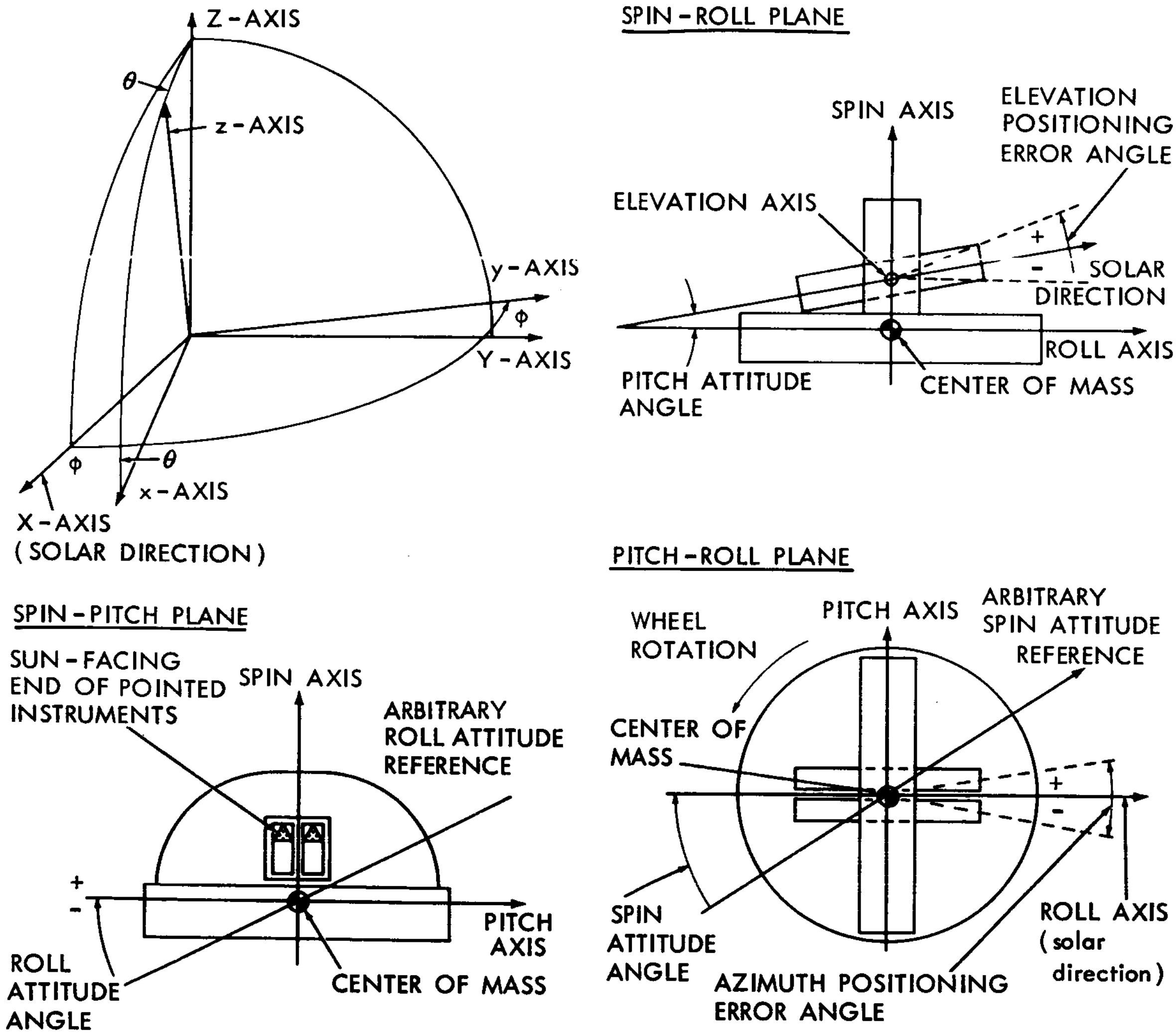


Figure 3-15—Coordinate Systems

The orientation of the x axis relative to the solar direction is given by an azimuth angle ϕ, and a pitch angle θ. Note that the pitch angle is negative for the sun above the x-y plane. The pitch angle response is the voltage output versus θ displacement with ϕ held constant. Assembly weight does not exceed 75 grams.

3.4.2.2 Electronics

If the automatic system continues to provide pitch error correction for 107 ±15 seconds, the lock out driver will turn on which will energize the auto-man relays, placing the system in the manual mode. An ASC number 2 sync pulse (Figure 3-11) is applied to a shaper through a buffer amplifier to the 3 stage flip-flop. This sync pulse is used as a timing pulse for the counter. When the pitch down or up solenoid is held at ground potential, through the auto pitch up or down driver, the flip-flop counter will also sense ground and start counting. After approximately 107 seconds, the flip-flop counter will turn on the lock out driver stage, which will energize the manual coil of the auto-man relays.

These relays may also be energized by a manual pitch command signal (number 73). This signal, as shown in the figure, is applied to the coil of the man-pitch relay. Energizing this relay applies 19v orbit power to the manual coils of the auto-man relays.

Figure 3-11 shows the command control functions of pitch backup operation. With backup control turned on, ground operations must command either pitch-down or pitch-up as required. An analog pitch error monitor measures the error angle and supplies a signal to telemetry. In response to a corrective command, a 10 second burst is generated. Here the decoder command pulses operate repeater relays, which then trigger 10 second electronic monostable multivibrator circuits. The monostable output signals control the pitch valves through the backup solenoid drivers. Pitch correction angle for each 10 second burst is about 0.6 degrees. The other two backup command inputs, as shown in Figure 3-11 are commands for changing the pitch control mode to either backup or automatic operation. These commands also operate through repeater relays, which in turn control the auto-backup latching relay.

3.4.2.3 Pneumatics

Refer to automatic pitch control (paragraph 3.4.1.3) for description of pneumatics.

3.5 POINTING CONTROL SYSTEM

The servo control for orienting the instruments to the sun operates about 2 orthogonal axes; azimuth and elevation. The two servo systems are independent of one another but are nearly identical. The azimuth servo system is more complicated because of the large acquisition angles required. It operates about the spin axis of the spacecraft, and is used to hold the sail fixed in space by driving against the rotating wheel. The elevation servo has only to rotate the instruments a few degrees in a plane containing the solar vector and the spin axis.

3.5.1 Sensors

All the sensors in the pointing control system are located on two different assemblies; the fine control sensor assembly and the fine readout sensor assembly. Both assemblies are the same except the fine control sensor assembly has an additional sensor called a target sensor.

3.5.1.1 Fine Control Sensors

The four fine sensors (eyes) for both elevation and azimuth are mounted directly on a pointed instrument (Figure 3-16). Fine eye detectors provide the final servo control of the instruments pointed at the sun. They operate as null devices. Two eyes are required to control a single axis of freedom. Figure 3-17 shows the angular characteristics of the fine eye. Pointing accuracy of the fine eye control system is better than ±1 minute of arc in elevation and azimuth. The combined field of view of an eye pair is a cone of half angle 10 degrees. If the conical field is cut by a plane passing through the axis of symmetry, the resulting half cones correspond to the field of view of the individual eyes. In practice the half cones are slightly lapped or toed-in in order to linearize the response of the pair through the zero position. (See Figures 3-17 and 3-18.)

The major components of this detector are: an objective lens, reticle, filter, back aperture and silicon cell detector. The objective lens is a plano-convex lens with a back focal distance of 0.320 inch. Its purpose is to image the sun's disc on the surface of the reticle.

The reticle is vacuum deposited on the front surface of a glass filter disc. It is in the form of a knife edge, the region to one side of the edge being opaque.

The deep red filter is used so the pass-band accepted by the detector falls in a natural window in the atmosphere. The cutoff point of this filter on the low side is approximately 0.60 micron, below which there is severe atmospheric attenuation. The filter, therefore, allows ground tests of servo systems to establish loop gains that will hold true during operation outside of the atmosphere.

The back aperture controls the output from errors between 1 degree and 10 degrees in such a way that a sharp drop-off at the outer edge of the field is avoided.

The lens and reticle are staked into the same piece of metal, therefore no possible shifting can occur as a result of vibration. The cylindrical tube mount of the objective lens is designed so it can be deformed by a special adjusting tool to achieve a bore sight adjustment of the detector. In these eyes, 0.0001 inch movements of the lens corresponds to a minute of angle so that the importance of a fixed alignment between objective lens and reticle is apparent.

3.5.1.2 Target Eye

The target eye, mounted on the fine control sensor assembly (Figure 3-16) is the same eye described in the azimuth control system. When the sail is oriented within 5 degrees of the solar vector, the target eye generates a signal to actuate the on-target relay which switches the azimuth control mode from the coarse eye output to the fine eye output.

3.5.1.3 Readout Sensors

This assembly (Figure 3-20) consists of two detector pairs. The detector pairs provide azimuth and elevation currents proportional to the angular displacement of the normal to the mounting surface from the line to the center of the sun. The operation of these sensors is the same as the fine control sensors described in paragraph 3.5.1.1.

The readout sensor assembly is mounted on an OSO pointed experiment. The experimenter provides three mounting surfaces in the same plane to accept the three mounting surfaces in the same plane to accept the three mounting pads of the sensor assembly. The three mounting pads of the sensor are also in a plane. Ideally, the plane provided by the experimenter is parallel to the elevation gimbal axis and to the spacecraft spin-axis with the instrument at zero elevation angle. The experimenter also provides an electrical connector which mates with the connector on the fine readout sensor assembly.

3.5.2 Electronics

Error signals produced by the fine eyes are sent to the fine preamplifiers and then through appropriate lead networks for stabilization. The error signal is chopped by a solid-state chopper at 2 kc, amplified in a carrier amplifier and demodulated by a solid-state demodulator. The amplifier then feeds the pulse width modulator, which converts the dc error signal to a pulse train in which the pulse width is proportional to the amplitude of the error signal. The repetition rate of the pulse width modulator is about 1,000 pulses per second.

prevents the current from flowing through the cell so the current must flow through the preamplifier. The input impedance of the preamplifier must be low enough so the eye current flowing into it does not cause a large enough potential to make the dark cell conduct. It must also be low enough so it looks like a short circuit to the illuminated cell. Both these requirements are met if the input voltage is held to 100 millivolts, or less. The maximum eye current is about 1.2 milliamps for a fully illuminated eye so the input impedance must be kept to about 80 ohms. This is done by a grounded base preamplifier. By making the preamplifier a differential amplifier, common mode rejection is gained for both pickup on the input leads and power supply variations.

A schematic of the preamplifier is shown in Figure 3-21. The bases of the input transistors are clamped to a fixed potential by the emitter current of a third transistor, so that the voltage at the emitters of the input transistors is held constant by the base emitter voltage. The quiescent current flowing through each input transistor at null (when no light current is flowing from the eyes), is slightly greater than the maximum current delivered by the photo cells. There is a differential output between the collectors of the input transistors. This output is then sent to the chopper and ac amplifier.

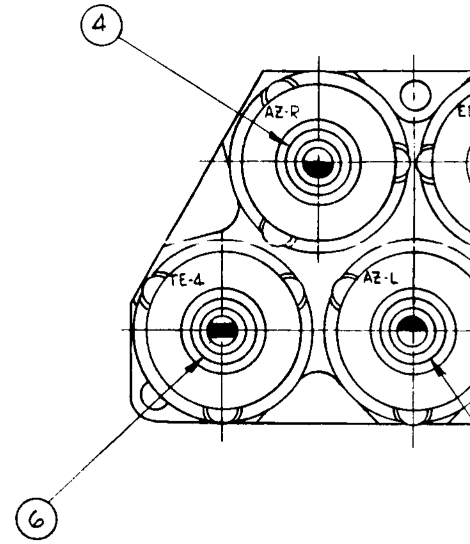
The azimuth coarse and fine preamplifiers are identical except for different value components needed by differing coarse and fine eye currents and differing lead networks parameters.

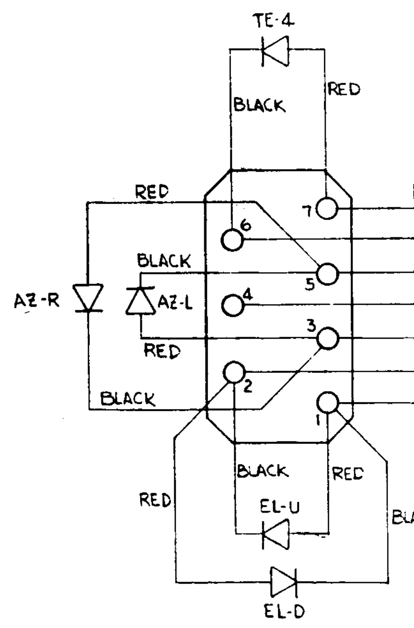
3.5.2.2 AC Amplifier Circuit

The differential error signal from the preamplifier is sent through a compensation network to a solid state modulator which converts the error signal to a 2 kc square wave whose amplitude is proportional to the error signal and whose phase is shifted either 0 degree of 180 degrees with respect to the modulator drive depending on the sense of the error signal. This square wave is amplified in a conventional ac amplifier and then demodulated and filtered back to dc.

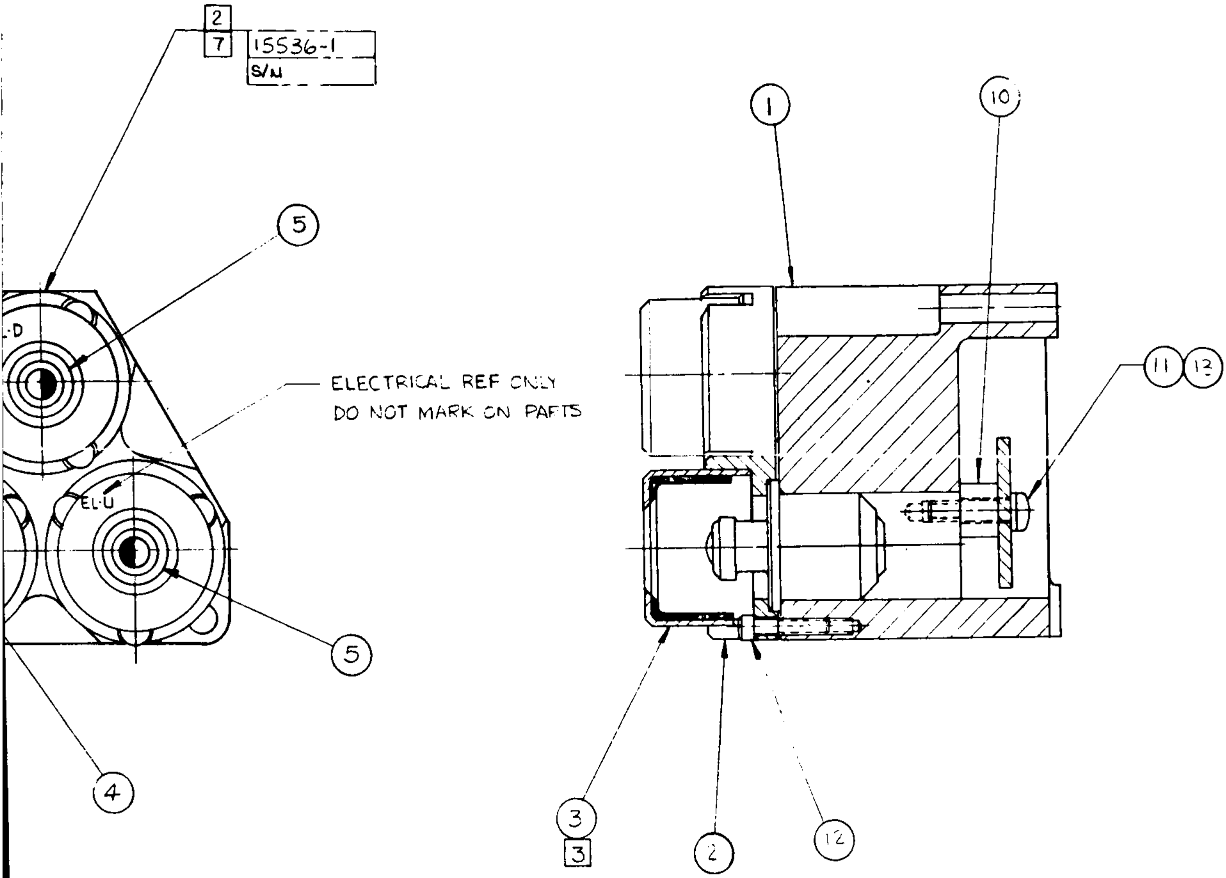
The demodulator is biased so that the output for a zero error signal is 7.5 volts, half-way down from the 15-volt regulated power supply. This is so a symmetrical swing can be obtained in either direction at the output. This swing about 7.5 volts is necessary to drive the pulse width modulator.

The gain of the ac amplifier can be adjusted from 50 to 300 depending on the servo gain required.



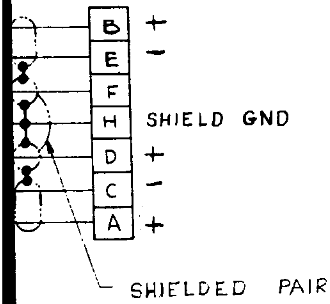


WIRING DIAGRAM



.06 GAP
POTTI...

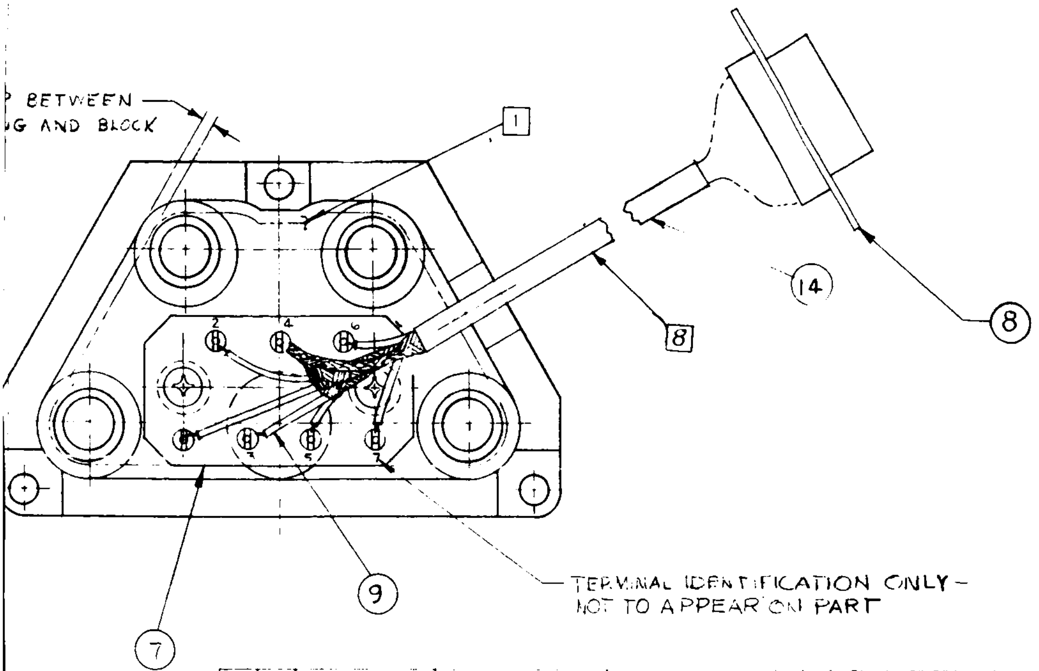
CONNECTOR PIN DESIGNATION



...CK

GEN. NOTES UNLESS OTHERWISE SPECIFIED:

1. [1] POTTING PER BPS 12.00
2. [2] MARK PER BPS 19.00-1-12
3. [3] BOND ITEM 3 IN ITEM 2 PER BPS 11.00
4. DO NOT PAINT EYE LENSES AND MOUNTING PADS
5. SOLDER TERMINALS PER BPS 2.00
6. SOLDER CONNECTORS PER BPS 2.10; SOLDER TERMINALS PER BPS 2.00
7. [7] SERIALIZE PER TEST SPEC A18959
8. [8] LENGTH OF LEADS TO BE DETERMINED AT INSTALLATION & ENGINEERING NOTIFIED
9. WIRING PER BPS 4.00
10. (A) TEST PER A16686 AND A18810



	-1	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL DESCRIPTION / REFERENCE DESIGNATION-ELEC DWG.	MATERIAL SPECIFICATION	ITEM NO
	AS REQ		FLEXIBLE TUBING	8		MIL-I-22129	14
	2	NAS620A4L	WASHER				13
	15	NAS1531-01-6	SCREW				12
	2	MS35216-15	SCREW				11
	1	NAS42DD4-12	SPACER				10
(A)	AS REQ	2C6E-22-00-09-STJ-09	WIRE	8 INSO ELECTRONIC PRODUCTS INC. NUTLEY, NEW JERSEY			9
	1	DEM-9S-NMB1A115	CONNECTOR	CINCH MFG. CO. CHICAGO 24, ILL.			8
	1	C15534-1	TERM BD ASSY				7
	1	C15929-501	SENSOR ASSY				6
	2	C7066-511	SENSOR ASSY				5
	2	C7066-509	SENSOR ASSY				4
	5	C17910	COVER				3
	5	C5333-3	RETAINER				2
	1	D15532	BLOCK				1

QUANTITY REQ'D PER ASSEMBLY — ODD DASH NUMBERS SHOWN — LIST OF MATERIAL — EVEN DASH NUMBERS OPPOSITE

Figure 3-16–Fine Control Sensors

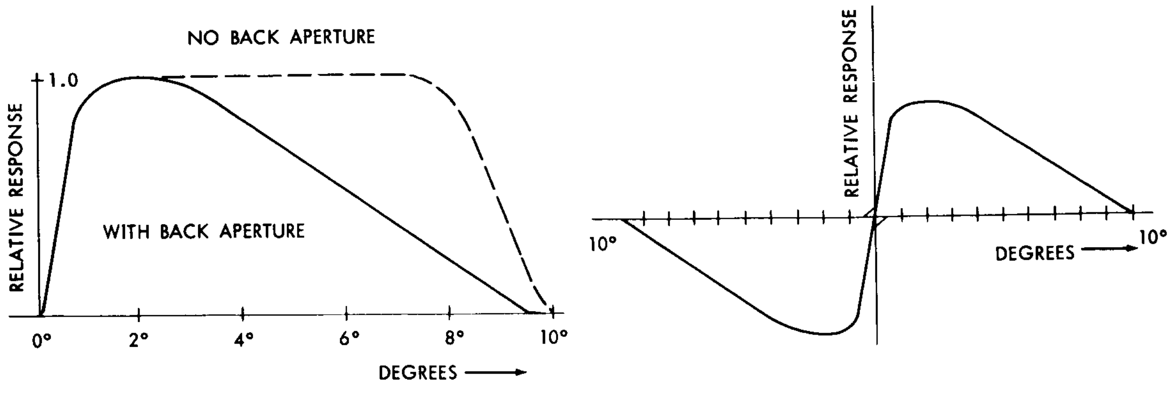


Figure 3-17—Fine Eye Response

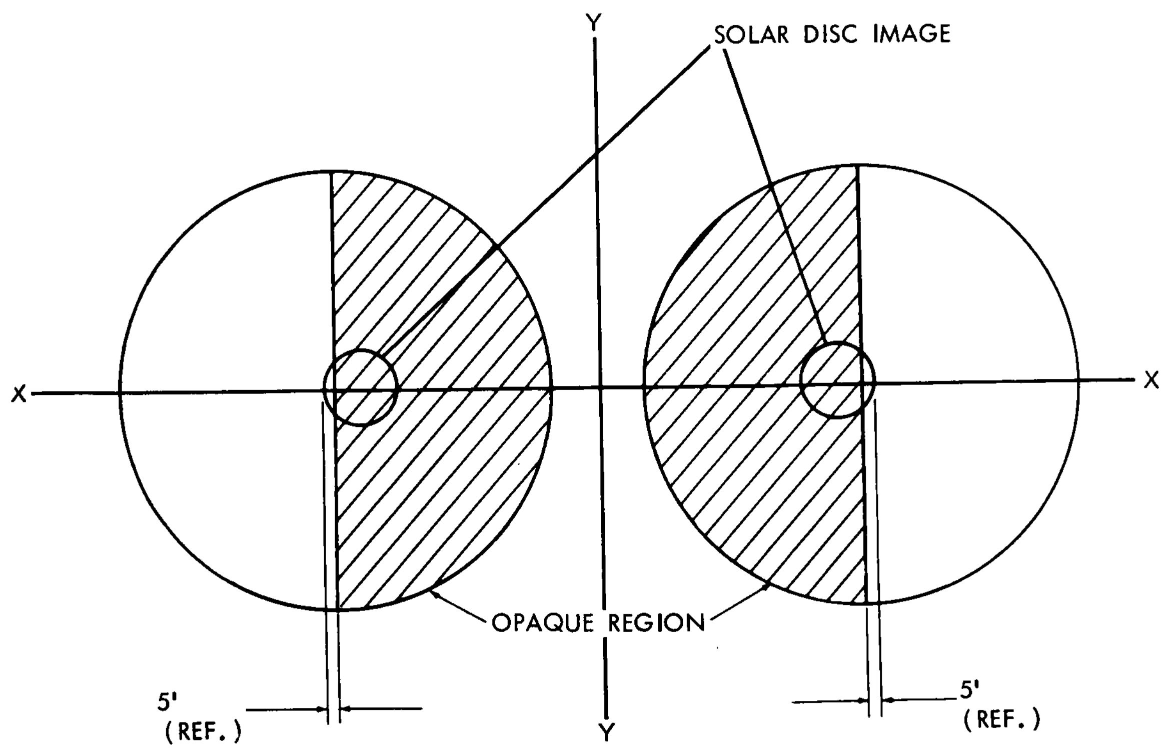


Figure 3-18—Fine Eye Pair-Image Position in On-Target Condition

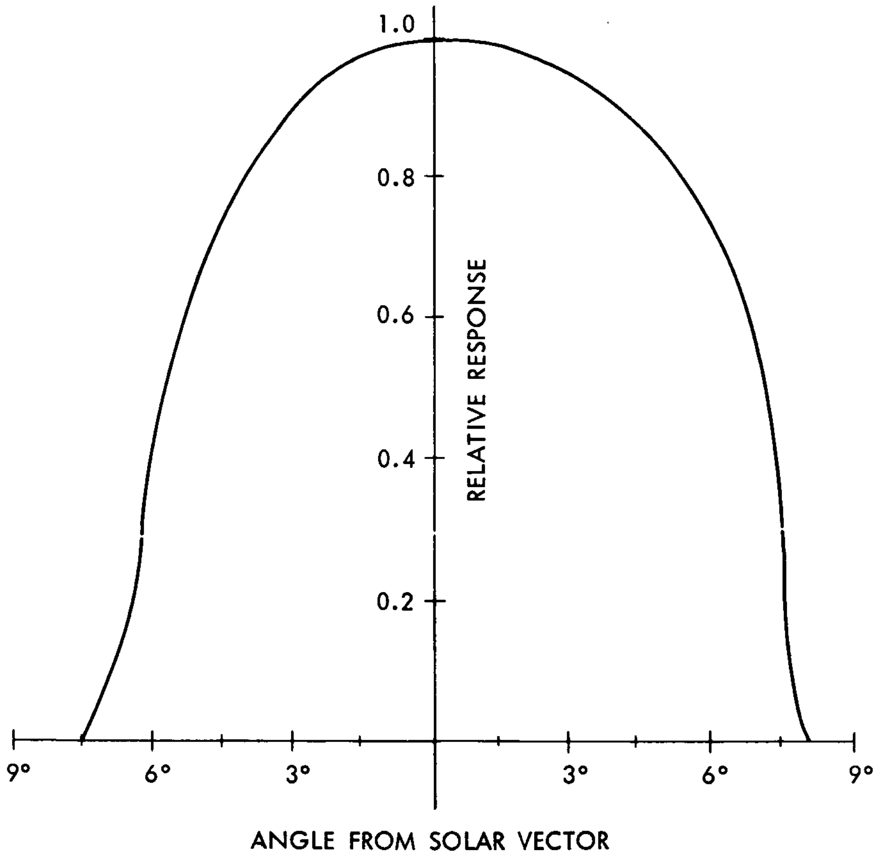


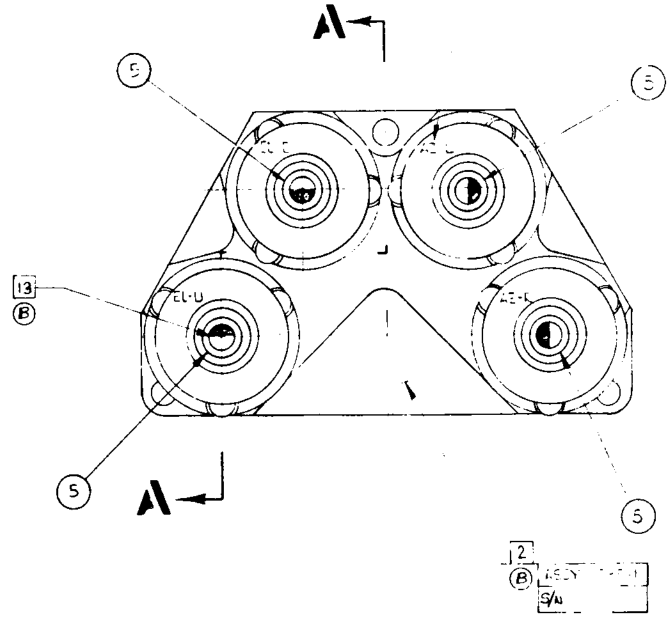
Figure 3-19—Angular Characteristics of Target Eye

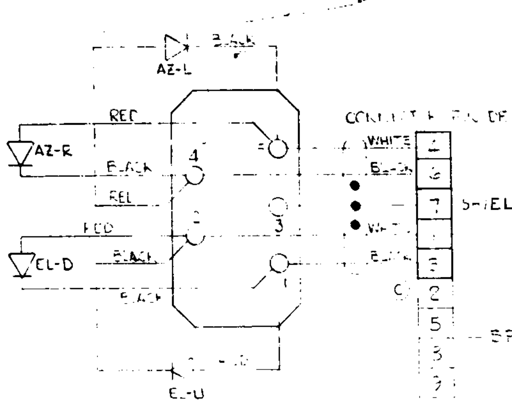
The pulse width signal drives a power amplifier and transistor switch which, in turn, feeds the motor. The transistors in the bridge are either saturated or cut off by the pulse width signal so that very little power is dissipated in the switch.

The motive element is a dc torque motor using a permanent magnet field. This type of motor delivers large torques directly to an output shaft at low speeds, which is the condition that we have in the spacecraft.

3.5.2.1 Preamplifier

The silicon photo cells of an eye pair are electrically connected in parallel and with opposed polarity. When the one eye is illuminated and the other eye is dark, the current generated by the illuminated cell flows through the cell in the backward diode direction. The forward diode characteristic of the dark cell





WIRING DIAGRAM

(B) [12] BOND ITEM 5 TO ITEM 1 PER BPS ... TO LEVEL SHOWN

(B) [13] SHADED AREA REPRESENTS ALUMINIZED PORTION OF RETICLE

GEN. NOTES UNLESS OTHERWISE SPECIFIED:

(B) [1] POTTING PER BPS 9.02

(B) [2] MARK PER BPS 19.00-12-10

[3] BOND ITEM 3 IN ITEM 2 PER BPS 11.00

6. SOLDER CONNECTORS PER BPS 2.10

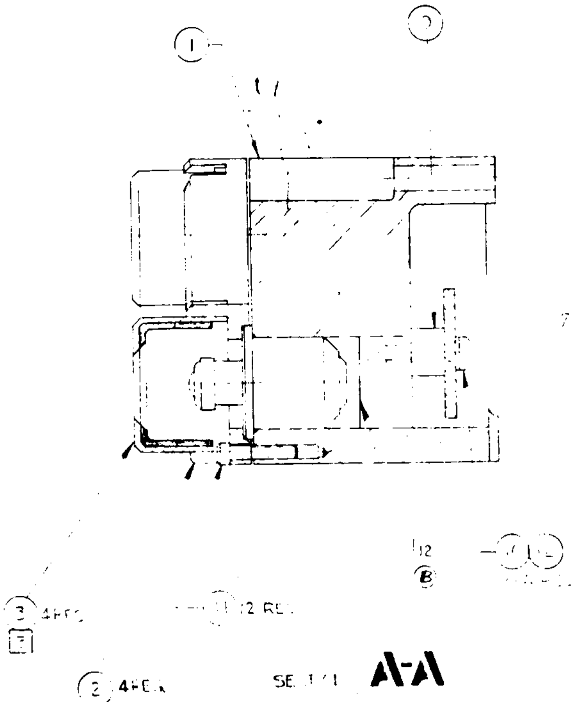
(B) 7. MODEL SPEC A16689

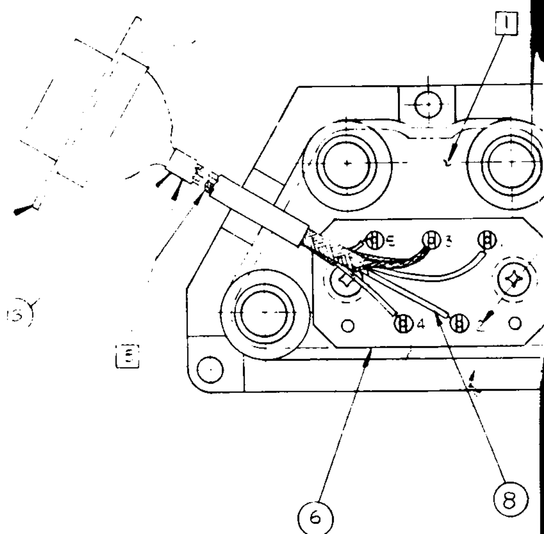
[8] LENGTH OF LEADS & FLEXIBLE TUBING TO BE DETERM... INSTALLATION & ENGINEERING NOTIFIED.

9. WIRE MARK PER BPS 4.00

10. SOLDER TERMINALS PER BPS 2.00

(B) (A) 11. TEST PER A18610





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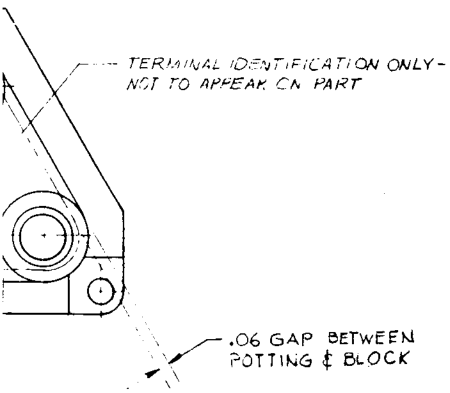

	QUANTITY REQ'D PER ASSEMBLY -1	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL DESCRIPTION / REFERENCE DESIGNATION-ELEC DWG.	MATERIAL SPECIFICATION	ITEM NO.
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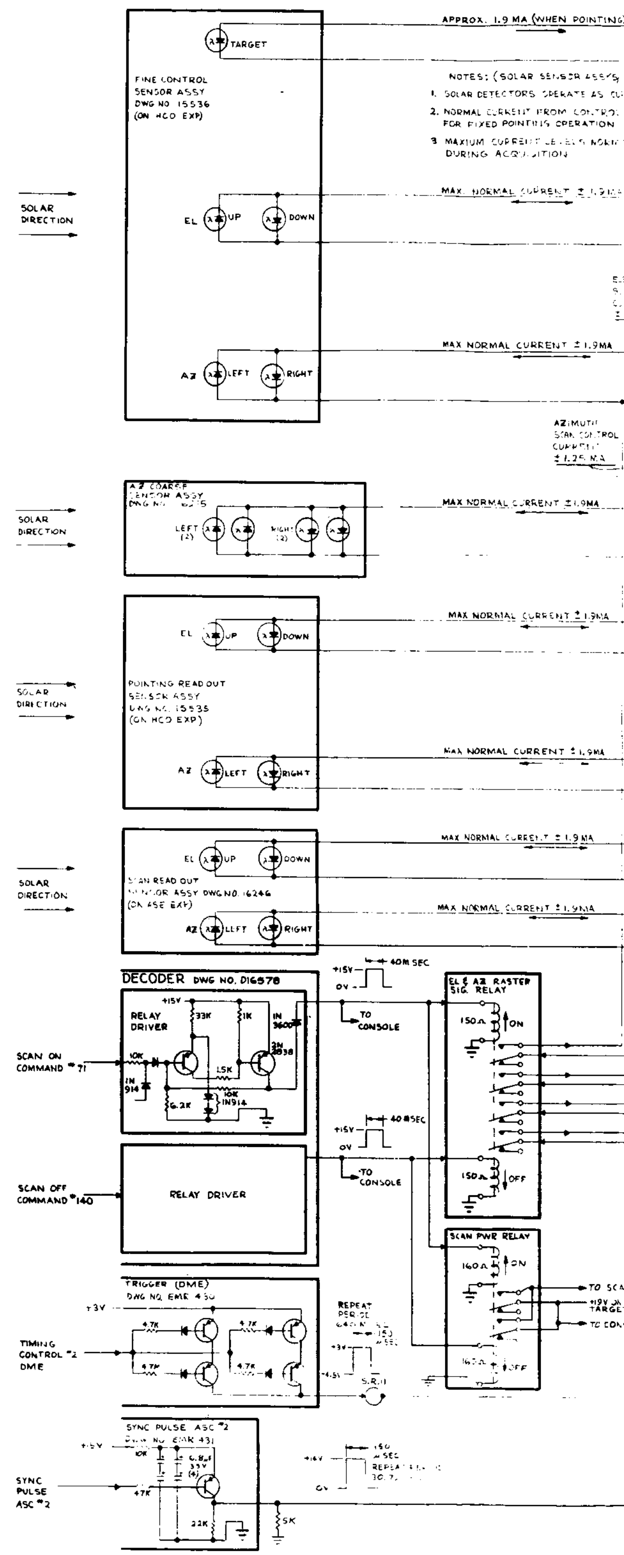
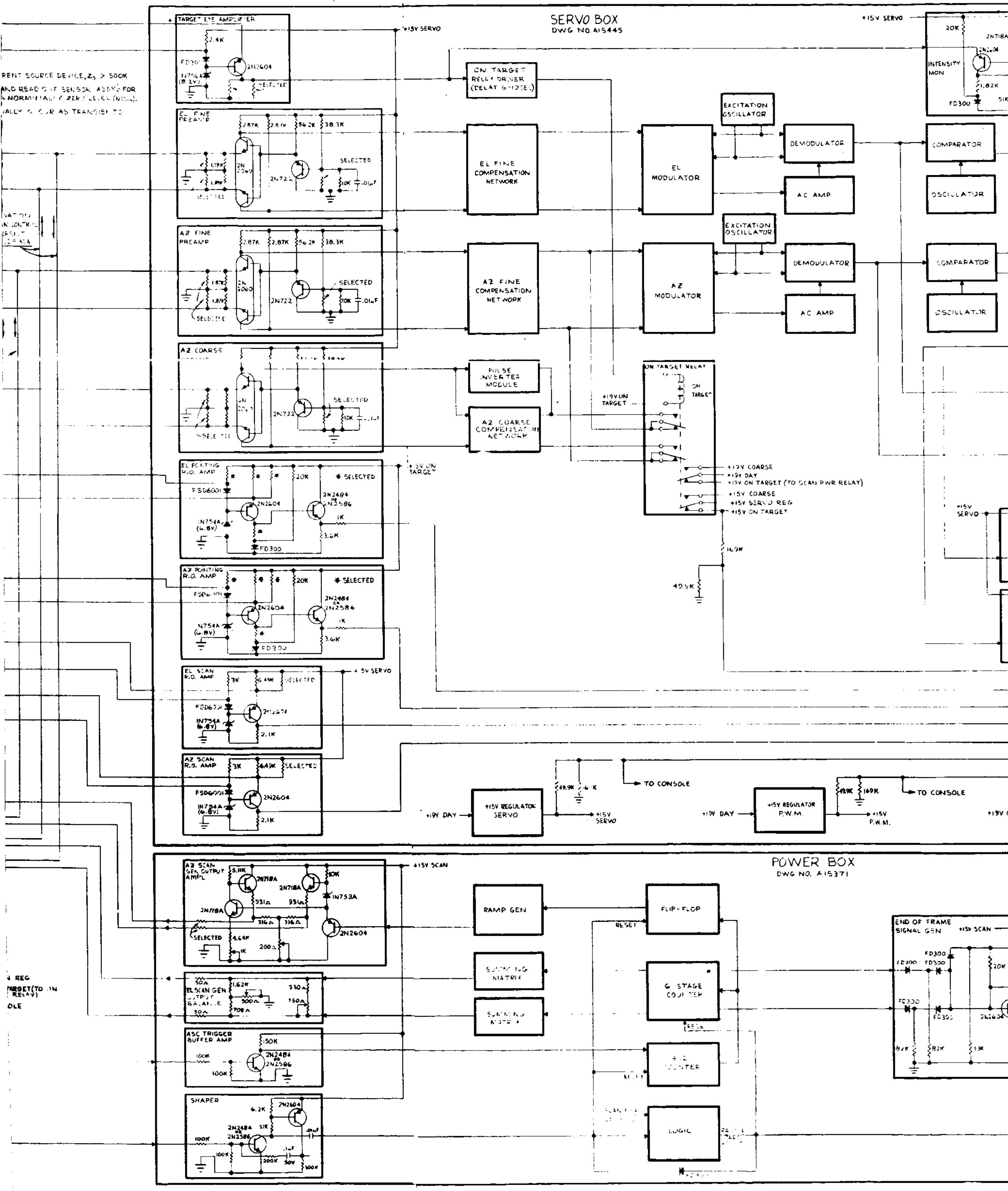
	2	[illegible]DA4L	WASHER				12
	12	NAS1351C-01-6	SCREW				11
	2	MS35[illegible]-15	SCREW				10
	2	NAS42DD4-12	SPACER				9
(B) (1)	AS REQ	A9730-3099	WIRE	[8]			8
(B)	1	SP0030-2	CONNECTOR				7
	1	15534-5[illegible]	[illegible]				6
(B)	4	[illegible]-511	DETECTOR ASSY F106				5
							4
	4	[illegible]	[illegible]				3
	4	[illegible]	RETAINER				2
	1	[illegible]	[illegible]				1

QUANTITY REQ'D PER ASSEMBLY — ODD DASH NUMBERS SHOWN — LIST OF MATERIAL — EVEN DASH NUMBERS OPPOSITE

Figure 3-20–Readout Sensors


APPROX. 1.9 MA (WHEN POINTING
TARGET
FINE CONTROL
SENSOR ASSY
DWG NO. 15536
(ON HCO EXP)
NOTES: (SOLAR SENSOR ASSYS
1. SOLAR DETECTORS OPERATE AS
2. NORMAL CURRENT FROM CONTROL
FOR FIXED POINTING OPERATION
3. MAXIMUM CURRENT LEVELS NORM
DURING ACQUISITION
SOLAR
DIRECTION
EL
UP
DOWN
MAX NORMAL CURRENT ± 1.9MA
AZ
LEFT
RIGHT
AZIMUTH
SCAN CONTROL
± 1.25 MA
AZ COARSE
SENSOR ASSY
MAX NORMAL CURRENT ± 1.9MA
POINTING READ OUT
SENSOR ASSY
DWG NO. 15535
(ON HCO EXP)
MAX NORMAL CURRENT ± 1.9MA
SCAN READ OUT
SENSOR ASSY DWG NO. 16246
(ON ASE EXP)
DECODER DWG NO. D16578
RELAY
DRIVER
+15V
33K
1K
10K
1.5K
6.2K
IN914
2N3838
SCAN ON
COMMAND #71
40M SEC
TO
CONSOLE
EL & AZ RASTER
SIG. RELAY
150Ω
ON
OFF
SCAN OFF
COMMAND #140
RELAY DRIVER
SCAN PWR RELAY
160Ω
TRIGGER (DME)
DWG NO. EMR 430
+3V
4.7K
TIMING
CONTROL #2
DME
REPEAT
PERIOD
TO CON
SYNC PULSE ASC #2
47K
22K
5K
SYNC
PULSE
ASC #2
+15V
0V

3-43, 1



SERVO BOX
DWG NO. A15445
TARGET EYE AMPLIFIER
+15V SERVO
ON TARGET RELAY DRIVER (DELAY 6-10 SEC)
EL FINE PREAMP
EL FINE COMPENSATION NETWORK
EXCITATION OSCILLATOR
EL MODULATOR
DEMODULATOR
AC AMP
COMPARATOR
OSCILLATOR
INTENSITY MON
AZ FINE PREAMP
AZ FINE COMPENSATION NETWORK
AZ MODULATOR
AZ COARSE
PULSE INVERTER MODULE
AZ COARSE COMPENSATION NETWORK
ON TARGET RELAY
+19V ON TARGET
EL POINTING R.O. AMP
AZ POINTING R.O. AMP
* SELECTED
+19V COARSE
+19V DAY
+19V ON TARGET (TO SCAN PWR RELAY)
+15V COARSE
+15V SERVO REG
+15V ON TARGET
EL SCAN R.O. AMP
AZ SCAN R.O. AMP
TO CONSOLE
+15V REGULATOR SERVO
+15V REGULATOR P.W.M.
+19V DAY
POWER BOX
DWG NO. A15371
AZ SCAN GEN OUTPUT AMPL
+15V SCAN
RAMP GEN
FLIP-FLOP
RESET
SUMMING MATRIX
6 STAGE COUNTER
EL SCAN GEN OUTPUT BALANCE
ASC TRIGGER BUFFER AMP
SHAPER
LOGIC
END OF FRAME SIGNAL GEN

3-43, 2

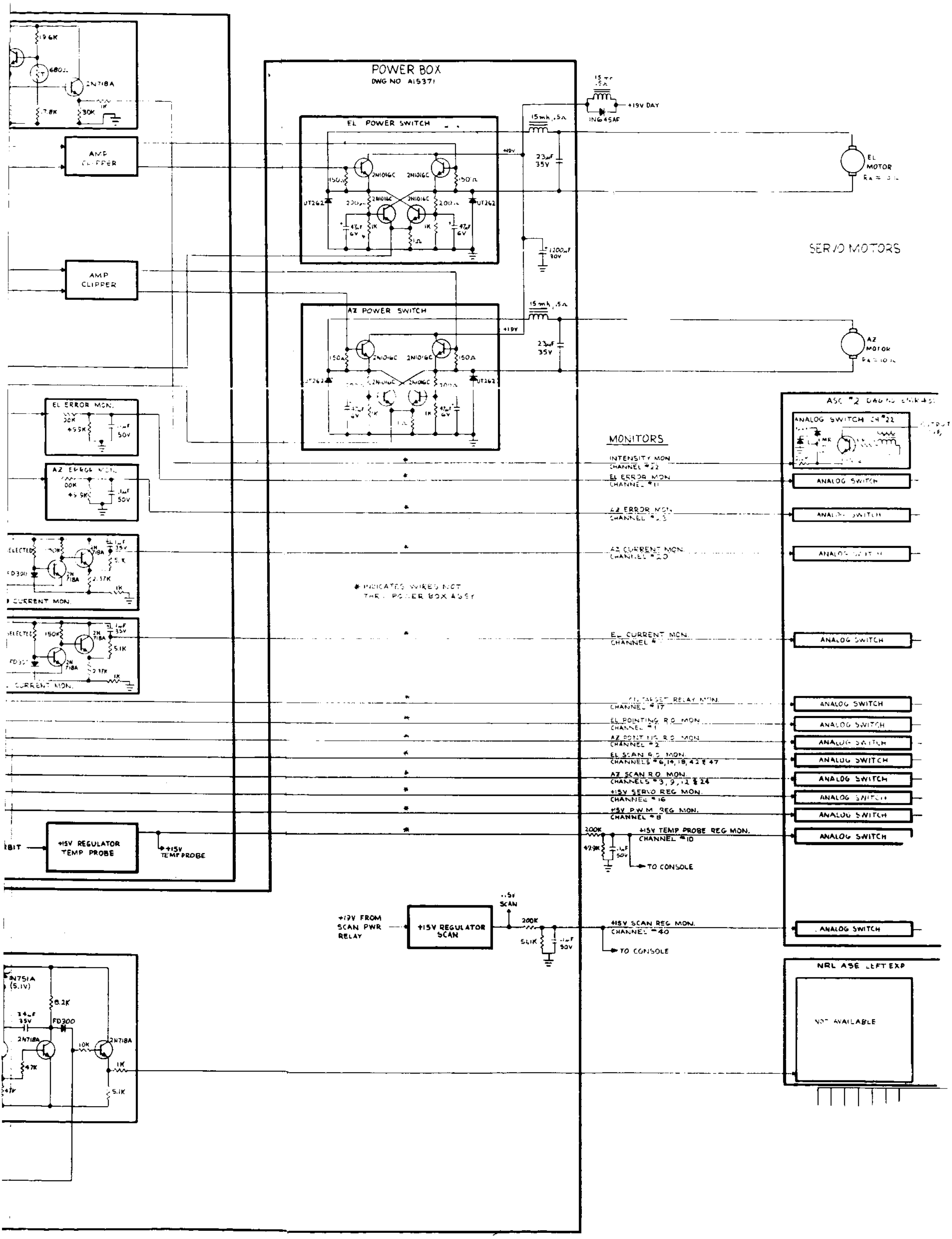


Figure 3-21—Pointing and Scanning Control System Diagram

3.5.2.3 Pulse Width Modulator

The servo drive motors are driven by a pulse width modulated signal; that is, a pulse whose width is directly proportional to the amount of drive. This results in a highly efficient use of the motor power, since almost no power is dissipated in the control transistors, which act only as switches.

The pulse width modulators convert the dc error voltages to a constant amplitude pulse having a duration proportional to the error voltages. The repetition rate of the pulses from the modulators are approximately 1,000 pps. These pulses from the modulators are used to drive power switch circuits which in turn drive the azimuth and elevation torque motors. The modulator consists of a comparator, oscillator, and amplitude clipper.

3.5.2.4 Power Switch

Up to this point the current requirements of the circuits discussed have been measured in milliamps. However, the drive motors require approximately 1.5 amperes to deliver the necessary torque. The power amplifier delivers this current.

The motive element is a dc torquer with a permanent magnet field. This motor is a 2-terminal device which requires that the current through the winding be reversed to reverse the direction of rotation. For this reason, a switch arrangement must be used to drive the motor since only one polarity power supply is available. The switch uses power transistors as the control elements.

The pulses from the pulse width modulator are in the form of a string of positive pulses whose width is proportional to the error signal. The positive pulses are fed directly to the base of the trigger transistor, switching it on for the duration of the pulse. The pulses are of sufficient amplitude and from a low enough source impedance to cause saturation. The outputs from the trigger transistors will place the multivibrator in the proper state for either clockwise or counterclockwise rotation of the servo motor. Both conducting transistors have low impedances compared to the motor, so most of the energy is dissipated in the motor. The capacitor across the motor helps in lowering the inductive spike developed when the current through the motor is abruptly cut-off at the end of the pulse.

3.5.2.5 Readout Amplifiers

The high gain readout amplifiers produce voltages proportional to the azimuth and elevation pointing angles.

Sensor output current provides the base-emitter bias to the input transistor in the amplifier. The base of the transistor is clamped by a 6.8 volt zener diode. The base resistor is selected for the proper temperature compensation; the emitter resistor for 2.5 volts output with no input; and the collector resistor is selected for the required gain (20 mv/ua). Proper impedance matching of the amplifier to ASC number 2 is accomplished by an emitter follower output stage. Power supply voltage for these stages is the 15 volts target on supply. The output of the elevation amplifier is applied to channel 1 of ASC number 2, and the aximuth amplifier output is applied to channel 2.

3.5.3 Torque Motors

Both spacecraft servos use dc torque motors as driving elements. These large diameter pancake motors deliver large torques directly to the output shaft without the use of gears. The azimuth motor is capable of applying 1.8 pound-feet to torque and the elevation motor 0.9 pound-foot of torque directly to the shafts. Since the motors and drive system are directly exposed to vacuum, the elimination of gears is very important.

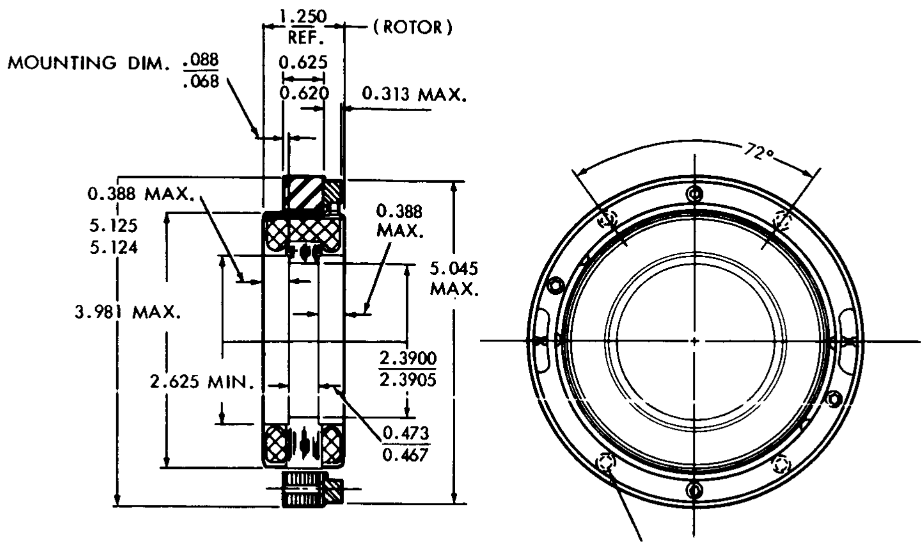
A serious problem with this type of motor lies in the use of brushes exposed to vacuum. However, by treating the brushes with a special lubricant, these motors are run for several times the expected number of revolutions in a vacuum of 2×10^{-8} millimeters of mercury with negligible brush wear.

The back emf of the motor is small, since it is operated at low speeds causing a negligible velocity error. It also contributes a negligible velocity error. It also contributes a negligible amount of damping to the servo.

Figure 3-22 shows a diagram and a typical operating curve for the Type T-4006 torque motor, (manufactured by Inland Motor Corporation of Virginia), which is employed in the azimuth servo system. Figure 3-23 gives all the structural characteristics and Table 3-1 the performance characteristics of the elevation torque motor which is a Type T-2907-B also manufactured by Inland Motor Corporation of Virginia, a subsidiary of Kollmorgen Corporation, Northampton, Massachusetts.

TYPE T-4006

1.8 LB.-FT. TORQUE MOTOR DATA SHEET



DESCRIPTION

This is a frameless torquer which requires that the mounting and bearings be considered separately. The mounting of the field or outer member is done against the face opposite the brush holder and is piloted on the O.D. Securing to the mating member is done by inserting four No. 6-32 flathead screws through the holes in the field intended for that purpose. A suggested mating diameter is 5.1255/5.1260. The brush life on this unit should exceed ten million revolutions. The fields are shipped with keepers which must not be removed until rotor is in place. Jack screw holes are provided for this removal.

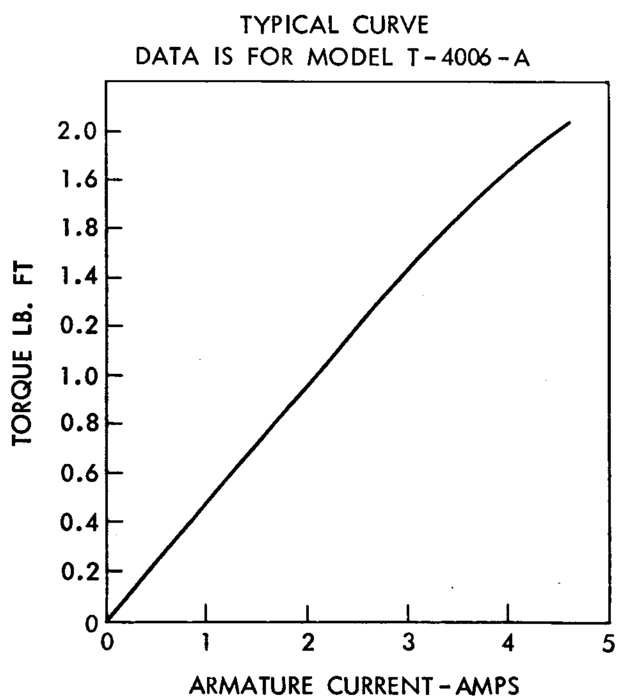
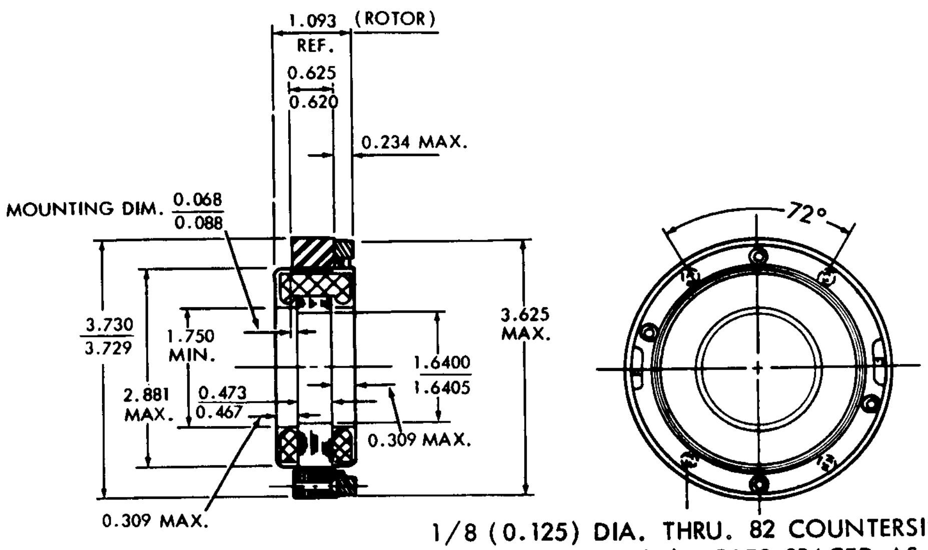


Figure 3-22–Azimuth Torque Motor

TYPE T-2907

1.8 LB.-FT. TORQUE MOTOR DATA SHEET



1/8 (0.125) DIA. THRU. 82 COUNTERSINK TO 230 MON. DIA. (4) HOLES SPACED AS CH SHOWN ON 3.468 B.C.

DESCRIPTION

This is a frameless torquer which requires that the mounting and bearings be considered separately. The field or outer member is mounted on the face opposite the brush holder as shown in the engineering drawing. The field is piloted on the O.D. and is held to the mating member by using the through holes provided for four No. 4-40 flathead screws. A suggested mating pilot diameter is 3.7303/3.7308. The brush life on this unit should exceed ten million revolutions. The fields are shipped with keepers which must not be removed until rotor is in place. Jack screw holes are provided for this removal.

TYPICAL CURVE

DATA IS FOR MODEL T-2907-B

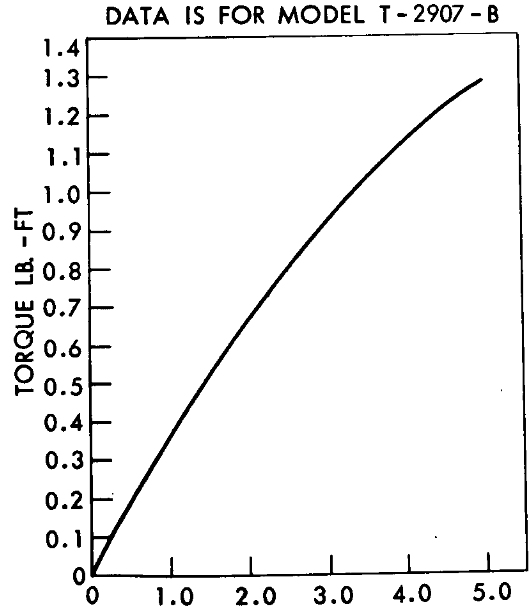


Figure 3-23—Elevation Torque Motor

Table 3-1
Torque Motor Ratings

Characteristics	Model Number T-4006-C	Model Number T-2907-B
Peak torque, pound-feet	1.8	0.85
Volts at peak torque, stalled at 25°C	32.7	28.7
Back EMF, volts/rad/sec	0.81	0.42
Amps at peak torque	3.0	2.73
Sensitivity, pound-feet per amp	0.60	0.31
D-C resistance at 25°C, ohm	10.90	10.50
Self Inductance, Henrys	0.021	0.016
Temperature rise per watt, ultimate, °C	1.60	2.90
Maximum permissible winding temperature, °C	105.0	105.0
Total friction, pound-feet	0.035	0.013
Viscous damping, pound-feet/rad/sec		
Zero impedance source	0.045	0.014
Infinite impedance source	0.001	0.0005
Ripple torque, pound-feet		
At low torque levels	0	0
At peak rated torque	0.12	0.10
Rotor inertia, pound-feet sec^2	7.6×10^{-4}	2.1×10^{-4}
Weight, pounds	3	1-1/2

All ratings are nominal values

3.6 SCANNING CONTROL SYSTEM

Provisions have been made to control the oriented instruments in a scanning mode. This scan mode sweeps the oriented compartment in such a way that the entire solar disc and portions of the solar corona can be mapped by the experimental instruments. The scanning control system is controlled by command from the ground.

3.6.1 Sensors, Readout

This assembly (Figure 3-24) consists of two detector pairs. The detector pairs provide azimuth and elevation error currents proportional to the angular displacement of the normal to the mounting surface from the line to the center of the sun.

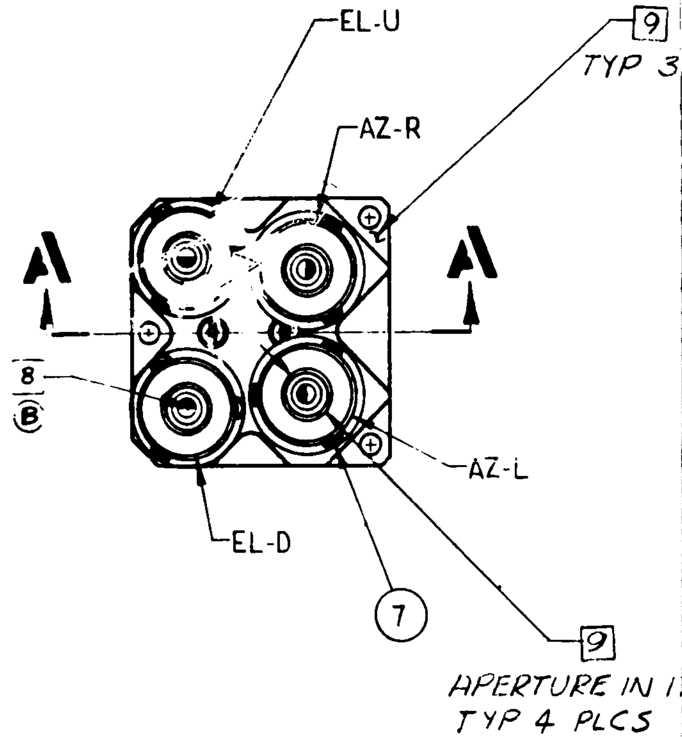
The sensor assembly is mounted on a pointed experiment. The experimenter provides three mounting surfaces in the same plane to accept the three mounting pads of the sensor assembly. The three mounting pads of the sensor assembly are also in a plane. Ideally, the plane provided is parallel to the elevation gimbal axis and to the spacecraft spin-axis with the instrument at zero elevation angle. Refer to paragraph 3.5.1.1 for an explanation on the operation of the sensors.

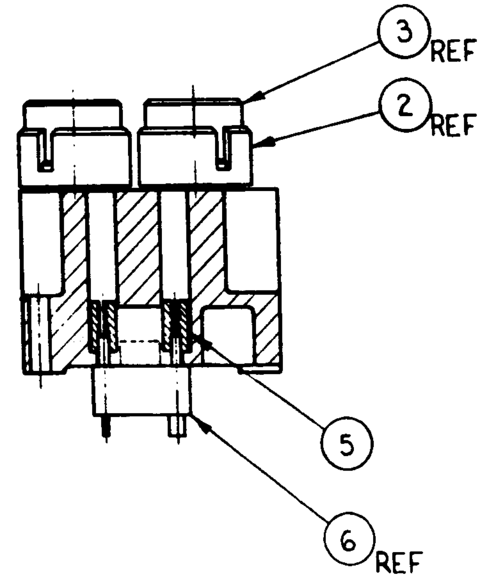
3.6.2 Electronics

The scanning control system is turned on and off by commands number 71 and 140, respectively. See Figure 3-21. The scan on command will apply a pulse, as shown in the diagram, to the on coil of the EL and AZ raster signal and scan power relays. Energizing the scan power relay applies 19v target on power to the 15v scan regulator located in the power box. The output from this regulator is monitored on channel number 40. Power supply voltage for the scanning circuits is also supplied by the scan regulator.

With the EL and AZ raster signal relay energized, signals from the scan generators are applied as input signals to the fine preamplifiers. These signals will then control the upper structure and the pointed instruments in a raster mode. The azimuth and elevation servo systems are made to scan in such a way that the entire solar disk and portions of the solar corona can be mapped by the experimental instruments.

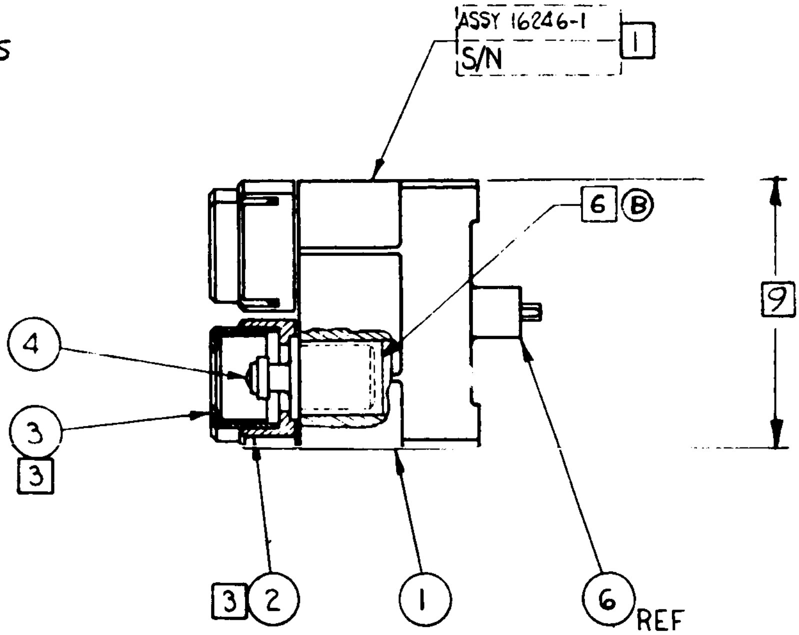
The scan consists of a square raster pattern as shown in Figure 3-25, 40 minutes of arc on a side, centered on the maximum intensity of the solar disc.

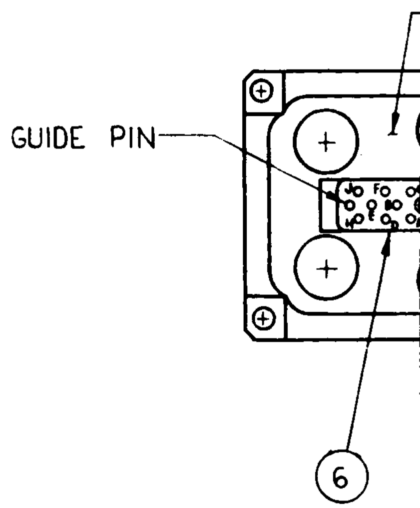

EL-U
9
TYP 3
AZ-R
A
A
8
B
AZ-L
EL-D
7
9
APERTURE IN
TYP 4 PLCS


3 REF
2 REF
5
6 REF

SECTION A - A

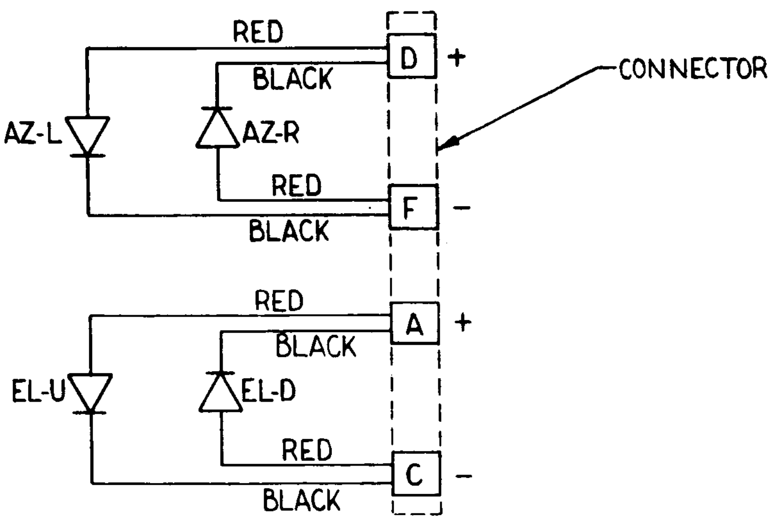
PLCS





TEM 3

CONNECTOR
PIN
DESIGNATION



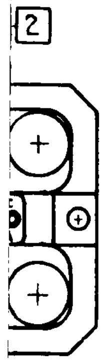
WIRING DIAGRAM

B

B

QUANTITY REQ'D PER ASS

3-5', 2



GEN. NOTES UNLESS OTHERWISE SPECIFIED:

Ⓑ [1] MARK ASSY NO. & SERIAL NO. PER BPS 19.00-12-10

Ⓑ [2] POTTING PER BPS 9.02

[3] BOND ITEM 3 TO ITEM 2 PER BPS 11.00

4. SOLDER CONNECTORS PER BPS 2.10

Ⓑ Ⓐ 5. TEST PER A18810

Ⓑ [6.] BOND ITEM 4 TO ITEM 1 PER BPS 11.00 TO LEVEL SHOWN

Ⓑ

Ⓑ 7. MODEL SPEC A16692

Ⓑ [8.] SHADED AREA REPRESENTS ALUMINIZED PORTION OF RETICLE

[9] *INDICATED AREAS TO BE FREE OF PAINT*

10. *FINISH PER BPS 16.05*

12	NAS1351C-01-6	SCREW			
1	SP0051-1	CONNECTOR			
2	B6840	NUT			
4	C7066-511	DETECTOR ASSY F106			
4	C17910	COVER			
4	C5263-3	RETAINER			
1	D16226	BLOCK			
-1	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL DESCRIPTION / REFERENCE DESIGNATION-ELEC DWG.	MATERIAL SPECIFICATION

...MBLY ODD DASH NUMBERS SHOWN LIST OF MATERIAL EVEN DASH NUMBERS OPPOSITE

Figure 3-24–Fine Readout Sensor Assembly

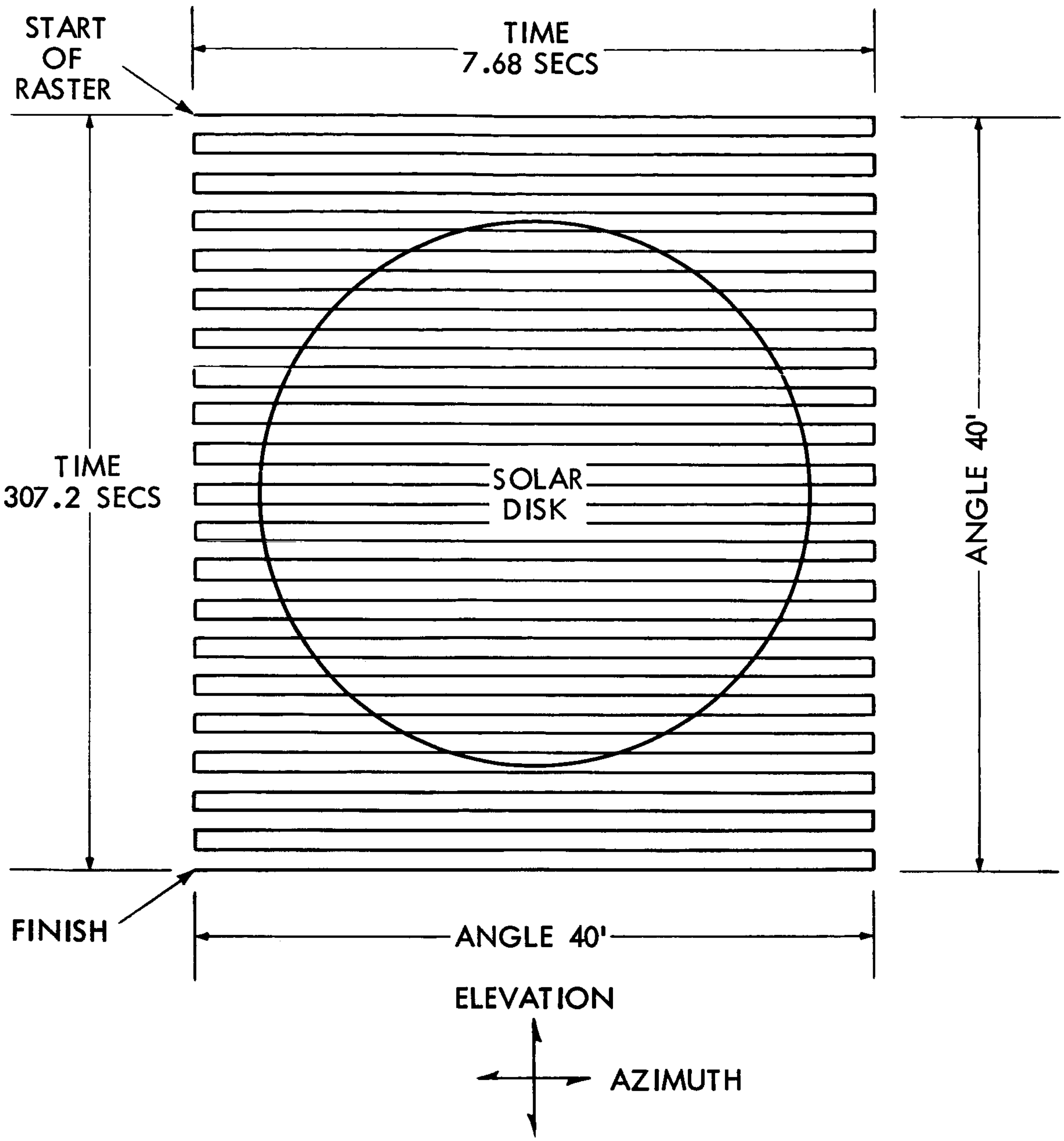


Figure 3-25–Sun Scan Raster

The scan motion originates from a point approximately 20 minutes of arc in azimuth and elevation from the center, and sweeps in azimuth. An azimuth sweep is completed in 7.68 seconds, in synchronization with the telemetry clock. As seen in Figure 3-26, at the end of each azimuth sweep, the elevation angle steps down one minute of arc and the azimuth sweep is reversed. This pattern continues for forty steps in elevation, taking 307.2 seconds to complete the entire scan.

It should be pointed out that this raster pattern may suffer distortion near the edges, and that the scan increment of 1 minute of arc is a nominal value based on calibration data taken at the surface of the earth. Above the earth's atmosphere, the intensity of the sun's radiation will change which will cause the scan control to sweep and step over a larger or smaller solid angle. The solar intensity will be measured with an auxiliary eye and its output will be telemetered.

In addition to a possible change in the scan solid angle, distortion in the incremental elevation pattern and the sweep angle rate may rise. This is due to the nonlinear response function of the sensing system at large angles from the center of the sun.

Figure 3-27 is a timing diagram showing the relative readout points of the azimuth position, elevation position, and the experiment data when the spacecraft is in the scanning mode.

The scan readout low gain amplifiers produce voltages proportional to the azimuth and elevation pointing angles.

Sensor output current provides the base-emitter bias to the input transistor in the amplifier. The base of the transistor is clamped by a 6.8 volt zener diode. The base resistor is for temperature compensation and the emitter resistor is selected for the proper gain. Power supply voltage for these stages is the 15 volts servo supply. The output of the elevation scan amplifier is applied to channels 6, 14, 18, 42, and 47. Azimuth scan amplifier outputs are applied to channels 3, 9, 12, and 24.

3.7 DAMPING NUTATION

Nutation occurs when the spacecraft is precessed by the gas jets. The nutation amplitude is given by

$$\alpha_{\text{nutation}} = \frac{M_n}{1wp} = \frac{(0.05)\ (1.8)}{24\pi\ \frac{3\pi}{2}} = 0.00025 \text{ rad} = 0.75 \text{ min.}$$

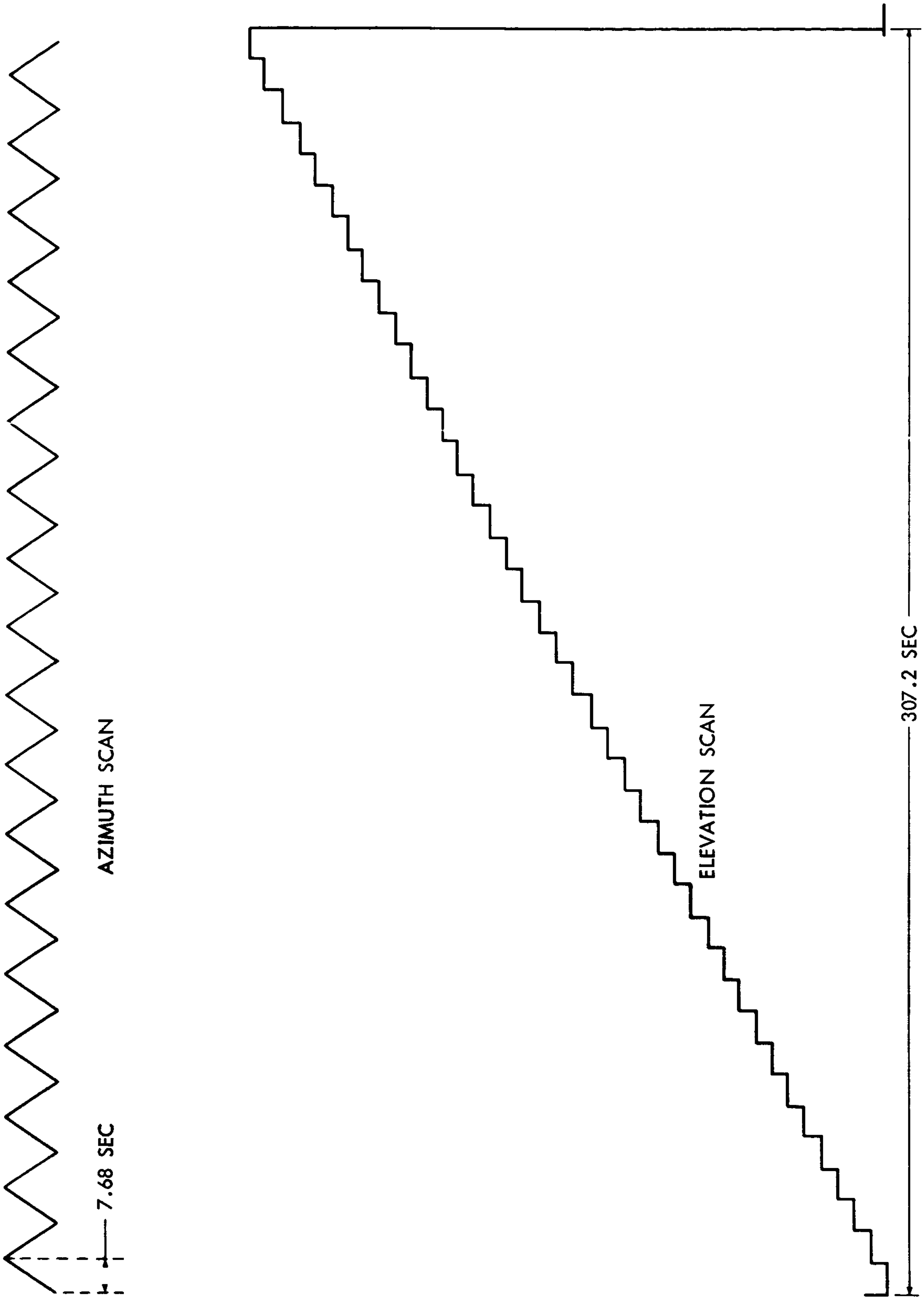
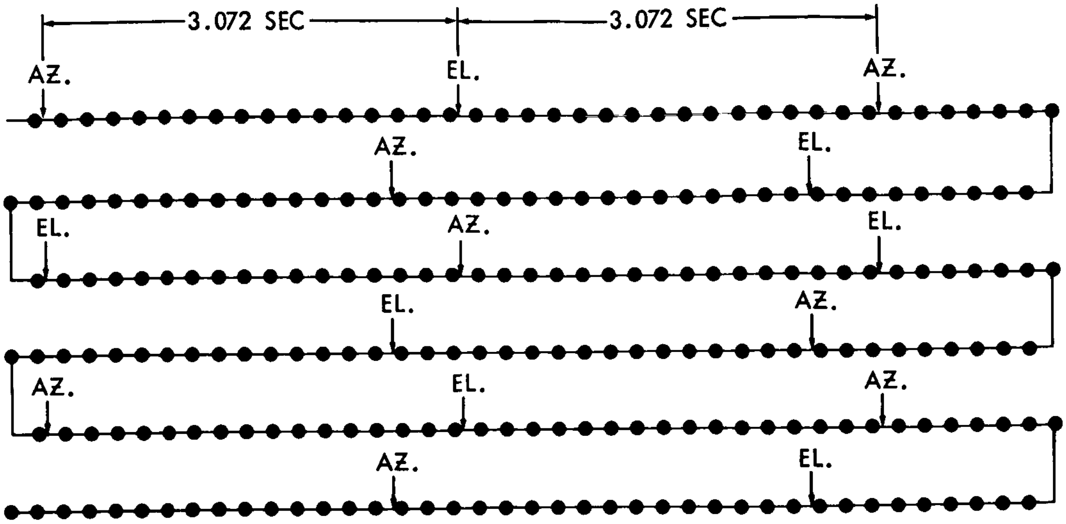


Figure 3-26–Sun Scan Raster Signals



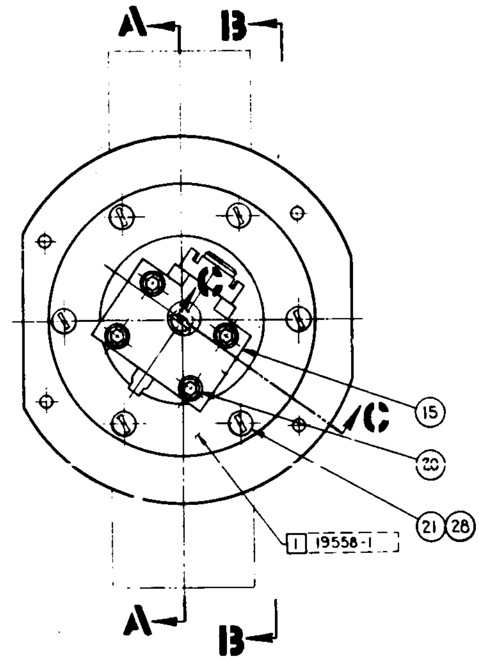
● INDICATES TIME AT WHICH EXPERIMENT IS READ OUT
AZ. INDICATES TIME AT WHICH AZIMUTH POSITION IS READ OUT
EL. INDICATES TIME AT WHICH ELEVATION POSITION IS READ OUT
NOTE: AZIMUTH AND ELEVATION POSITION ARE READ OUT EVERY FOURTH CHANNEL OF SUB-COMMUTATOR.

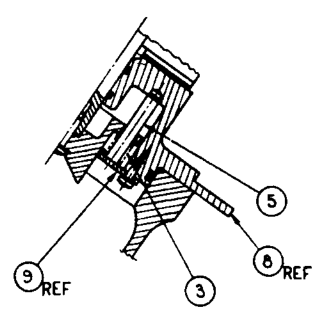
Figure 3-27–Timing Diagram

The nutation will persist after the jets are turned off at some amplitude between 0 and 0.75 minute, depending on the exact instant the jets are stopped. This much wobble will demand that the servo do some work to counteract the wobble, but the amount is negligible. Further, the inherent nutation damping due to the structure and antennas flexing would eventually damp out this nutation.

When the spacecraft is separated from the third-stage rocket, it will have a nutation due to the wobble of the unbalanced burned-out third stage, the unsymmetrical thrust of the separation spring and the unsymmetrical motion of the arms as they are swung out. It is estimated that this will result in a nutation of several degrees amplitude after despin. A nutation of this amplitude would seriously disturb the servo system and must be removed quickly by the nutation damper (Figure 3-28).

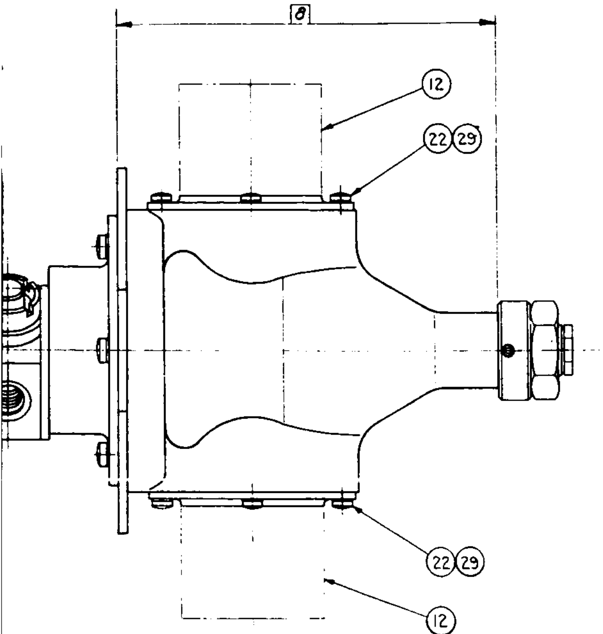
A further cause of nutation is unbalance of the pointed instruments. These two instruments have mechanical scanning mechanisms which move photodetectors inside the instrument. The detectors are placed at some specific point for initial balance of the spacecraft and for launch. However, as soon as they operate, the detectors move from this balance position. No nutation occurs during the time the instrument is pointed, but as soon as the pointing control





SECTION C - C

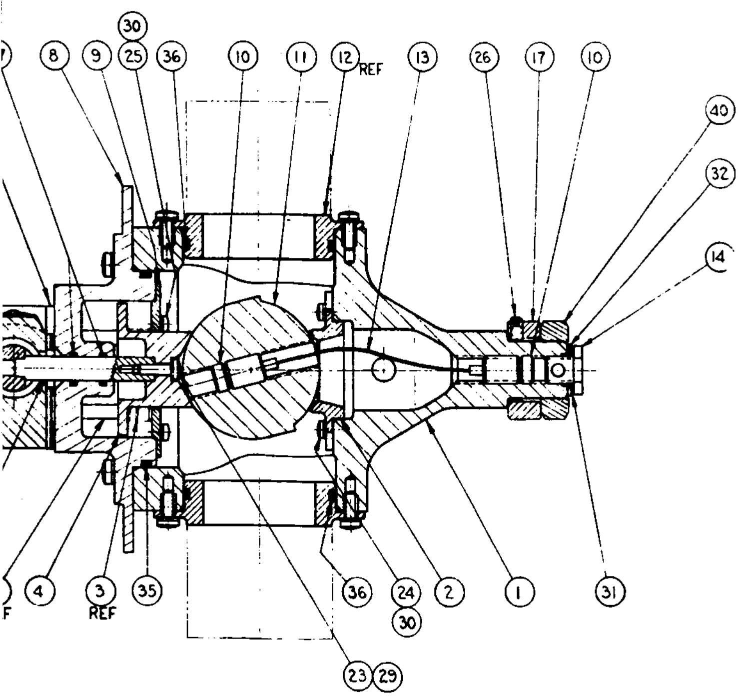
3-57, 1



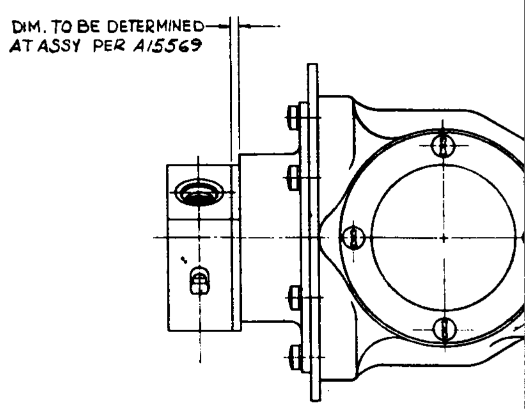
VIEW **B - B**

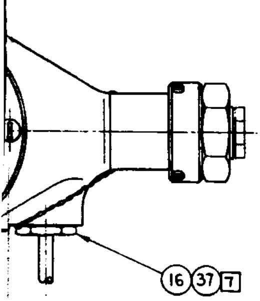
GENERAL NOTES UNLESS OTHERWISE SPECIFIED:

1. MARK PER BPS 19.00-1-12
2. DASH NO. OF WIRE ASSY (ITEM #13) TO BE DETERMINED AT ASSY. SEE A15569
3. ASSEMBLE PER A15569
4. TEST SPECIFICATION PER A 15610
5. FILL PER A15661
6. (D) PARTS LISTED BELOW TO BE TORQUED TO VALUES SHOWN.
   - B15617 — 80 IN. LBS
   - B15564 — 80 IN. LBS
   - B15565 — 112 IN. LBS
   - NAS 1081C08D5L — 15 IN. LBS
   - NAS 1218-04 – 4 IN LBS
   - NAS 1218-06 – 12 IN LBS
   - NAS 1218-08 – 20 IN LBS
   - NAS 1352 C08-16 (20 IN LBS ± 2 IN LBS)
   - MS 35216-13 2 IN LBS
7. SAFETY WIRE PER MS 33540
8. THE AREA INDICATED SHALL BE PAINTED PER BPS 16.05 EXCEPT ITEM NO. 12 (2 PLCS) WHICH WILL NOT BE PAINTED.



SECTION **A - A**





-1	PART NO.	PART NAME	STOCK SIZE	MATERIAL DESCRIPTION / REFERENCE DESIGNATION—ELEC DWG.	MATERIAL SPECIFICATION	[illegible]
1	AN316C12R	NUT				40
						39
						38
3	MS28775-011	'O' RING				37
2	MS28775-134					36
1	MS28775-143	'O' RING				35
						34
AS REQ	MS20995C32	WIRE, LOCK				33
1	SP0003-2-$\frac{3}{8}$	SEAL				32
1	AN960C616L	WASHER				31
7	NAS620C4					30
9	NAS620C6					29
6	NAS620C8	WASHER				28
						27
3	NAS1081C08D5L	SETSCREW				26
4	MS35216-13	SCREW				25
3	NAS1218-04C2					24
1	SP0014-06C-3-B					23
8	NAS1218-06C2					22
6	NAS1218-08C4					21
4	NAS1352C08-16	SCREW				20
						19
						18
1	B15568	COLLAR				17
1	B15565	TUBE				16
1	D15559	LATCH ASSY				15
1	B15564	PLUG				14
1	C16505 [2]	WIRE ASSY				13
2	C15574	BELLOWS				12
1	C6603	BOB				11
2	B15617	SETSCREW				10
1	C19663	RETAINER				9
1	D15562	BASE ASSY				8
1	C19708	SPACER				7
1	C19654	SHAFT				6
4	B19662	GUIDE				5
1	D19665	PISTON				4
4	B15563	SPRING				3
1	C19594	SOCKET				2
1	E15553	HOUSING				1

Figure 3-28—Nutation Damper

turns off at night and the oriented section starts spinning, a dynamic unbalance occurs that causes a wobble of about 10 minutes. When the servo points again the next day, the unbalance is gone, but the wobble shows up as a nutation.

3.8 MAGNETIC BIAS COIL

On OSO-2 spacecraft, the rapid use of the compressed nitrogen to control the pitch attitude shortened the usable life of the spacecraft. To supplement the pneumatic system, a magnetic bias coil has been installed. The primary purpose of the coil is to control pitch attitude after the pneumatic system is expended; however, the coil may also be used to provide small amounts of roll correction.

The coil is attached to the base of the wheel and is protected by an aluminum shield. The approximate characteristics of this coil are as follows:

a. Physical

   (1) Inside diameter: 13.1 inches.

   (2) Outside diameter: 13.9 inches.

   (3) Thickness (along spin axis): 0.70 inches.

   (4) Coil plane: 2.4 inches above separation plane.

   (5) Weight: 4 pounds.

b. Electrical

   (1) Turns: 2170 No. 31 wire.

   (2) Resistance: 1075 ohms at 25°C.

   (3) Inductance: 3.2H.

c. Operational

   (1) Dipole moment for 10 ma dc current: 2000 dyne-cm per gauss.

   (2) Field at center of coil for 10 ma dc current: 0.8 gauss (along spin axis)

Two attitude control problems are expected to be solved by incorporation of the magnetic bias coil:

a. Control of the observatory magnetic dipole moment along the spin axis to prevent excessive pitch drift rate and consequent high usage of pitch gas.

b. While meeting item a, control of the observatory magnetic dipole moment along the spin axis to obtain a roll angle change with time, and thereby permit certain wheel experiments to properly view the celestial sphere.

The bias coil will be controlled only by ground commands. The six commands employed will be as follows:

a. Power on.

b. Power off.

c. High current 10 ma dc (dipole moment 2000 dyne-cm per gauss).

d. Low current 5 ma dc (dipole moment 1000 dyne-cm per gauss).

e. Field polarity: north on sail side of coil.

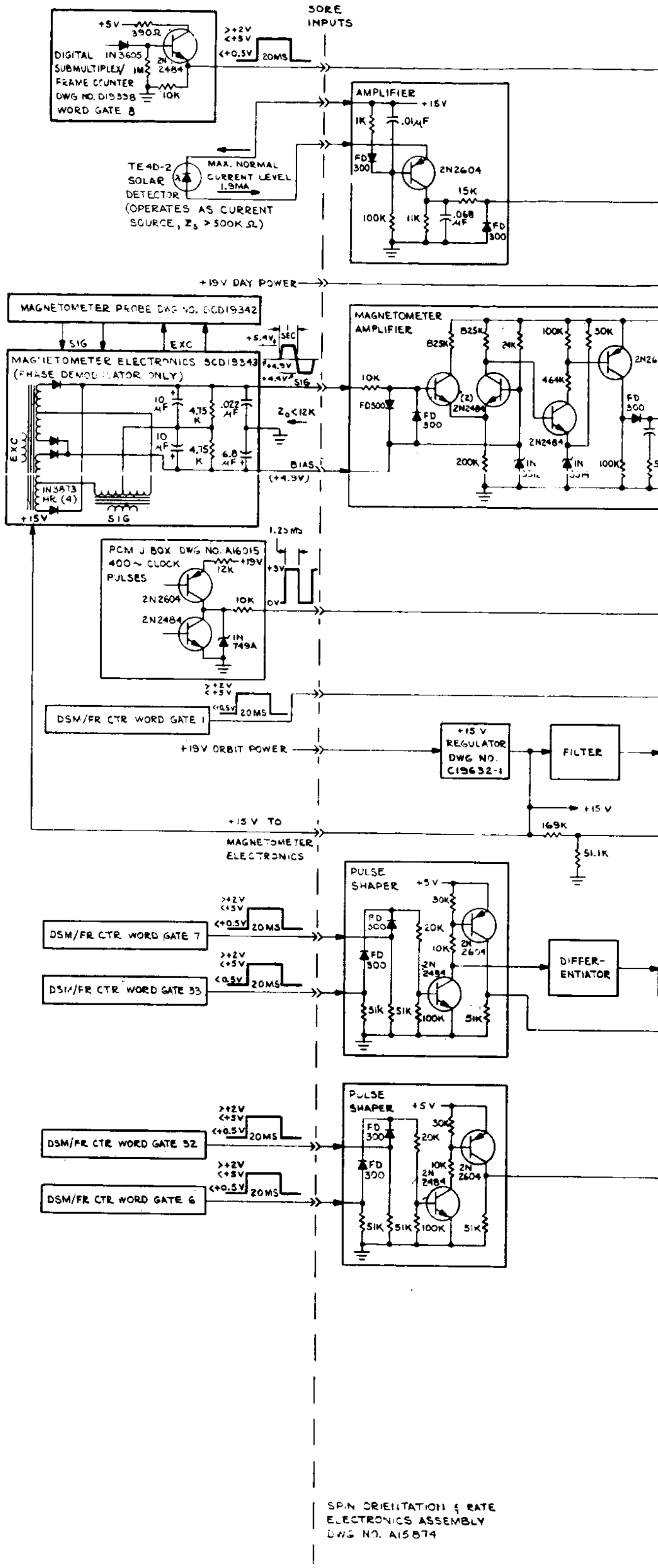
f. Field polarity: south on sail side of coil.

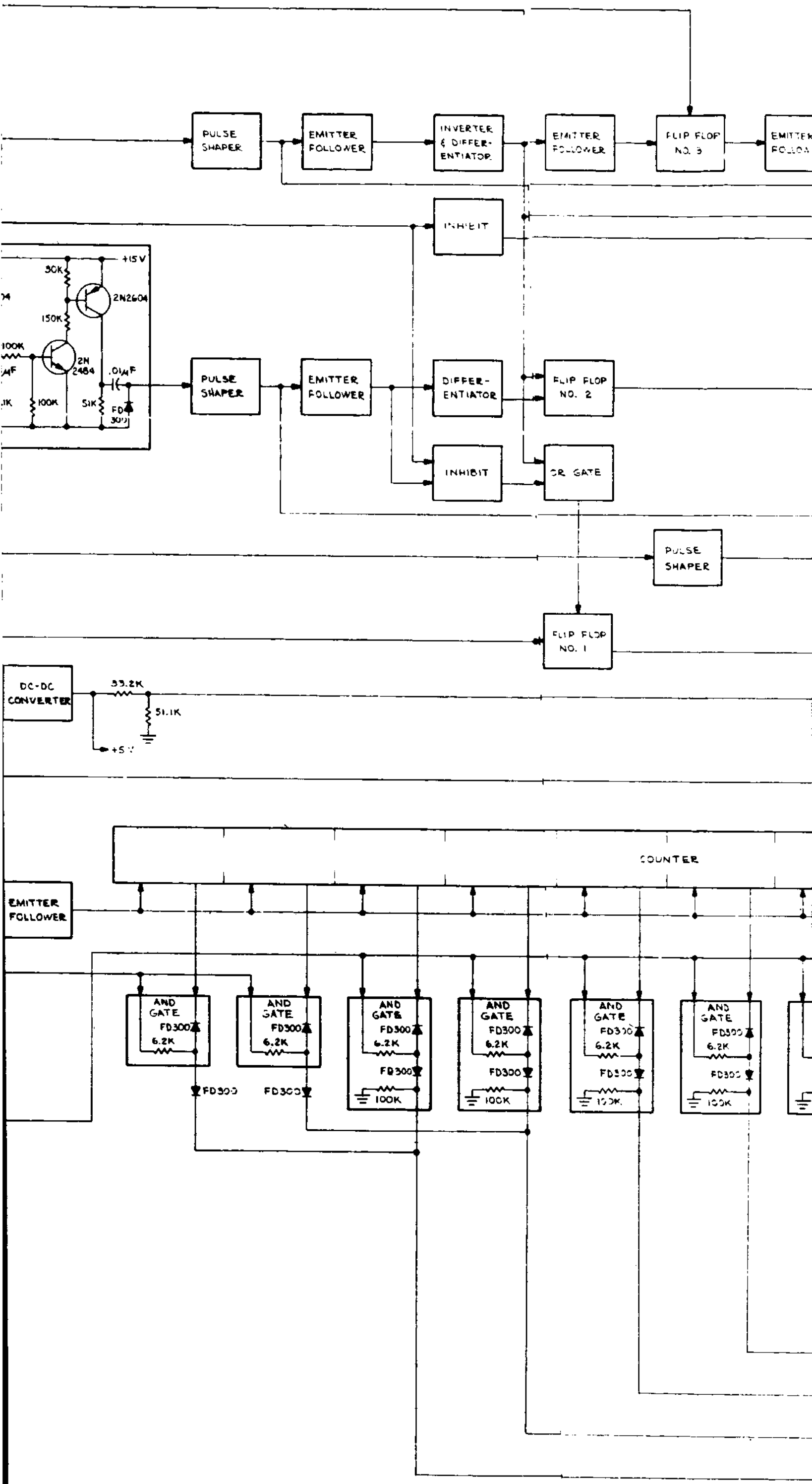
In orbital operation, the time of bias coil turn-on, the level, and the polarity will be determined from an analytical program whose inputs are actual measurements of attitude in space, pitch drift rate, and roll angle change. The expected effects of energizing the coil will not be detectable in observatory data until several days after turn-on because of the low dipole moment produced. This long period for assessing the coil performance, knowing that no large undesirable observatory attitude change will occur, makes practical some degree of trial and error experimentation to control the bias coil.

3.9 ASPECT MEASURING SYSTEM

The aspect measuring system (Figure 3-29) locates the solar and field vectors in the spacecraft, measures the necessary angles, and computes the roll aspect angle in ecliptic coordinates. Once the roll aspect angle has been computed, it is combined with the pitch angle (from telemetry) and orbital data in a computer program to establish the orientation of the spacecraft. A comprehensive description of the program together with a set of instructions for its general usage, is published in the OSO Aspect System Manual, TM 65-1, dated 15 July 1965.

The system provides a method of determining 3-axis aspect with respect to the celestial sphere for the spacecraft. Aspect can be determined within 3 degrees. The basic measurement requires a magnetometer mounted on one arm of the spacecraft, with its sensitive axis in the plane of rotation. The aspect subsystem provides two sets of measured data in a form to be read out directly by the telemetry system. These data are: a measurement of a time interval which


SORE INPUTS
DIGITAL SUBMULTIPLEX/ FRAME COUNTER DWG NO. D19338 WORD GATE 8
AMPLIFIER
TE4D-2 SOLAR DETECTOR
MAX. NORMAL CURRENT LEVEL 1.9MA
(OPERATES AS CURRENT SOURCE, Zs > 500K Ω)
+19V DAY POWER
MAGNETOMETER PROBE DWG NO. SCD19342
MAGNETOMETER ELECTRONICS SCD19343 (PHASE DEMODULATOR ONLY)
MAGNETOMETER AMPLIFIER
PCM J BOX DWG NO. A16015 400~ CLOCK PULSES
DSM/FR CTR WORD GATE 1
+19V ORBIT POWER
+15 V REGULATOR DWG NO. C19632-1
FILTER
+15 V TO MAGNETOMETER ELECTRONICS
PULSE SHAPER
DSM/FR CTR WORD GATE 7
DSM/FR CTR WORD GATE 33
DIFFER-ENTIATOR
DSM/FR CTR WORD GATE 32
DSM/FR CTR WORD GATE 6
SPIN ORIENTATION & RATE ELECTRONICS ASSEMBLY DWG NO. A15874


PULSE SHAPER
EMITTER FOLLOWER
INVERTER & DIFFER-ENTIATOR
EMITTER FOLLOWER
FLIP FLOP NO. 3
INHIBIT
+15V
30K
2N2604
150K
100K
2N 2484
.01μF
100K
51K
FD 300
PULSE SHAPER
EMITTER FOLLOWER
DIFFER-ENTIATOR
FLIP FLOP NO. 2
INHIBIT
OR GATE
PULSE SHAPER
FLIP FLOP NO. 1
DC-DC CONVERTER
33.2K
51.1K
+5V
COUNTER
EMITTER FOLLOWER
AND GATE
FD300
6.2K
100K

3-62

GENERAL NOTES UNLESS OTHERWISE SPECIFIED:

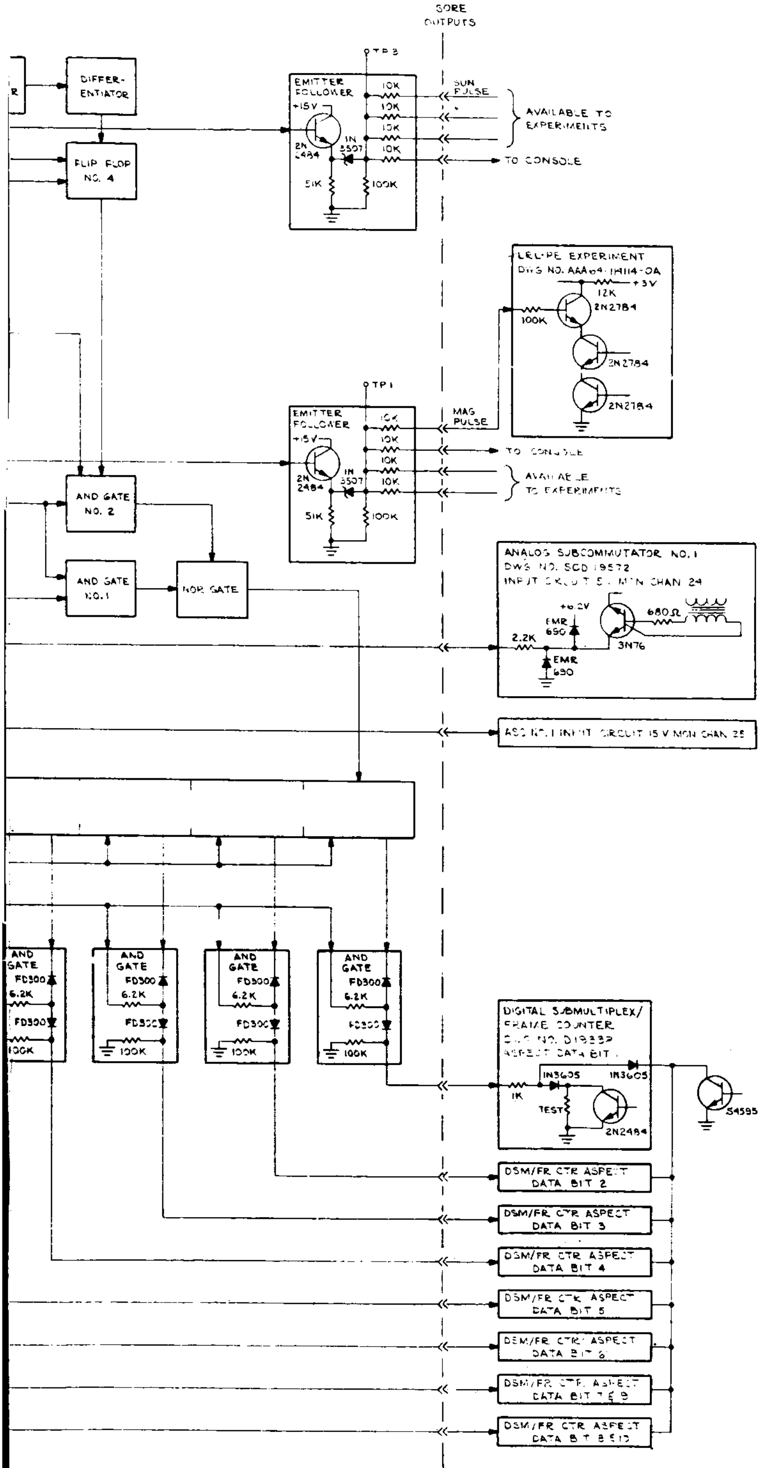


Figure 3-29—Aspect Measuring System Diagram

(2)

relates the wheel position in time to the spacecraft data word pulses for spin rate and spin angle determination, and a measurement of the time interval between the magnetic field position and the solar direction for spacecraft roll angle determination.

Except in the special case when the spin axis is parallel to the geomagnetic field, the magnetometer produces a sinusoidal output as the spacecraft wheel rotates. The positive excursion reaches its peak when the angle between the field and the sensor axis is a minimum. The maximum negative value occurs when the wheel has rotated 180 degrees and the sensor's sensitive axis is opposed to the field but forms the minimum angle between the sensitive axis and the lines of force. The zero output occurs when the sensitive axis of the magnetometer becomes perpendicular to the field.

Since the zero output of the magnetometer is distinguished with electronic signal conditioning, the instantaneous time at which the magnetometer's axis is perpendicular to the magnetic field can be determined. This event is recorded from a pulse output which may be channeled both to an experiment and to an on-board logic circuit.

A second pulse, to locate the spin vector in the spin plane relative to the magnetometer sensitive axis, is generated from a sun sensor. The angle in the spin plane between the normal to the magnetic field and the spin vector is determined, for a known spin rate, by measuring the time interval between these two pulses with a counter circuit which counts the spacecraft 400 cps clock pulses. The roll angle of the spin axis, with respect to the ecliptic plane, is calculated by using this angle, the magnetic field characteristics, and the earth-sun line at that point in space and time.

A positive voltage pulse can be provided to the experimenter the instant the optical axis of the sun sensor swings through the plane of the spin axis and the solar direction. Should an experimenter decide not to utilize the aspect information, it then becomes the task of the experimenter to relate this pulse in time with collected data, and to determine spin angle and spin rate information.

Figure 3-30 shows the spacecraft geometry with roll angle and pitch angle in respect to ecliptic coordinates. Superimposed is a field vector, its projection on a wheel plane, and the angle between the roll axis and the projection of the field vector. If the wheel is rotating, the roll angle can be measured with the aid of a magnetometer, a solar sensor, and a timer.

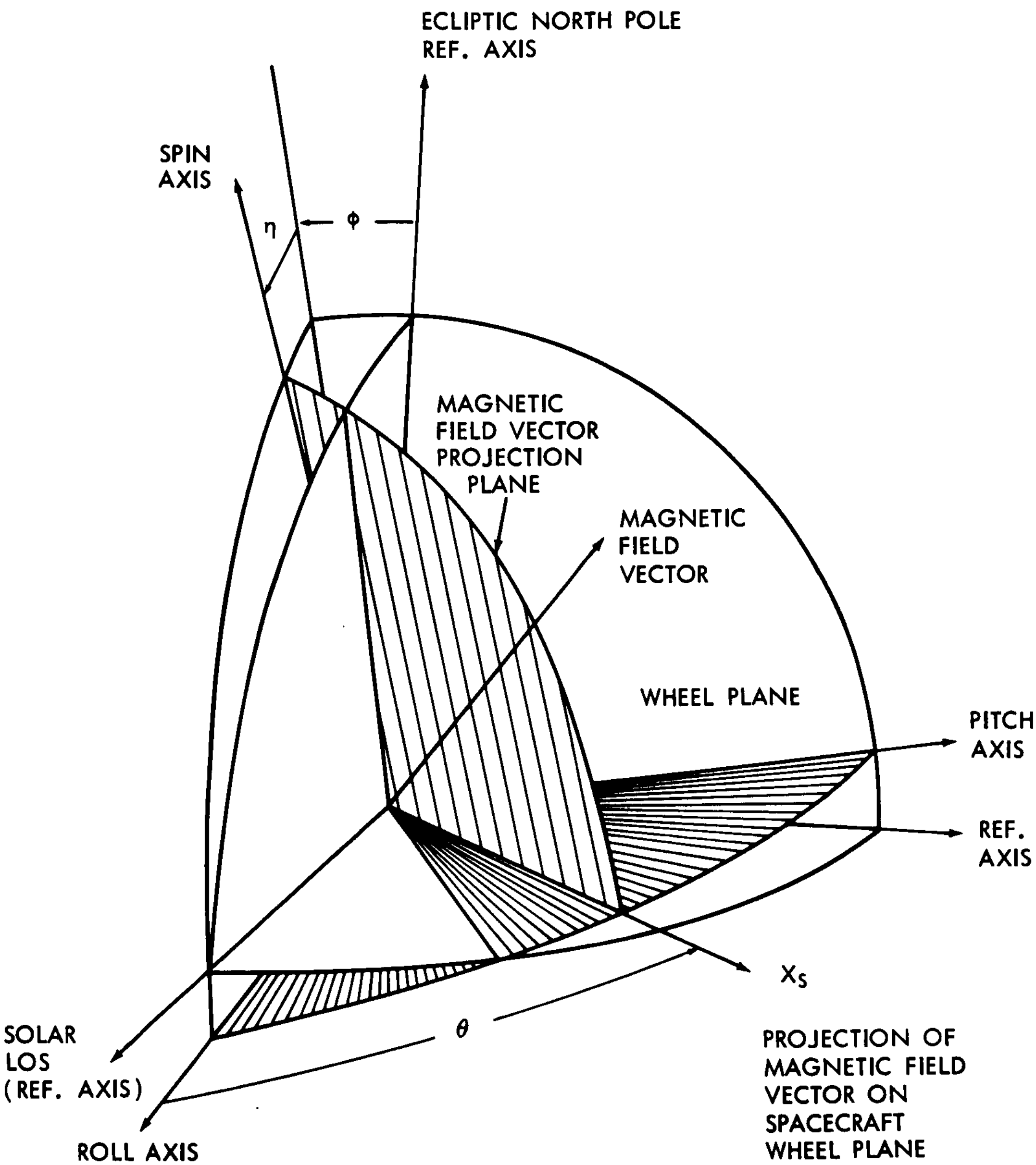


Figure 3-30–OSO Aspect Geometry

3.9.1 Spin Orientation and Rate Electronics (SORE)

The SORE unit consists of an array of electronic scaler circuits and logic gates. These elements function together to perform a scaler addition of the spacecraft 400 cps clock pulses between various gating functions. The various gating functions are received and derived from the main telemetry word gates and the output of the sun sensor and the magnetometer. The system also derives the pulses indicative of the magnetic field null from the magnetometer signal input, and it derives a pulse indicative of the center of the sun from the sun sensor current input.

The beginning of the 1st digital submultiplexer word (8th main frame word, 1st word of the 40 digital submultiplexer cycle) is used to start the SORE counter. This is done by a pulse derived from the telemetry word gate (Figure 3-31). The SORE counter counts clock pulses until a sun pulse (during the day) or a magnetometer pulse (at night) shuts it off. This count is stored until readout during the 6th and 7th word times about 3 seconds later (Figure 3-32). Thus, every 25.6 seconds there is an accurate determination of the orientation of the wheel about the spin axis. The number of clock pulses counted times the pulse period times the wheel spin rate gives the angle through which the solar sensor must turn to reach the pitch plane (magnetometer zero-crossing position at night) after the beginning of the 1st digital submultiplexer word.

Two successive SORE counts also provide data necessary to establish the spin rate accurately. Since the spin rate is controlled within certain limits, the number of revolutions the wheel makes in 25.6 seconds varies between 10.0 and 16.9 with 13.5 as the average value.

3.9.1.1 Magnetometer

The magnetometer is a Schonstedt type SAM-4B-HS flux gate magnetometer designed specifically for null detection in the earth's field. The electronic unit is mounted in compartment 4 of the wheel.

Figure 3-33 shows a block diagram of the subassembly. A drive coil is wound around the walls of a hollow cylinder of highly permeable material. A solenoidal pickup coil is wound around the outside of the cylinder. Because of the geometry there is no coupling from the drive coil to the pickup coil. A 10 kc oscillator connected to the drive coil provides a signal that saturates the magnetic cylinder twice per cycle, gating out the earth's field each time. A pulse with a peak height proportional to the strength of the axial component of the earth's field occurs each time the drive current goes through zero because

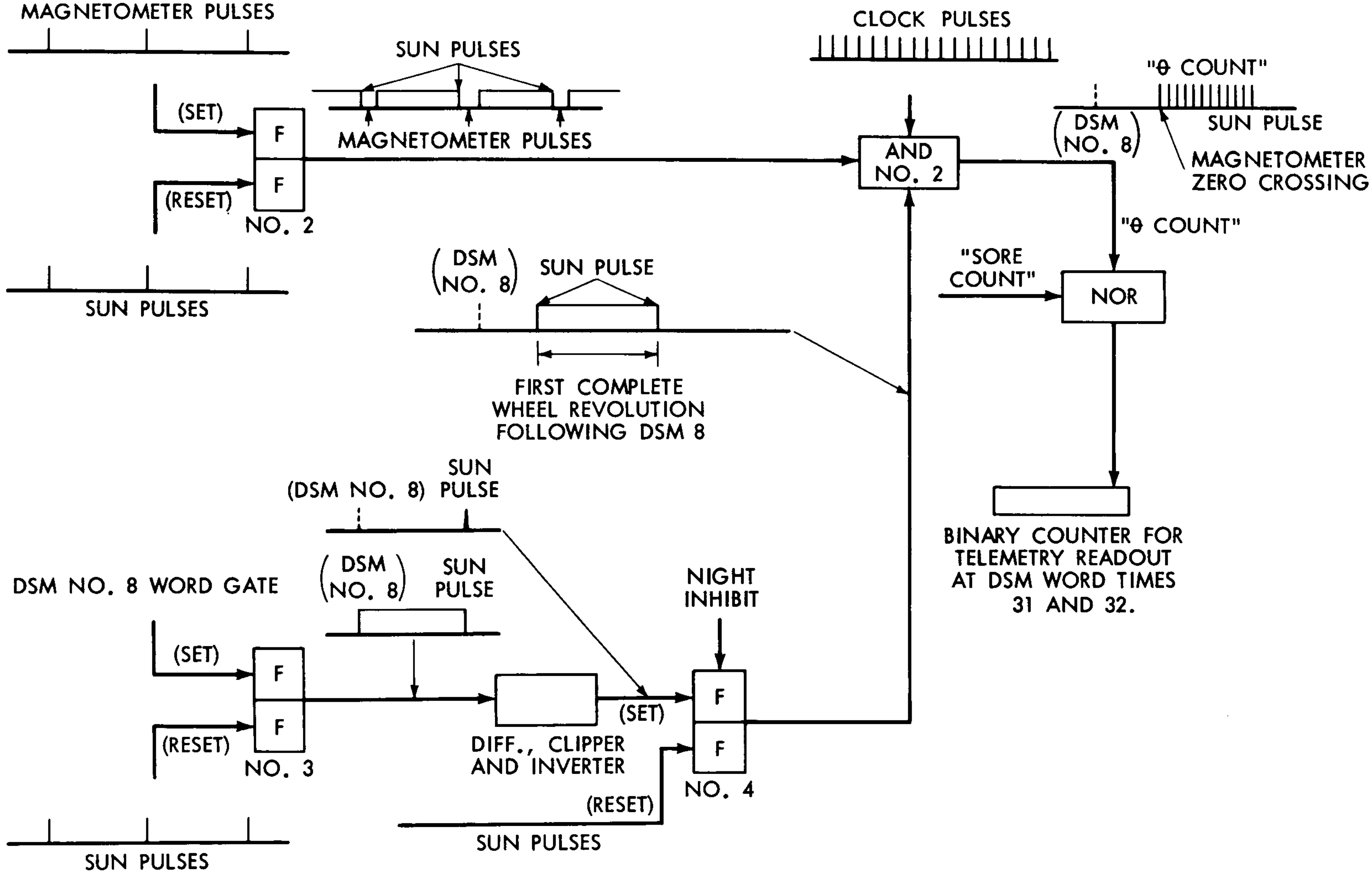


Figure 3-31–SORE Functional Diagram.

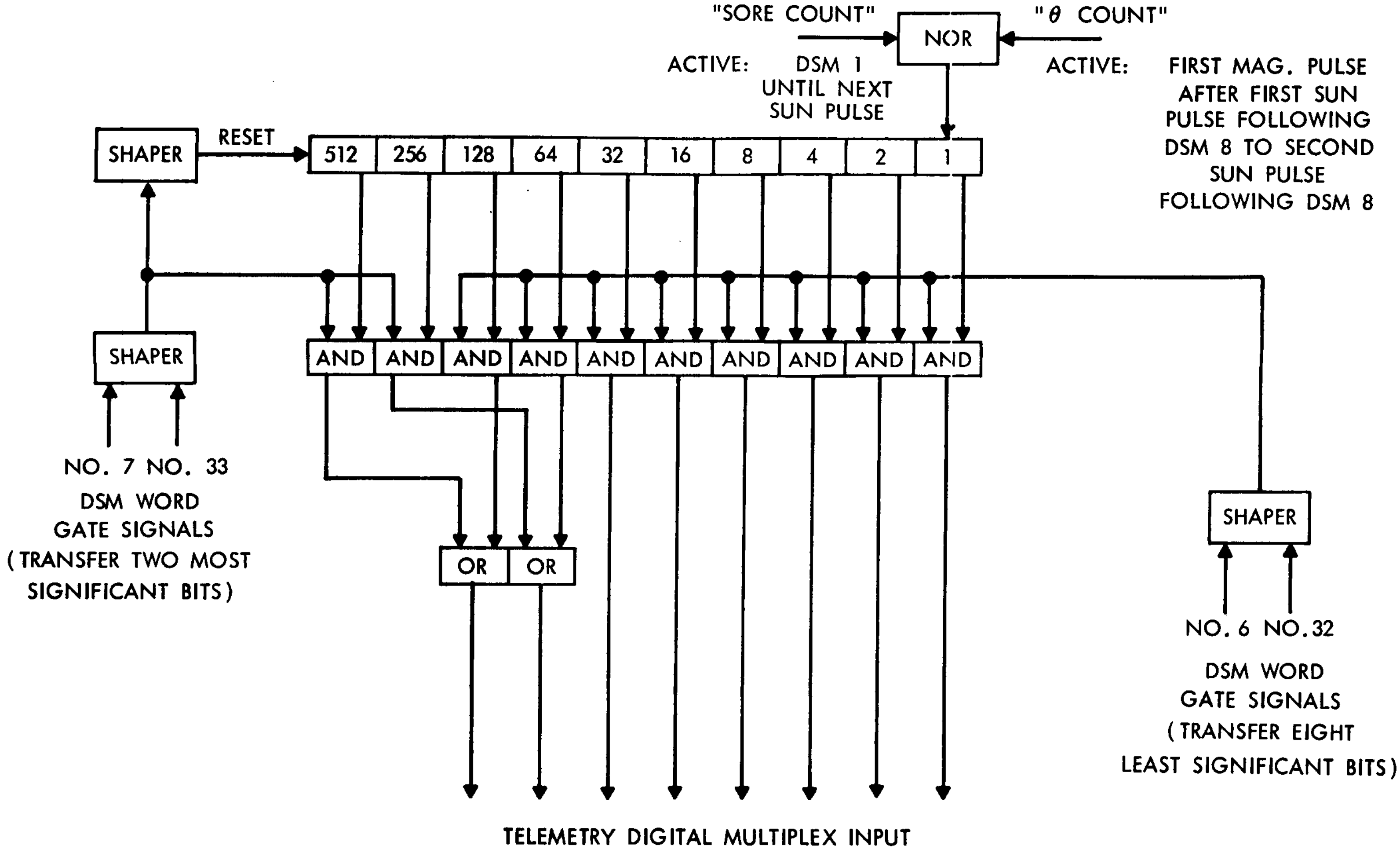


Figure 3-32–Counter and Input to Telemetry Diagram

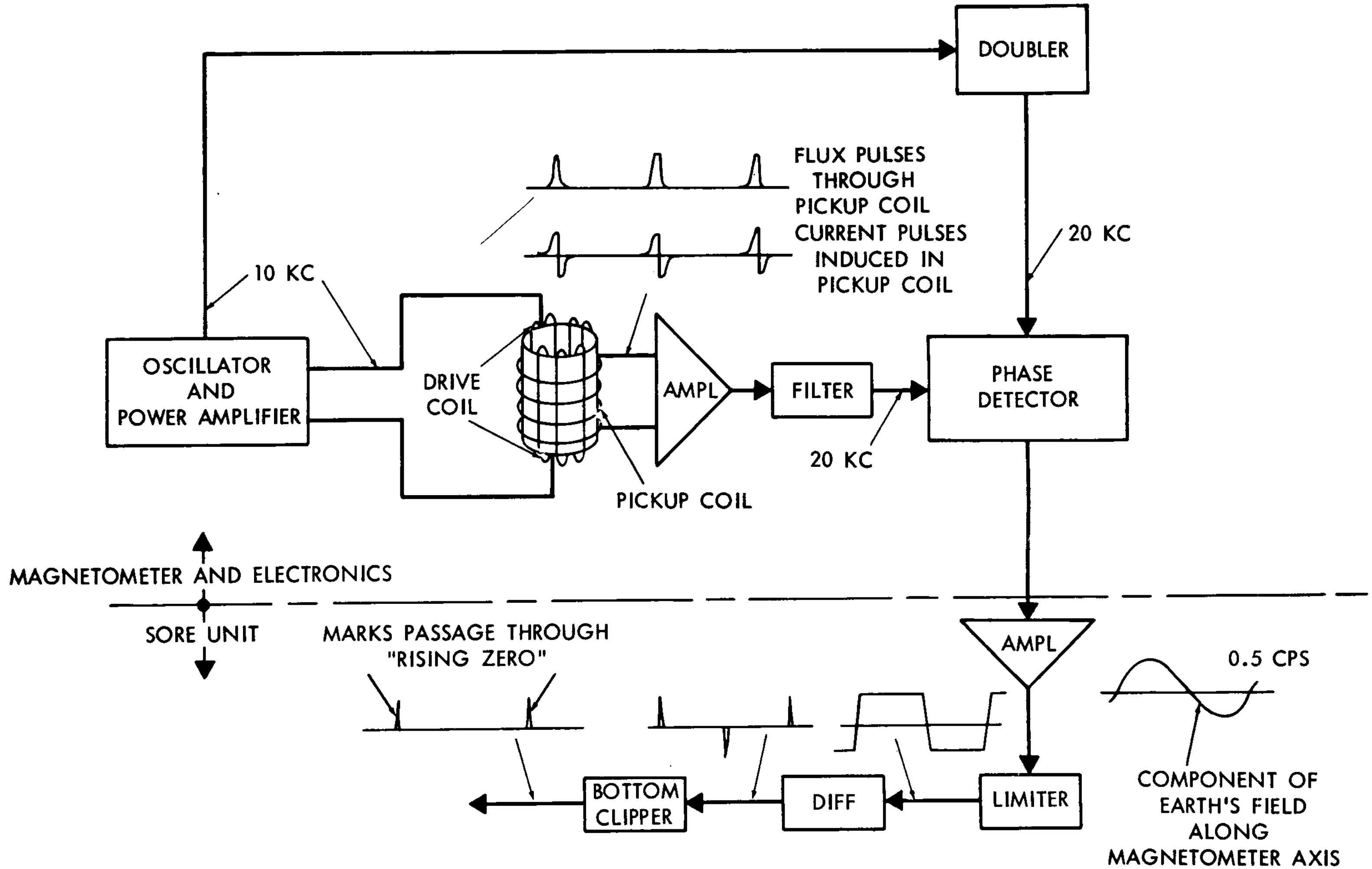


Figure 3-33–Magnetometer and SORE Block Diagram

of the change in flux through the pickup coil. This pulsating signal is filtered to produce a clean sinusoidal signal of frequency twice that of the drive signal. The drive signal is also passed through a frequency doubler to provide a reference sinusoidal signal of the same frequency as that of the filtered pickup coil signal. The two signals are in phase or 180° out of phase depending upon the direction of the axial component of the earth's field in the magnetometer. Both signals are used in a phase detector – the second harmonic of the drive signal as the reference and the filtered pickup coil signal as the signal.

If the earth's field component is constant, the output of the phase detector is a dc voltage proportional to the magnitude of the axial field component through the magnetometer with polarity determined by the sense of the axial field component. Since the spacecraft is spinning, however, the output of the phase detector is an ac voltage with a frequency the same as the rotation rate of the wheel section.

In the SORE assembly, the output signal of the phase detector is amplified and limited to provide an approximate square wave. This signal is differentiated to produce two spikes; one positive, making the falling zero. A clipping circuit eliminates the negative pulse. The remaining pulse is used to mark the time at which the magnetometer passes through the rising zero.

3.9.2 Aspect System Reference Axis (Solar Sensor Axis)

The aspect system reference axis is not located physically; rather it is determined by the occurrence of a pulse triggered by the rising edge of the solar sensor signal. As the sun moves across the field of view of the solar aspect sensor (Figure 3-3) the image of the sun moves across a slotted mask covering a filter and detector. The slot is wider than the solar image so that the signal from the sensor is flat on top, with a rising front corresponding to the 32 arc minute width of the sun as its image moves onto the slot. When approximately 35 percent of the image area overlaps onto the slot, the SORE system generates a sun pulse. The sun pulse is used internally by the SORE system and is also available to wheel experiments as a reference. It is this pulse that defines the location of the aspect system reference axis.

Section 4

TELEMETRY SYSTEM

4.1 INTRODUCTION

The telemetry is accomplished by a PCM/PM system. This system consists of the PCM multiplexing and encoding equipment, two tape recorders, two transmitters, and a PCM junction box. Included in the multiplexing and encoding equipment are five separate subassemblies; two digital multiplexers and encoders, two analog subcommutators and a digital submultiplexer/frame counter. See Figure 4-1 for a typical block diagram of the system.

4.2 FUNCTIONAL DESCRIPTION

A functional description of each individual unit is presented. Theory for the data handling operation which utilizes most of these units as a system is then discussed. Data transmission and the data storage and reproduction system are discussed separately.

4.2.1 Digital Multiplexer and Encoder

The digital multiplexer and encoders are located in compartment number 1 of the wheel. One of these units accepts both analog and digital data, and converts it into a serial non-return-to-zero (NRZ) binary signal. The signal is then processed to produce a biphase return-to-zero (RZ) signal for storage in the tape recorder, and for real time transmission. Included in this unit is a digital multiplexer to multiplex the experiment and spacecraft monitoring data, and an encoder for converting the subcommutator analog outputs into binary words. Selection of either multiplexer-encoder is accomplished by energizing a relay via the command link.

4.2.2 Analog Subcommutator

One subcommutator is located in compartment number 1 of the wheel and the other is located on the experiments in the sail. Both subcommutators are continually operating and supply output signals to one digital multiplexer and encoder. Each analog subcommutator is capable of multiplexing as many as 47 analog input voltages. The subcommutators are synchronized with each other

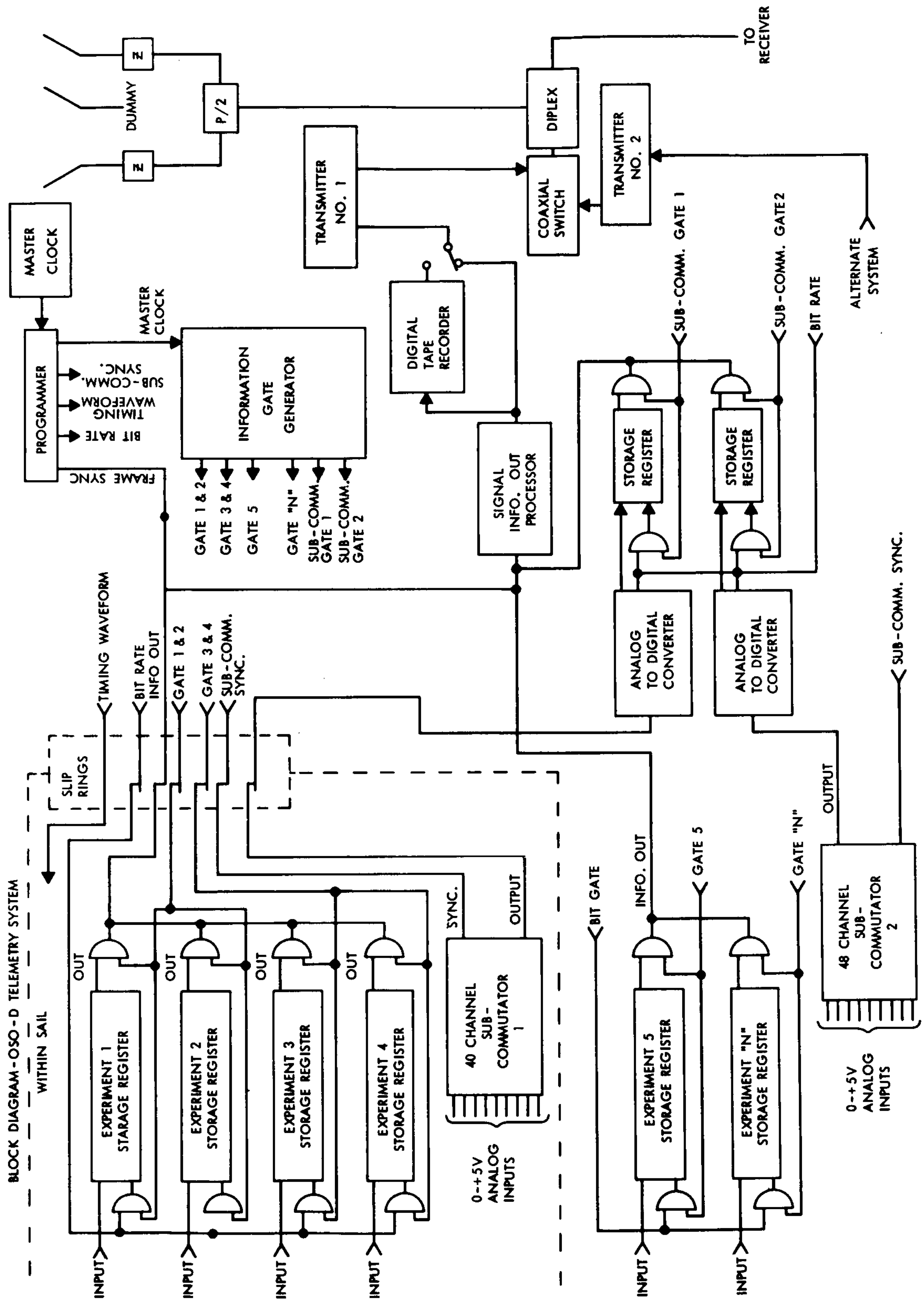


Figure 4-1—Telemetry System Block Diagram

so that each subcommutator is sampling the same channel during any main frame. Also, the subcommutators are synchronized with the digital multiplexer so that the subframe sync word of each subcommutator will be the last word to occur in the main frame.

4.2.2.1 Encoding

The sampled output of each subcommutator is encoded into 8-bit binary words. The most significant digits will occur first in time, proceeding to the least significant digit. The encoder is so constructed that the subframe sync code is inhibited from appearing as data. If the analog input is of the proper level to be encoded as the sync word, the encoder shall automatically complement the least significant digit. The encoded word for analog input voltages greater than +5 volts are all ones, and for voltages having a negative sign, zero.

4.2.2.2 Frame Synchronization

Channel 48 of each subcommutator is used for synchronization. The encoded word is 01010101 for the 8 bits. A subframe rate pulse is provided as an output which is coincident with the sample period of channel 48.

4.2.3 Tape Recorder

The tape recorder is a digital recorder/reproducer located in compartment number 8 of the wheel. It records the information from the multiplexer-encoder for a complete orbit of 100 minutes, and on command plays back in 5 minutes the recorded information from the previous orbit. After the playback is completed, it reverts to the record mode automatically. The tape recorder includes the electronics necessary to process the signal for the record and playback cycles. The command signal energizes a relay which applies power to the recorder selected for operation.

4.2.4 Frame Counter/Submultiplexer

The frame counter/submultiplexer assembly is located in compartment number 8 of the wheel. This assembly provides a means of counting main frames of the data handling system and provides a means of submultiplexing digital data. Two output signals are provided: a non-return-to-zero binary; and 40 sequential timing pulses. Each timing pulse output occurs on a separate output line. A synchronization code is inserted into the digital output signal once during each subframe. An internal counter is provided for counting gate pulses from a specified submultiplexer channel. It has a continuous counting capacity of 255 counts before automatically recycling to zero. The counter output is also inserted into the digital output signal once during each subframe. The counter will reset to zero when the proper reset input pulse is applied.

4.2.5 PCM Junction Box

The PCM junction box, located in compartment number 1 of the wheel, provides electrical interface between experiment and the data handling assembly and the communication subsystem. This junction box provides 17 gate output signals which are developed from the 32 gate channel input signals. Provisions are made for combining two or more gate channel input signals into a single gate output signal as required. Terminations are provided so that each input gate signal is applied to a resistive load of 1000 ohms when the gate outputs are not terminated. Each gate output has a 2000-ohm isolation resistor connected in series.

The PCM junction box also provides a digital word output and clock outputs. The digital word output is derived from the twelve digital data input signals. These twelve input signals are combined into a single signal which is connected to two output lines. Twenty separate clock signal outputs are provided with each having a source impedance of 10,000 ohms resistive.

4.2.6 Transmitter

The two transmitters are located in compartment number 8 of the wheel. These transmitters are solid state devices with a modulator section, and an rf section. Both units are capable of producing approximately 600 milliwatts of power. The transmitter can be used as a beacon with no modulation for tracking purposes, or as an FM transmitter for telemetry purposes. When modulated, it transmits real time continuously, and stored data when the spacecraft is commanded to playback. In the event of failure of one of the transmitters, the remaining one would be used for tracking and telemetry. A command signal can be used to select either transmitter for operation. Also, the modulation can be removed by a command signal. The output of either transmitter is selected and connected to the antenna system by a coaxial relay. Refer to Section 7 for the operation of the antenna system.

4.3 DATA HANDLING SYSTEMS

The data handling system consists of four separate subassemblies; two digital multiplexers and encoders (DME), and analog subcommutators (ASC). Refer to paragraphs 4.2.4 and 4.2.5 for operation of the frame counter/submultiplexer and the PCM junction box. See Figure 4-2 for a diagram of the system.

The data handling system is designed to accurately and reliably record the measured solar phenomena from the spacecraft experiments and the monitoring subcommutators.

The main facets of this system include representation of the measured data in binary coded form; time sharing between the experiments; on board tape storage of the coded data; and transmission of real time and stored data to the surface stations.

The measured data in binary coded form are stored within each instrument package in shift registers. The shift registers in the instruments are sequentially emptied by the clock and gate signals, according to the multiplex format. The resulting time shared serial pulse train is processed by the main multiplexer for storage and is directed to the tape recorders, and to the transmitting system for real time transmission.

The data are transmitted in real time as a back-up to the primary transmission of the stored data. The latter transmission takes place upon command from the assigned surface station. The stored data for a complete orbit are transmitted in approximately five minutes by means of a high speed recorder playback.

The transmitted PCM signal is demodulated at the receiving station and recorded for later reduction and analysis. These recorded data are processed in a data reduction facility, where the coded data for each experiment are decommutated from the serial pulse train. Further data reduction and analysis can then be performed to relate the coded data to the measured solar phenomina.

The system is capable of accepting serial binary-coded digital data, and 94 separate channels of analog data for processing into both PCM-NRZ or biphase (Manchester code) output data; and also provides 32 sequential digital gating signals, a subframe rate pulse and a clock signal.

4.3.1 Digital Data Handling

A simplified block diagram of system operation is shown in Figure 4-3. The outputs of the ASC units are parallel-connected providing a common input into each of the DME units. Both of the ASC units are operative at the same time, providing a system input capability of 94 analog channels (47 per unit). The two DME units are also parallel connected, but are system redundant to one another, and only one unit is operative at any one time. Selection of DME number 1 or

DME number 2 is accomplished by applying power to one unit or the other via the command link relay. Therefore, the system is composed of two ASC units feeding one DME unit.

A typical main frame of PCM output data from the system will be composed of data generated in the following manner:

28 serial 8-bit digital words

2 analog samplings

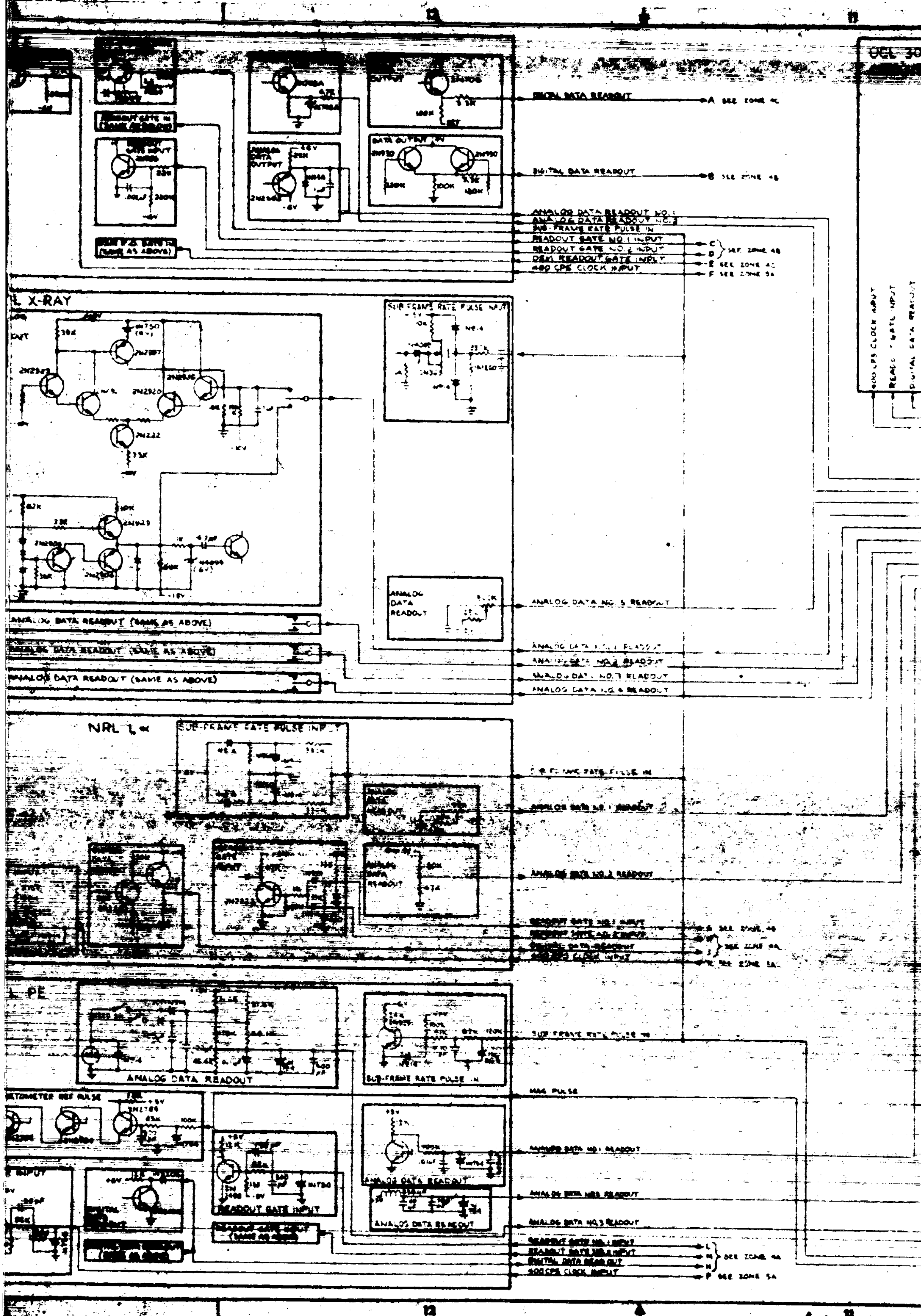
2 frame sync words

The serial digital data is fed into the system at the modulator circuit of the DME, where it is encoded in NRZ and biphase form. At the appropriate time word A and word B, respectively, are applied to the ASC timing control circuit in the DME, and the ASC trigger pulses fed to the ASC decoder and flip-flop circuits to initiate sampling of two of the analog input channels. Sampling of the analog data is via an analog switching circuit which provides an analog voltage level between 0.0 and 5.0 volts full-scale to the buffer amplifier. From the buffer amplifier, the analog sampling is fed to a comparator and A/D converter in the DME which converts the analog data into an eight-bit parallel word. This word is then converted to serial format and fed to the modulator for conversion in NRZ and biphase form (for inclusion in the main frame of data). Normally the 94 analog subframes require 48 main frames of data to achieve a complete sampling of the 94 analog input channels. The 32 sequential digital timing signals are generated by the digital gate drivers and gating circuits from a series of timing flip-flops. A self-generated subframe rate pulse is applied to the ASC buffer amplifier circuit and is inserted into the analog data line as the forty-eighth analog channel and is also provided as an output to the spacecraft instrumentation.

4.3.1.1 Analog Subcommutator (ASC)

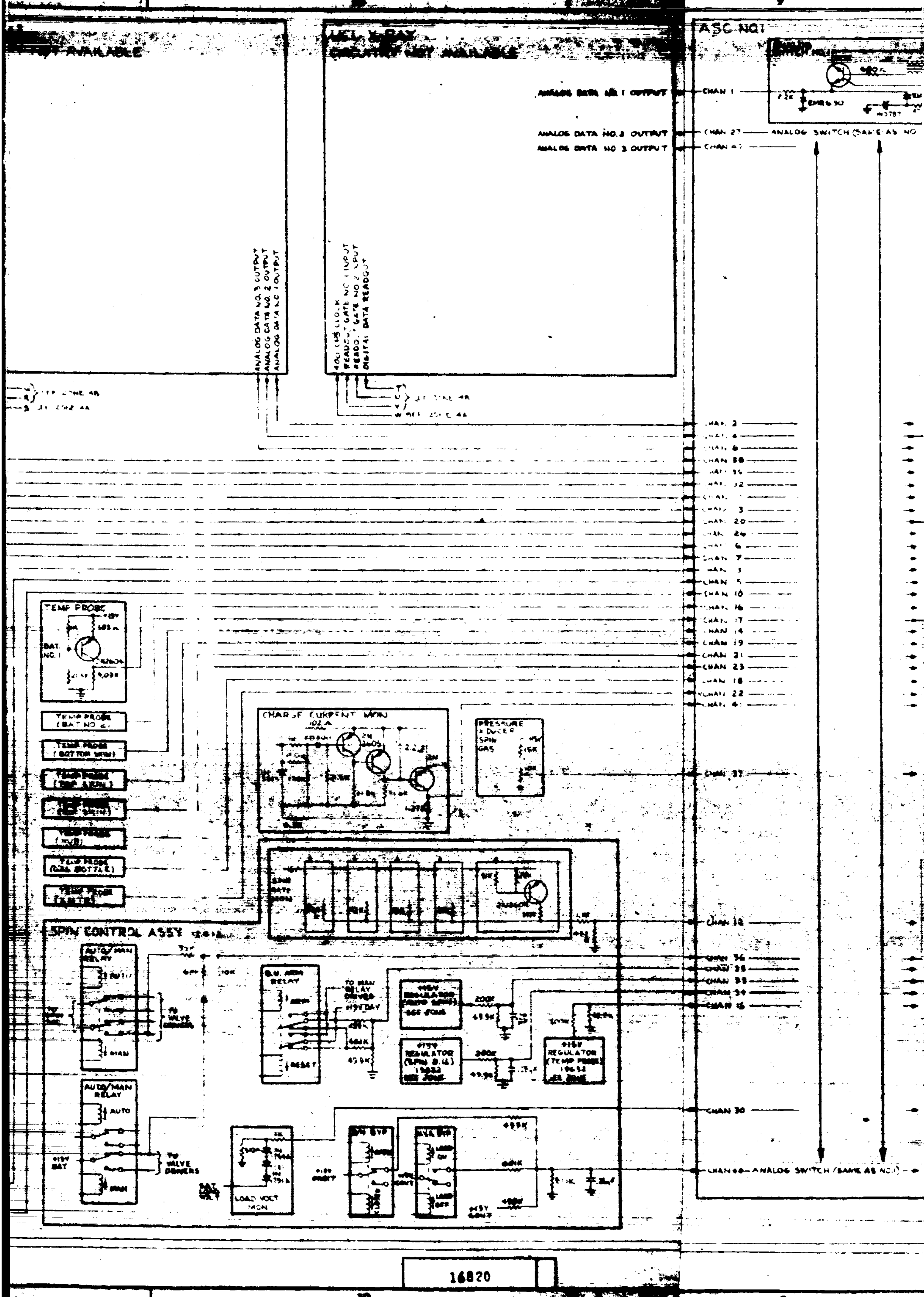
A simplified block diagram of an ASC is shown in Figure 4-4. Each ASC is provided with 47 parallel analog input channels. The analog channels feeds directly to a "first-tier" analog switch circuit which is closed on command of a "first-tier" decoder circuit. The analog channels are then fed to a "second-tier" decoder circuit which selects the channel to be sampled on command of a "second-tier" decoder circuit. Timing for the decoder circuit switching trees is provided by flip-flops number 1 through number 7 which, in conjunction with a feed-back loop, form a seven-stage 48 module counter which counts the incoming ASC trigger pulses. The ASC timing chart is shown in Figure 4-5.

47,1

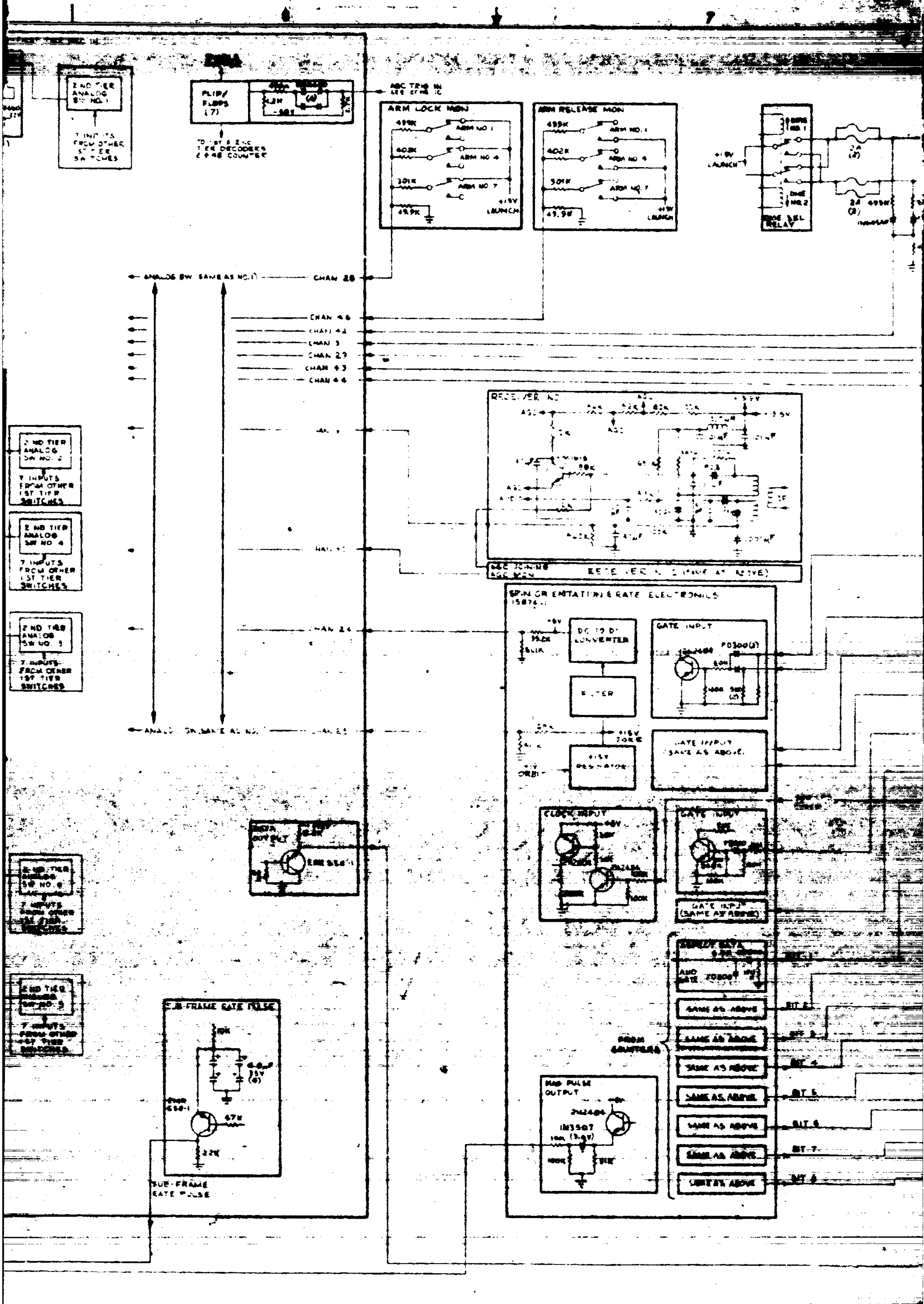


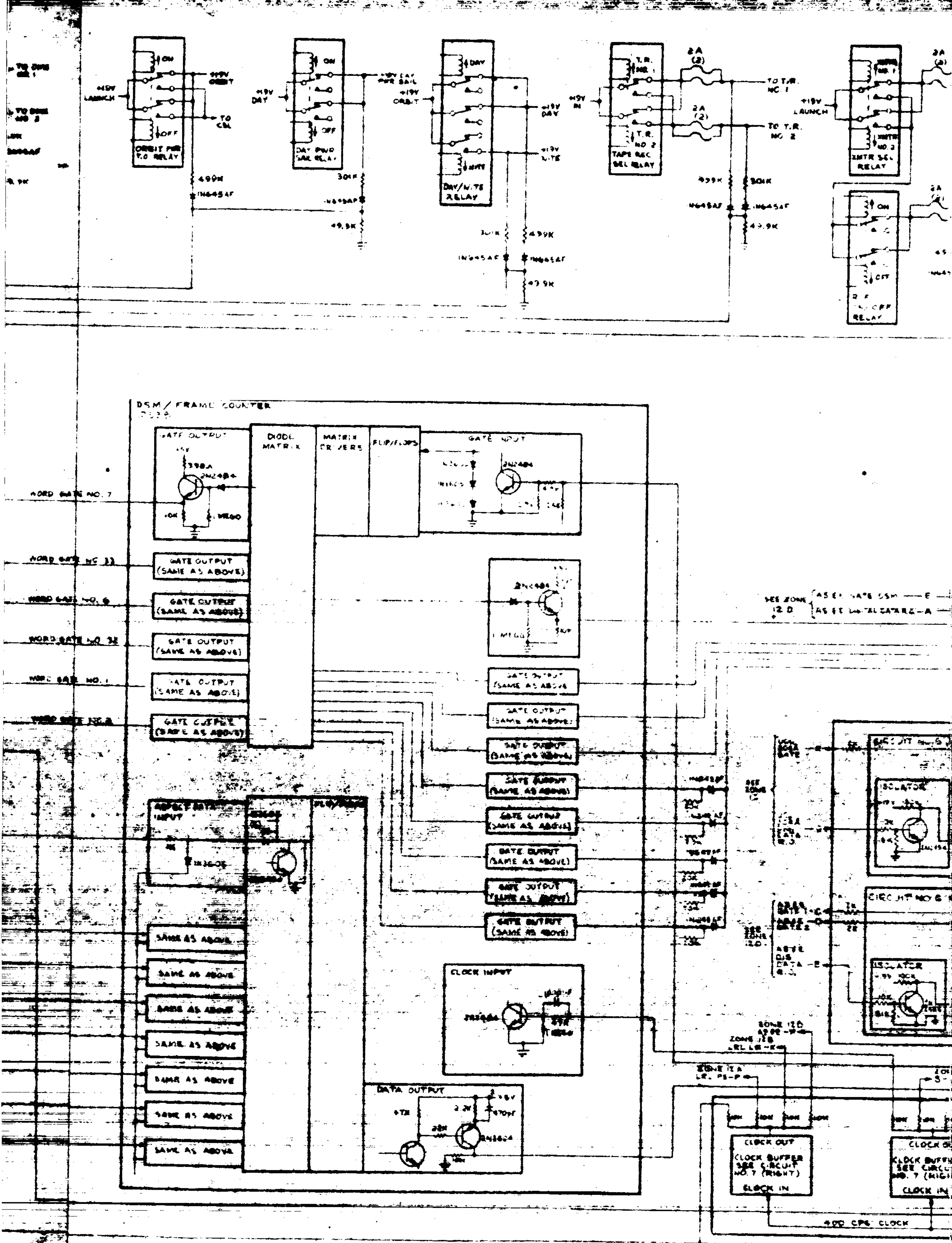
DIGITAL DATA READOUT
A SEE ZONE 4C
DIGITAL DATA READOUT
B SEE ZONE 4B
ANALOG DATA READOUT NO. 1
ANALOG DATA READOUT NO. 2
SUB-FRAME RATE PULSE IN
READOUT GATE NO. 1 INPUT
READOUT GATE NO. 2 INPUT
C
D
SEE ZONE 4B
REAL READOUT GATE INPUT
E SEE ZONE 4C
400 CPS CLOCK INPUT
F SEE ZONE 5A
X-RAY
SUB-FRAME RATE PULSE INPUT
ANALOG DATA READOUT
ANALOG DATA NO. 5 READOUT
ANALOG DATA READOUT (SAME AS ABOVE)
ANALOG DATA READOUT (SAME AS ABOVE)
ANALOG DATA READOUT (SAME AS ABOVE)
ANALOG DATA NO. 4 READOUT
NRL
SUB-FRAME RATE PULSE INPUT
ANALOG DATA NO. 2 READOUT
PE
ANALOG DATA READOUT
SUB-FRAME RATE PULSE IN
MAG PULSE
ANALOG DATA READOUT
READOUT GATE INPUT
ANALOG DATA READOUT
ANALOG DATA NO. 3 READOUT
READOUT GATE NO. 1 INPUT
L
M
N
SEE ZONE 4A
P SEE ZONE 5A
DIGITAL DATA READOUT
400 CPS CLOCK INPUT
12
11

47, 2

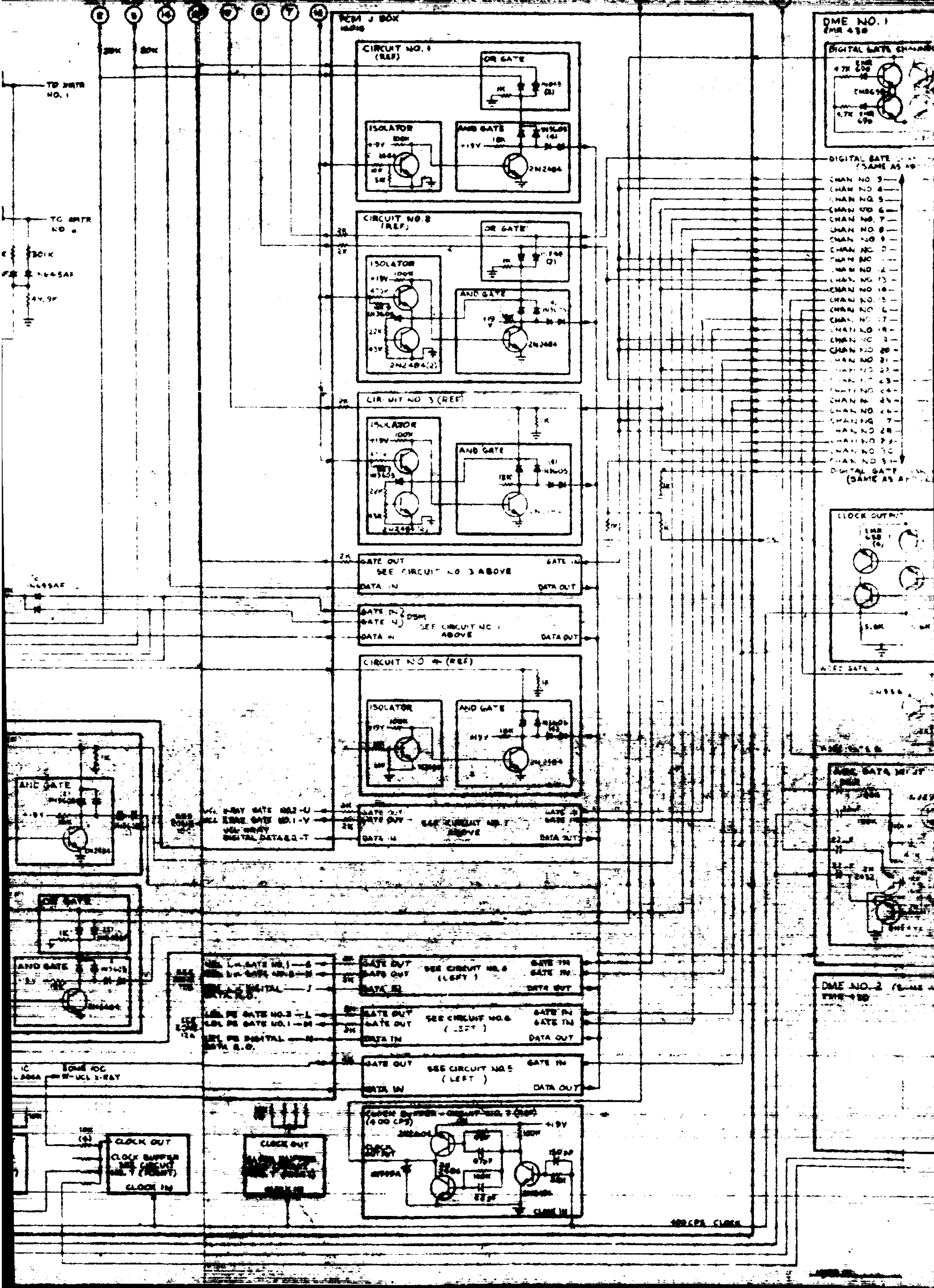


ASC NO1
ANALOG DATA NO. 2 OUTPUT
ANALOG DATA NO 3 OUTPUT
ANALOG SWITCH (SAME AS NO
CHAN 1
CHAN 27
CHAN 2
CHAN 6
CHAN 20
CHAN 24
CHAN 7
CHAN 5
CHAN 10
CHAN 19
CHAN 21
CHAN 23
CHAN 22
CHAN 30
TEMP PROBE
BAT NO. 1
CHARGE CURRENT MON
PRESSURE
SPIN CONTROL ASSY
AUTO/MAN RELAY
AUTO
MAN
TO VALVE DRIVERS
LOAD VOLT MON
REGULATOR
ANALOG SWITCH (SAME AS NO.1)
16820
10

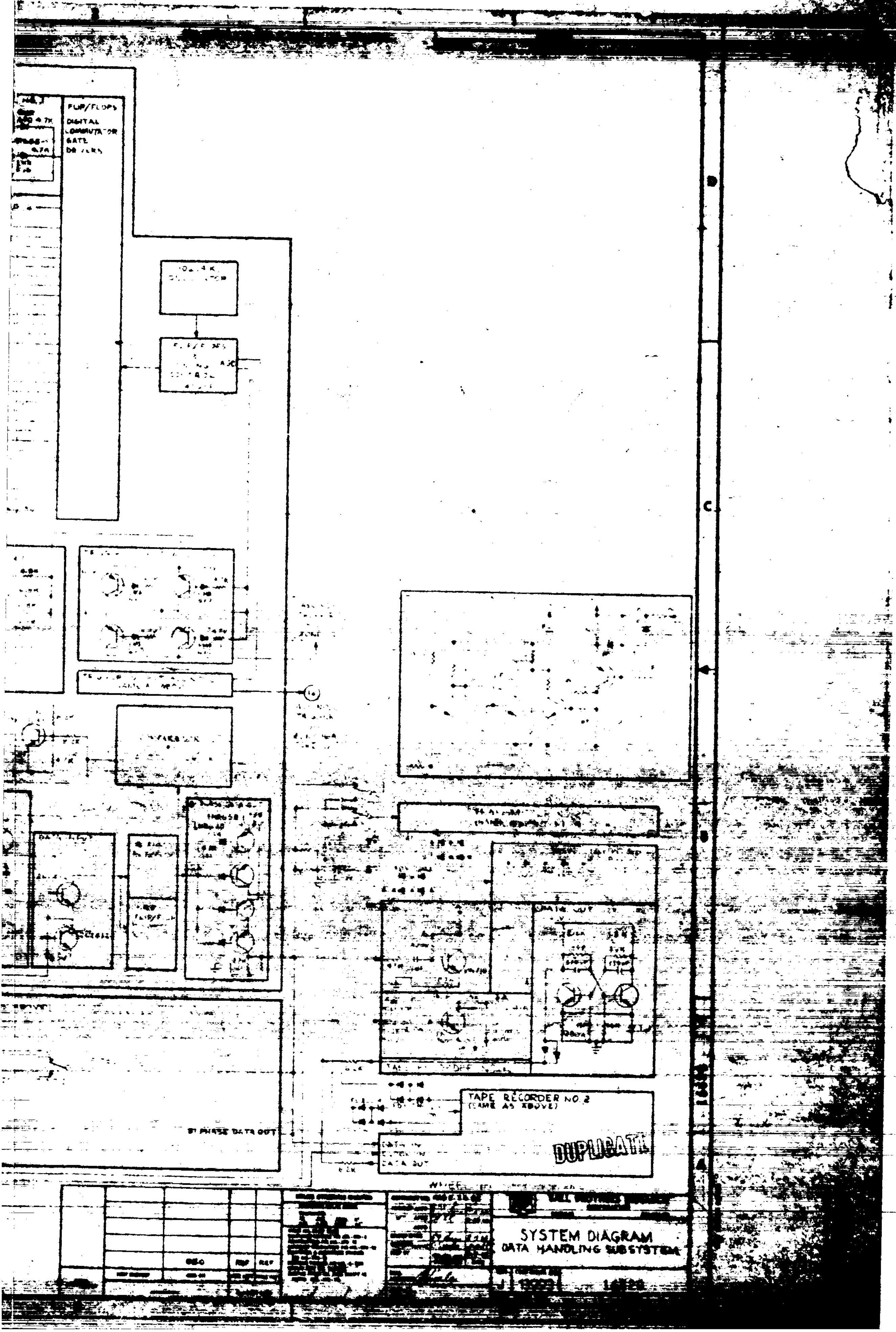

2ND TIER ANALOG SW NO. 1
7 INPUTS FROM OTHER 1ST TIER SWITCHES
FLIP/FLOPS (7)
AGC TRIG IN
ARM LOCK MON
ARM RELEASE MON
499K
402K
301K
49.9K
ARM NO. 1
ARM NO. 4
ARM NO. 7
+15V LAUNCH
ANALOG SW (SAME AS NO. 1)
CHAN 28
CHAN 46
CHAN 42
CHAN 27
CHAN 43
CHAN 44
RECEIVER NO.
2ND TIER ANALOG SW NO. 2
2ND TIER ANALOG SW NO. 4
2ND TIER ANALOG SW NO. 3
CHAN 24
SPIN ORIENTATION & RATE ELECTRONICS
DC TO DC CONVERTER
FILTER
GATE INPUT
GATE INPUT (SAME AS ABOVE)
+15V REGULATOR
CLOCK INPUT
DATA OUTPUT
AND GATE
SAME AS ABOVE
FROM COUNTERS
BIT 2
BIT 3
BIT 4
BIT 5
BIT 6
BIT 7
BIT 8
SUB-FRAME RATE PULSE
MAG PULSE OUTPUT
2N2484
1N3507
DIODE SEL RELAY

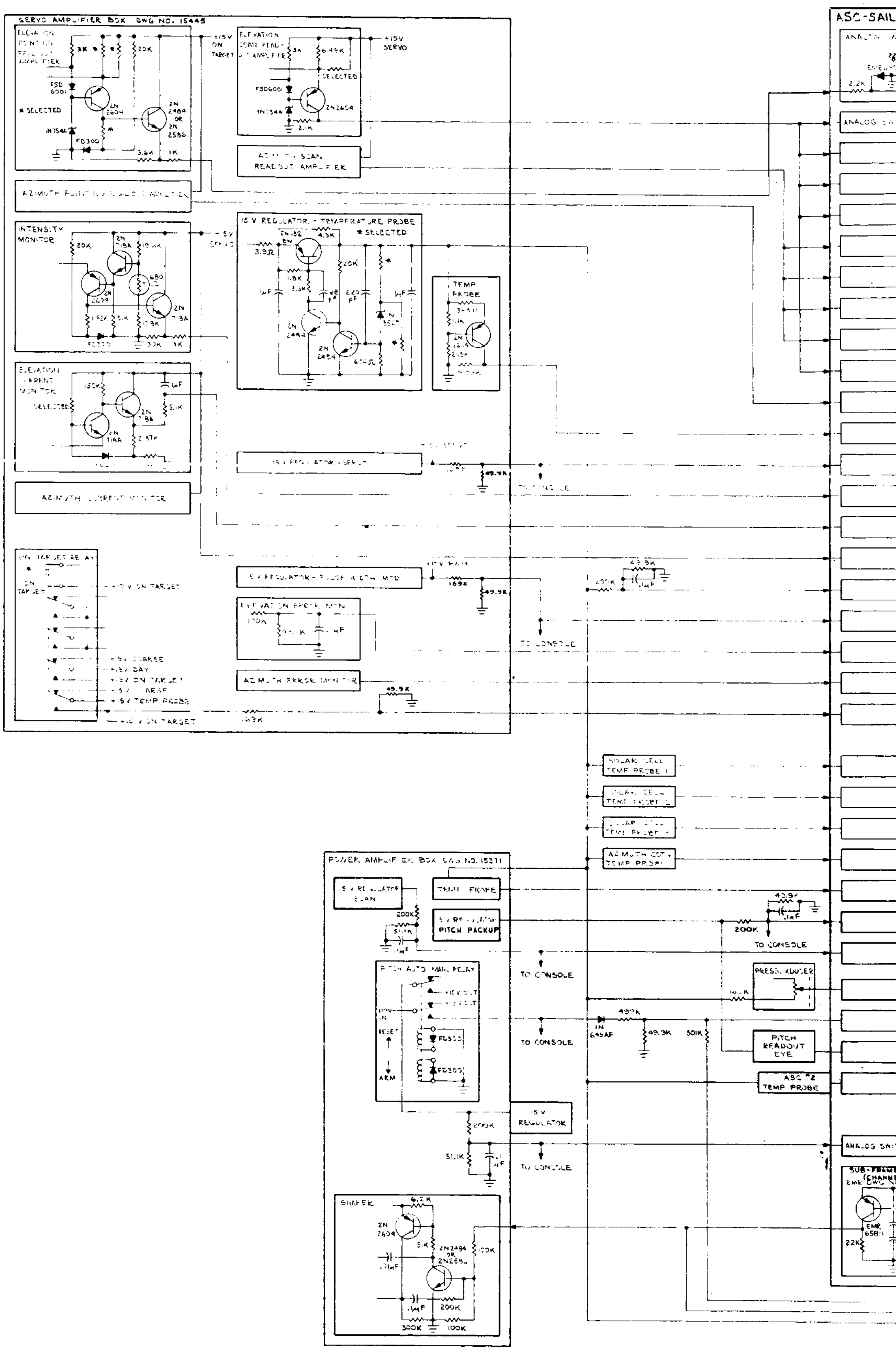

ORBIT PWR T.O RELAY
DAY PWR SAIL RELAY
DAY/NITE RELAY
TAPE REC SEL RELAY
XMTR SEL RELAY
+19V LAUNCH
+19V ORBIT
+19V DAY
+19V NITE
TO T.R. NO 1
TO T.R. NO 2
499K
1N645AF
49.9K
DSM / FRAME COUNTER
GATE OUTPUT
DIODE MATRIX
MATRIX DRIVERS
FLIP/FLOPS
GATE INPUT
2N2484
WORD GATE NO. 7
GATE OUTPUT (SAME AS ABOVE)
SAME AS ABOVE
CLOCK INPUT
DATA OUTPUT
2N3634
ISOLATOR
CLOCK OUT
CLOCK BUFFER SEE CIRCUIT NO. 7 (RIGHT)
CLOCK IN
400 CPS CLOCK

16820



PCM J BOX
CIRCUIT NO. 1 (REF)
OR GATE
ISOLATOR
AND GATE
2N2484
TO XMTR NO. 1
CIRCUIT NO. 2 (REF)
2N2484 (2)
CIRCUIT NO. 3 (REF)
GATE OUT
SEE CIRCUIT NO. 3 ABOVE
GATE IN
DATA IN
DATA OUT
SEE CIRCUIT NO. 1 ABOVE
CIRCUIT NO. 4 (REF)
SEE CIRCUIT NO. 6 (LEFT)
SEE CIRCUIT NO. 5 (LEFT)
CLOCK OUT
CLOCK IN
100 CPS CLOCK
DME NO. 1
DIGITAL GATE
CHAN NO. 3
CHAN NO. 4
CHAN NO. 5
CHAN NO. 6
CHAN NO. 7
CHAN NO. 8
CLOCK OUTPUT
DME NO. 2


FLIP/FLOPS
DIGITAL
COMMUTATOR
GATE
DRIVERS
TAPE RECORDER NO. 2
(SAME AS ABOVE)
DATA IN
DATA OUT
BI PHASE DATA OUT
DUPLICATE
SYSTEM DIAGRAM
DATA HANDLING SUBSYSTEM



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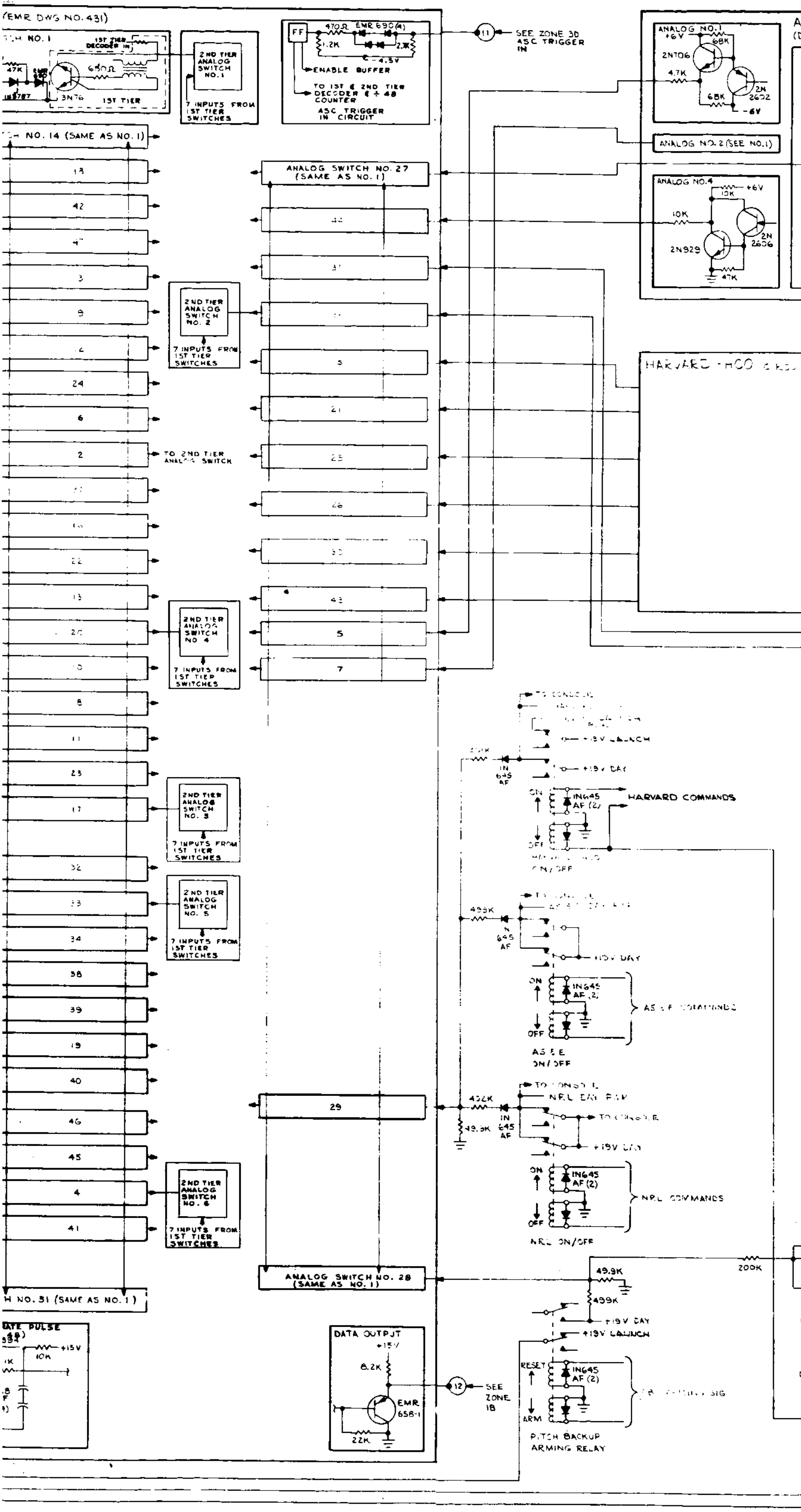
4-8, 1


(EMR DWG NO. 431)
1ST TIER DECODER IN
3N76
1ST TIER
2ND TIER ANALOG SWITCH NO. 1
7 INPUTS FROM 1ST TIER SWITCHES
FF
EMR 690(4)
ENABLE BUFFER
TO 1ST & 2ND TIER DECODER & ÷ 48 COUNTER
ASC TRIGGER IN CIRCUIT
SEE ZONE 3D ASC TRIGGER IN
ANALOG NO. 1
2N706
ANALOG NO. 2 (SEE NO. 1)
ANALOG NO. 4
2N929
NO. 14 (SAME AS NO. 1)
ANALOG SWITCH NO. 27 (SAME AS NO. 1)
2ND TIER ANALOG SWITCH NO. 2
TO 2ND TIER ANALOG SWITCH
2ND TIER ANALOG SWITCH NO. 4
2ND TIER ANALOG SWITCH NO. 3
2ND TIER ANALOG SWITCH NO. 5
2ND TIER ANALOG SWITCH NO. 6
HARVARD COMMANDS
NRL COMMANDS
+19V LAUNCH
+19V DAY
ANALOG SWITCH NO. 28 (SAME AS NO. 1)
NO. 31 (SAME AS NO. 1)
DATA OUTPUT
EMR 658-1
SEE ZONE 1B
RESET
ARM
PITCH BACKUP ARMING RELAY

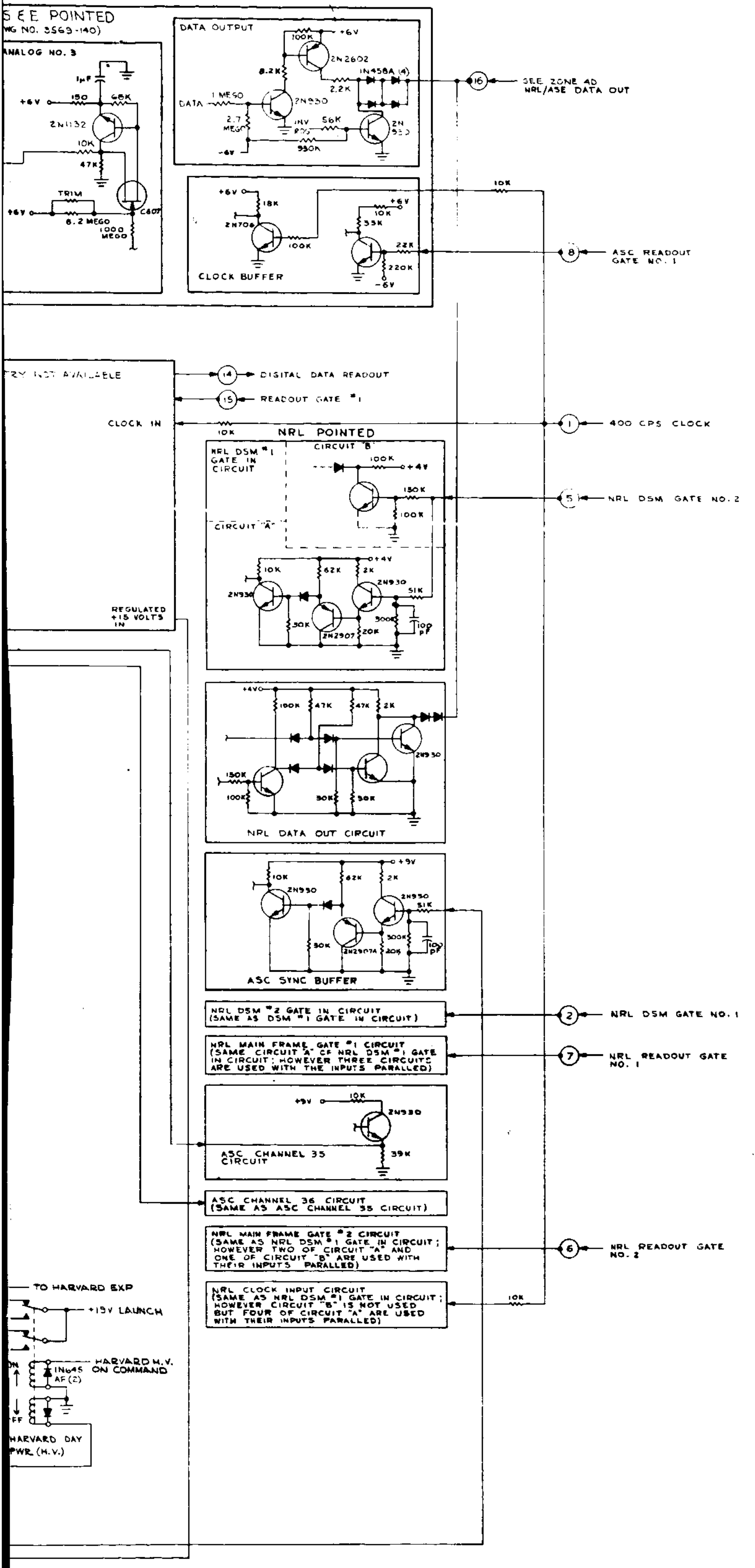


Figure 4-2—Telemetry System Diagram (Sheet 2 of 2)

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4-8, 2 3

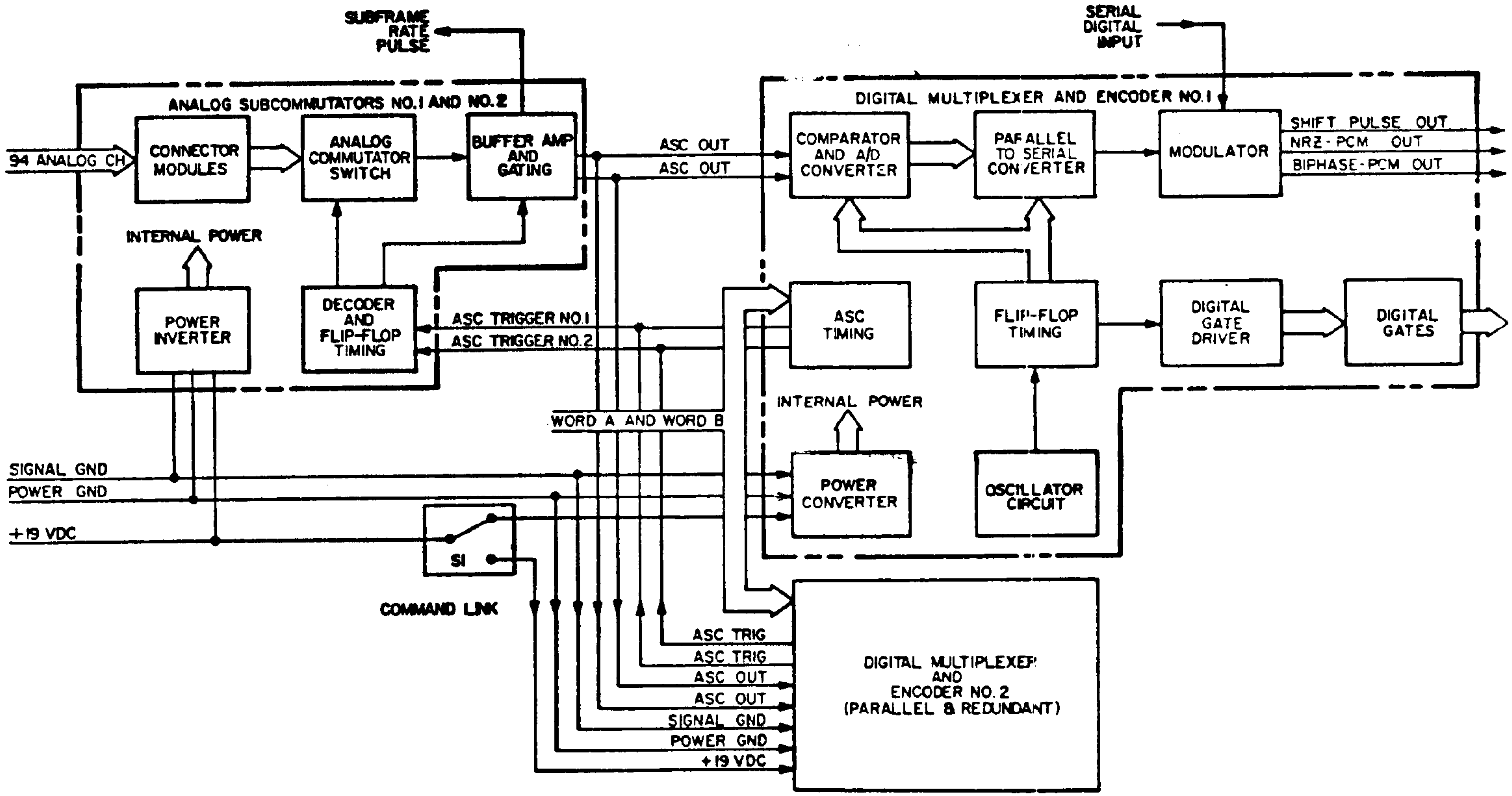


Figure 4-3—Data Handling System, Simplified Diagram

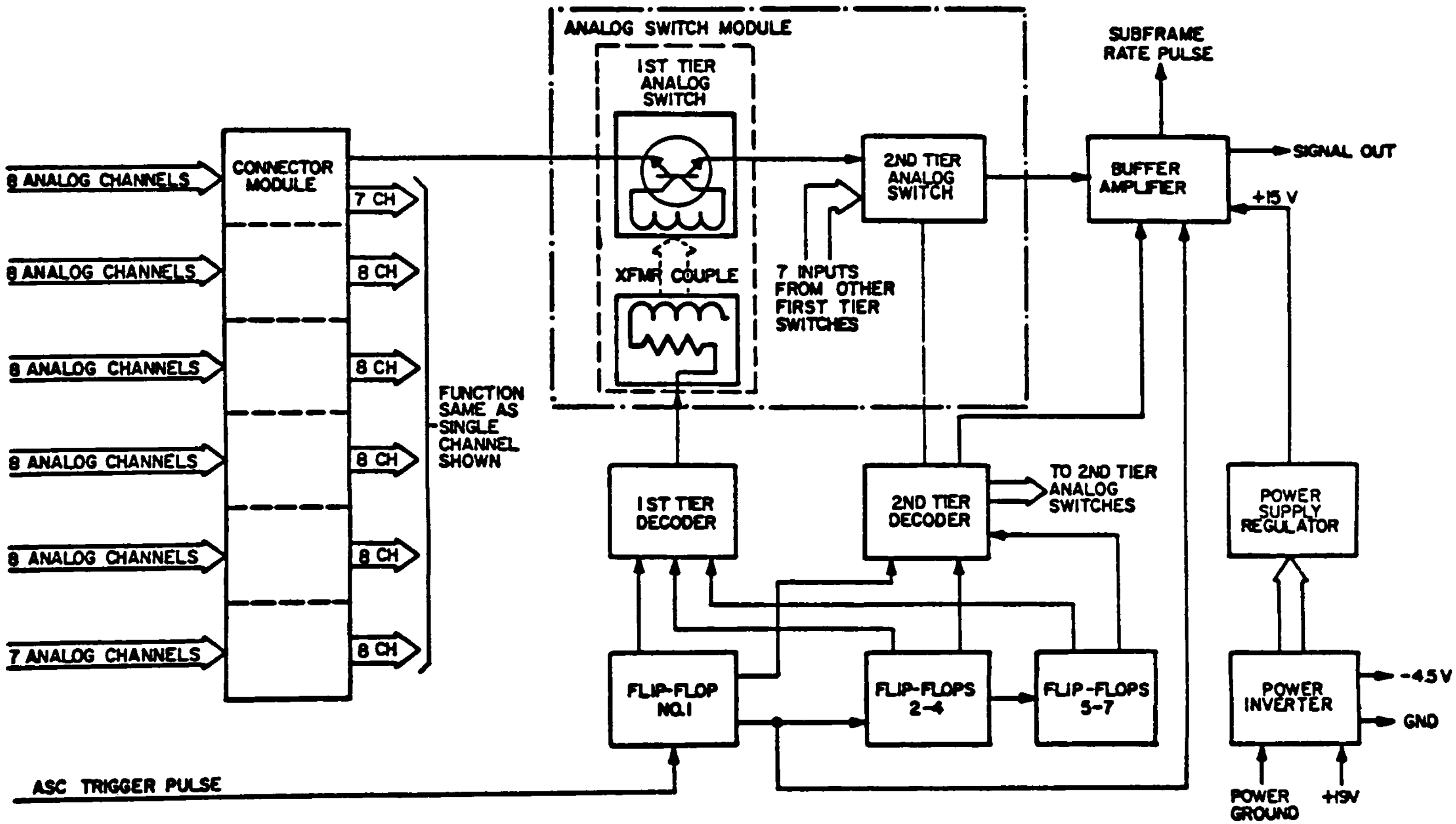


Figure 4-4—ASC Simplified Block Diagram

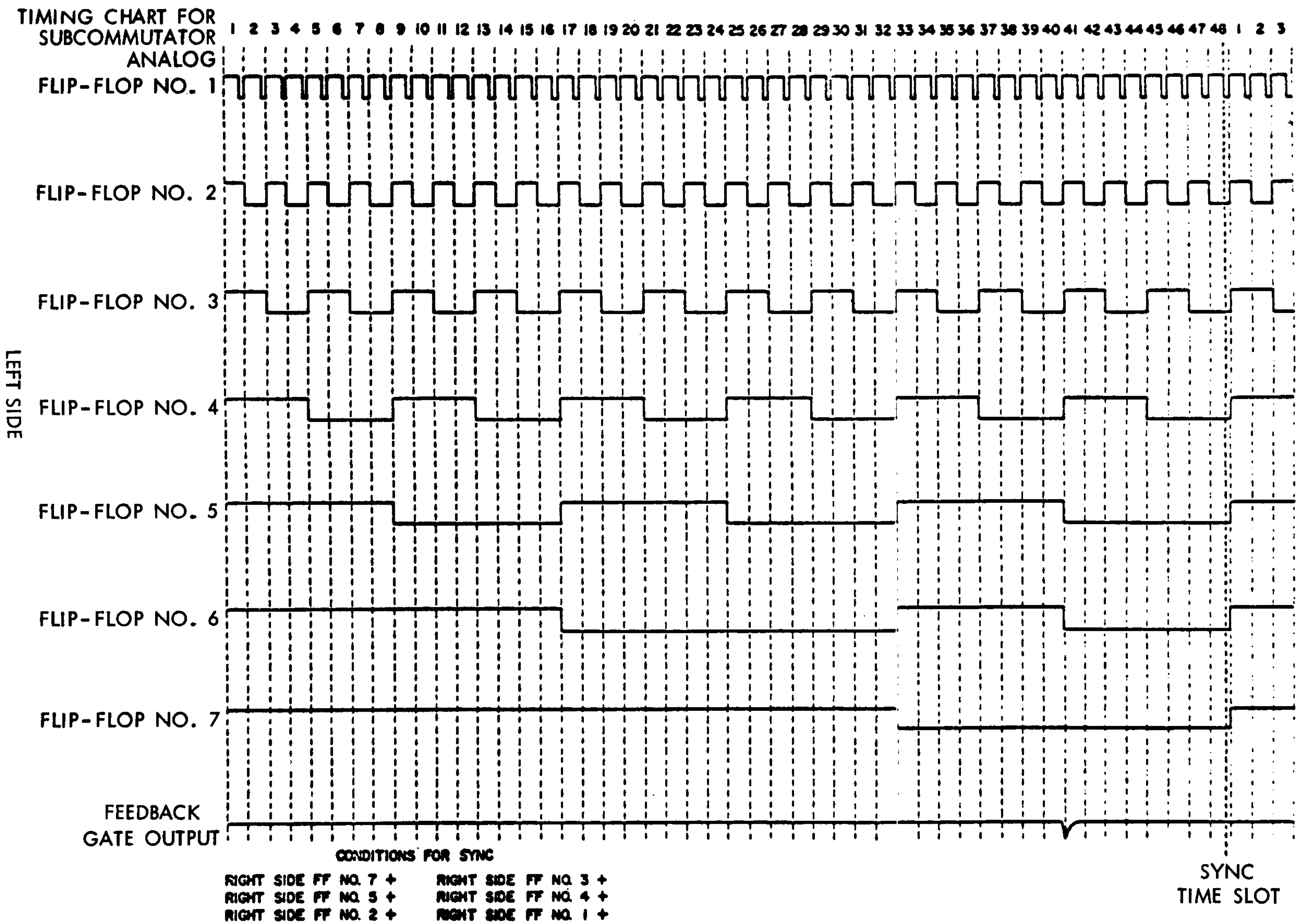


Figure 4-5–ASC Timing Chart

4.3.1.2 Digital Multiplexer and Encoder (DME)

A simplified block diagram of the DME is shown in Figure 4-6. As shown in this diagram, each single block represents a module, while the entire block represents a functional entity.

Either of the data outputs is comprised of a serial format main frame of data composed of 32 digital words (or subframes). Each main frame of data contains two frame-synchronizing words and 30 words of data. Two of the 30 words of data are normally derived from the analog data presented to the input of the DME from the 94 channels of analog input data at the ASC. The remaining 28 words of output data are obtained from the serial binary-coded digital input data with the input at the modulator circuit. The digital gating signals at the output, in conjunction with the shift pulse, are used in obtaining the serial digital input data from the spacecraft instrumentation. The sampling of analog data is initiated by the ASC timing control module (386) and the sampled analog data is then presented to the comparator module (454). The sampled analog data is then encoded into a paralleled eight-bit binary code and read from the parallel-to-serial converter module (371) when interrogated by the digital commutator circuit. All digital input data is applied to the modulator module (371) for conversion in NRZ and biphase pulse trains for transmission at a rate of either 400 or 800 pps. The output bit rate is selected externally at the output on a connector of the connector module.

The 32 main frame digital gating signals are generated internally by a digital commutator circuit comprising the timing flip-flops, digital gate drivers (in the form of a switching tree matrix) and digital output gates.

Power for each DME is provided by a power converter circuit which utilizes spacecraft primary power. Spacecraft primary power is applied to only one DME at a time via the command link relay. Thus, only one of the two DME units of the system are operative at any one time. The DME timing pulses are shown in Figure 4-7.

4.3.2 Physical Description

The two ASC packages and the two DME packages are identical in physical configuration, therefore, for purposes of description, only one each of the two units are described.

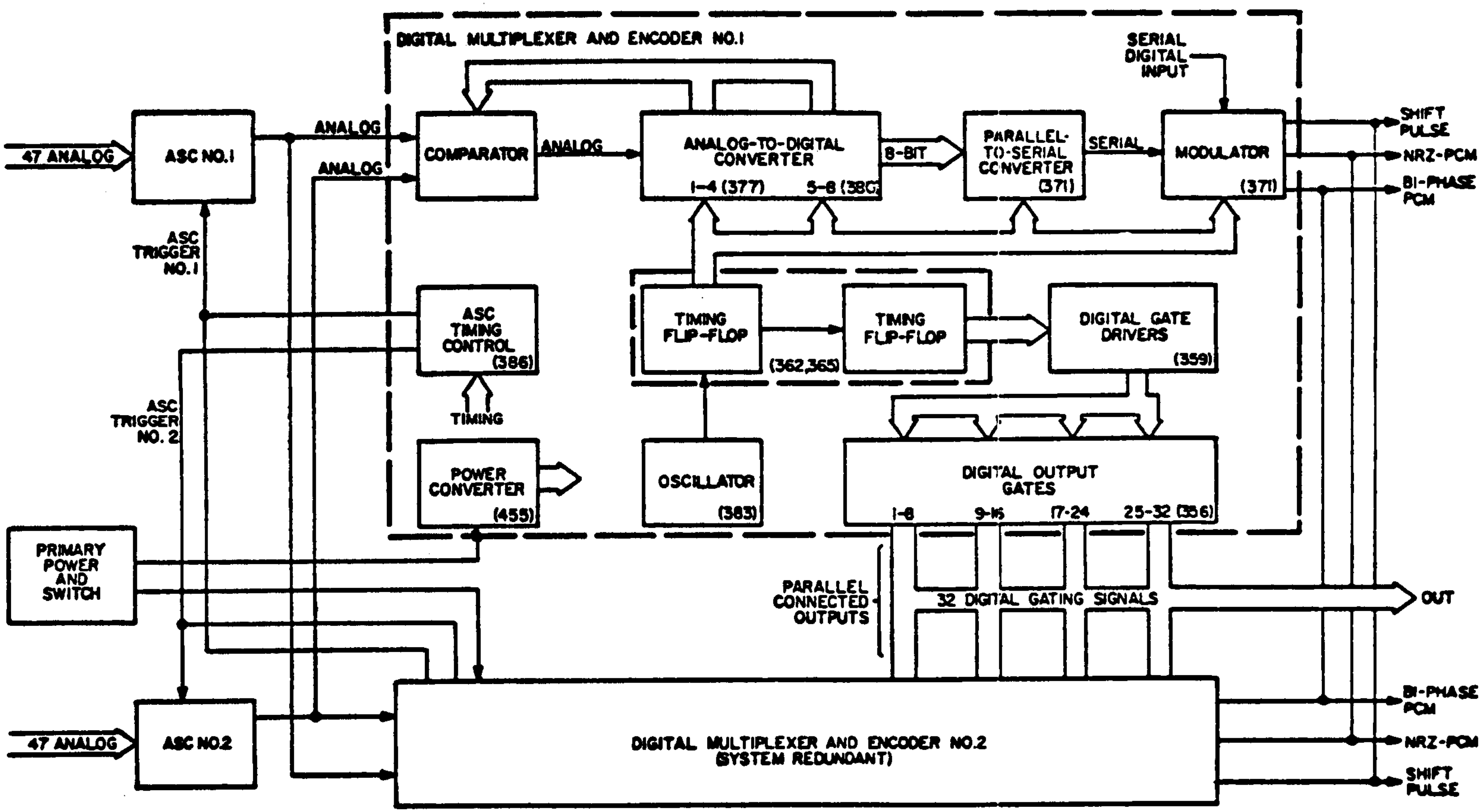


Figure 4-6–DME, Simplified Block Diagram

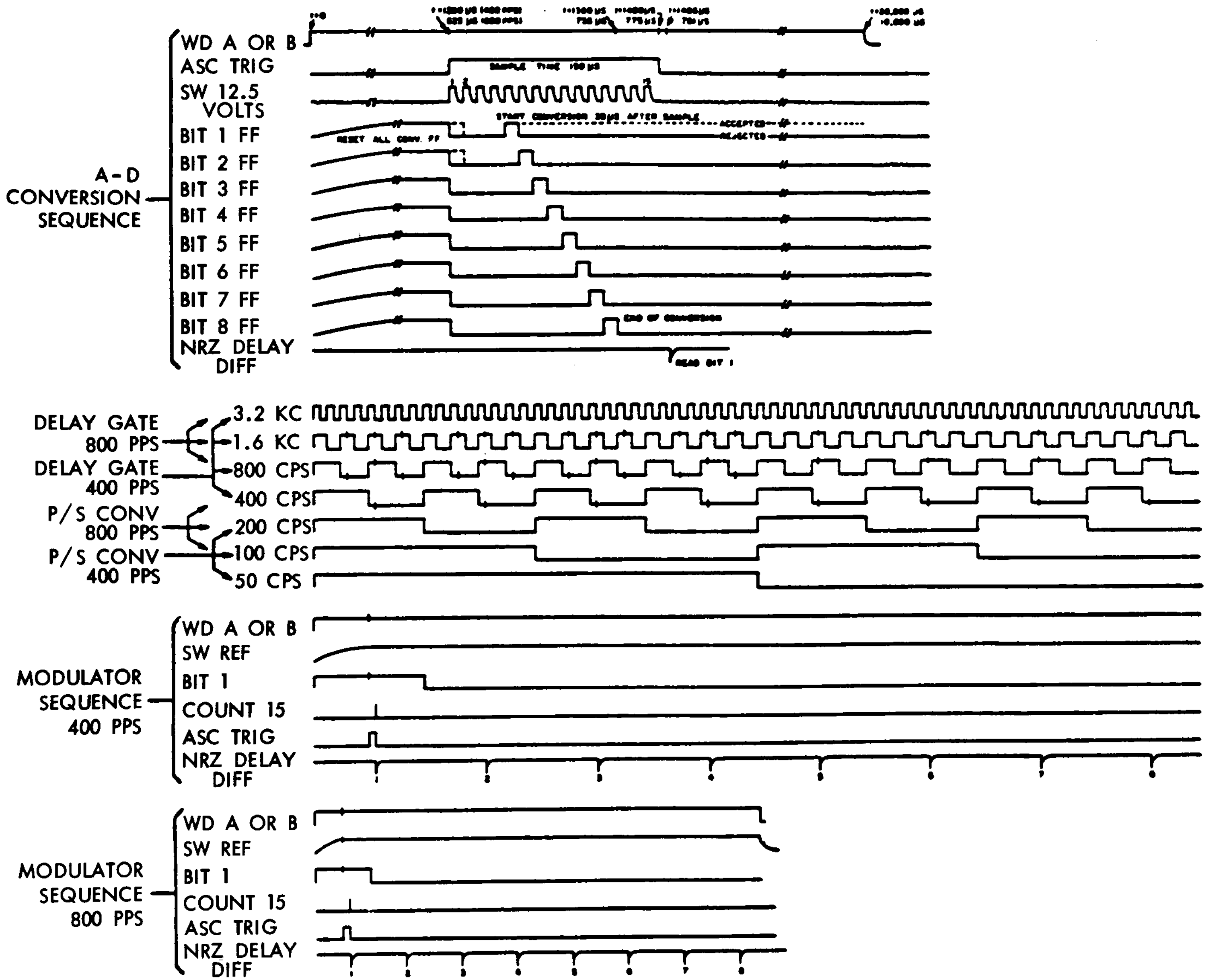


Figure 4-7—DME Timing Chart

4.3.2.1 Analog Subcommutators

Each ASC is contained in a case approximately 2.62 inches high by 3.25 inches wide by 6.00 inches long, and weighs less than 45 ounces. The units contain 12 potted module assemblies and one shielded assembly mounted to, and within, the case assembly. All input and output connections to the module, which project through one end of the case. The entire 13 potted modules of the assembly are encapsulated within the case, and are secured by four lock-screw assemblies to the case. The open end of the encapsulated assembly is covered by a cover base plate which contains mounting holes for securing the assembly in the spacecraft, and the entire assembly is sealed with an epoxy compound.

4.3.2.2 Digital Multiplexer and Encoder

The entire DME is contained in a case approximately 4.58 inches wide by 3.10 inches deep by 6.75 inches long, and weighs less than 70 ounces. Each DME contains 14 potted module assemblies and two shielded and potted module assemblies mounted to, and within, the case assembly. All input and output connections to the DME are via three connectors mounted to a module at one end of the case. All 16 module assemblies are encapsulated in the case sleeve, and are secured by four lock-screw assemblies to the case ends. The mounting holes for the encapsulated assembly are located at the case-end opposite the connectors. The entire assembly is sealed with an epoxy compound.

4.3.3 Data Allocations

Table 4-1 shows the OSO-D main frame word allocation. Tables 4-2 through 4-4 list the wheel and sail commutator channels and the points measured. Note that there are 48 channels for each subcommutator.

4.4 DATA STORAGE AND REPRODUCTION

Because there are not enough data acquisition stations to collect real time data from the spacecraft continuously during the orbit period, it is necessary to have a device for storing and reproducing data aboard the spacecraft. The description given is typical and may vary slightly from spacecraft to spacecraft.

4.4.1 Digital Tape Recorder/Reproducer

The purpose of the digital tape recorder is to store digital information at the rate of 400 bits per second for a period of 100 minutes and to reproduce this information, on command, at a speed 18 times faster in a period of five minutes.

Table 4-1
OSO-D Main Frame Word Allocation

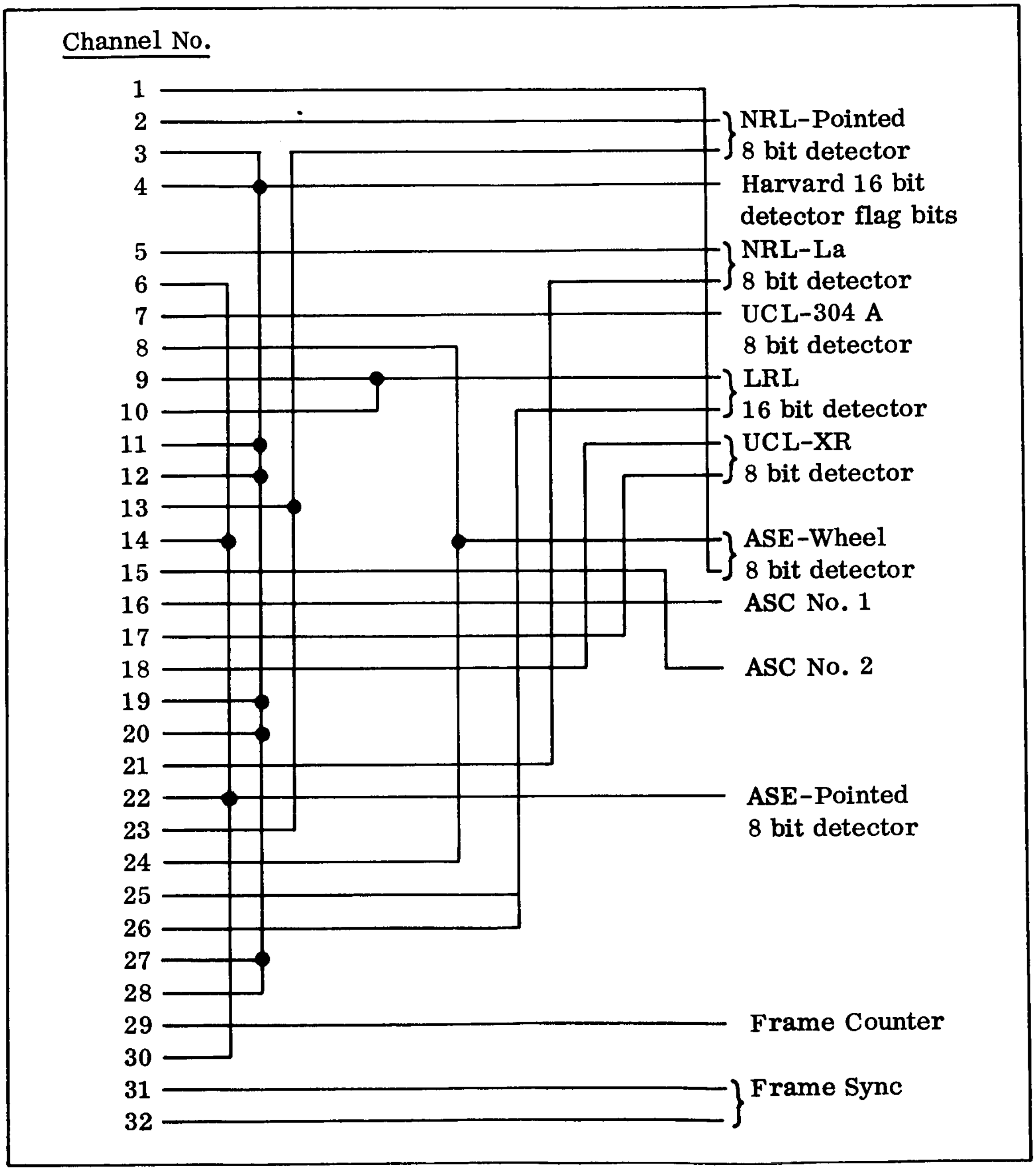


Table 4-2
OSO-D Frame Counter/Submultiplexer Word Allocation

Channel No.	Allocation
1	Sync and SORE – gate only
2	Spare
3	Single bit data (reserved)
4	ASE-Whl Gate No. 1 data state
5, 6	Spare
7	Aspect Data
8	SORE (gate only)
9	Single bit data (reserved)
10, 11, 12, 13, 14	Spares
15, 16, 17, 18, 19, 20	Spares

Channel No.	Allocation
21, 22	NRL-PTD 16 bit data Spectograph position and Single bit Identification
23	Spare
24	ASE-Whl Gate No. 2 data state
25, 26, 27, 28, 29, 30	Spares
31	Frame Count
32, 33	Aspect Data
34, 35, 36	Spares
37	Single bit data (reserved)
38, 39, 40	Spares

Table 4-3
OSO-D Analog Subcommutator Channel Allocation

Channel	Wheel Analog Subcommutator (ASC No. 1)
1	UCL X-Ray 1.6 k.v. Current Monitor
2	UCL 304 Å Peak Reader #1
3	LRL Shutter Position
4	UCL 304 Å Door Position, EHT Volts
5	LRL Power Supply Voltage
6	NRL $L\alpha$ Wheel Position
7	NRL $L\alpha$ Instrument Mode Monitor
8	UCL 304 Å Peak Reader #2
9	Receiver No. 1 AGC
10	LRL Sensitivity Mode Indicator
11	NRL X-Ray .5-3 Å Detector Data
12	Spin Rate Monitor
13	NRL X-Ray 2-8 Å Detector Data
14	Bottom Skin Temperature
15	Temperature Probe 15 Volt Regulator
16	Battery No. 1 Temperature
17	Battery No. 2 Temperature
18	Gas Bottle Temperature
19	Top Skin Temperature
20	NRL X-Ray 8-16 Å Detector Data
21	Rim Skin Temperature
22	Transmitter No. 1 Temperature
23	Hub Temperature
24	5 Volt Monitor – SORE
25	15 Volt Monitor – SORE
26	NRL X-Ray 44-60 Å Detector Data
27	UCL X-Ray 1.3 kv Current Monitor
28	Arm Lock Monitor
29	19 Volt Day-Night Power
30	19 Volt Battery (UVS Load Voltage)
31	Orbit Power, Day Sail
32	NRL X-Ray Wheel Position
33	Spin Circuit 15 Volt Regulator
34	Spin Backup 15 Volt Regulator
35	Spin Backup Arming Relay
36	Spin Auto-Manual Relay
37	Spin Gas Pressure
38	ASE X-Ray Subcommutated by:
	a. Na I detector current (Sodium Iodide)
	b. +4 kv
	c. -1.5 kv
	d. A current (Anthracene detector current)
	e. Wheel Position
	f. +1 kv
	g. A/C (anti-coincident detector) current
	h. -6 Volts
39	ASE X-Ray Subcommutated by:
	a. NaI current (detector count rate)
	b. Ped current detector
	c. A/C current detector
	d. A current detector
40	UVS and Day/Night Bypass Relay
41	Charge Current
42	DME Select
43	Tape Recorder Select
44	Transmitter Select – Transmitter No. 2 On-Off
45	Receiver No. 2 AGC
46	Arm Release
47	UCL X-Ray +6.5v monitor
48	Frame Sync

Table 4-4
OSO-D Analog Subcommutator Channel Allocation

Channel	Sail Commutator (ASC No. 2)	Channel	Sail Commutator (ASC No. 2)
1	Elevation Pointing Readout (Right Exp.)	26	Harvard Grating Position Monitor
2	Azimuth Pointing Readout (Right Exp.)	27	American Science and Engineering No. 3 Door Status, 20 kv and -6V Supply
3	Raster Position Readout (AZ) (1)	28	19 Volt Day Power
4	Pitch Position Readout	29	Experiment Day Power (On-Off)
5	American Science and Engineering FW Position and +6V Supply	30	Harvard +12 V and -5.5 V Monitor
6	Raster Position Readout (E1) (2)	31	15 Volt Automatic Pitch Regulator
7	American Science and Engineering AW Position and +6V Supply	32	Solar Cell Panel Temperature No. 1 (TH 106)
8	15 Volt PWM Regulator	33	Solar Cell Panel Temperature No. 2 (TH 105)
9	Raster Position Readout (AZ) (3)	34	Solar Cell Panel Temperature No. 3 (TH 107)
10	15 Volt Temperature Probe Regulator	35	NRL Subcommutated by: a. NRL HV #1 Volts b. NRL HV #2 Volts c. +4.0 Volts Supply d. package temperature
11	Elevation Error Signal	36	NRL Crystal Temperature
12	Raster Position Readout (AZ) (4)	37	Servo Amplifier Box Temperature
13	Elevation Current Monitor	38	Azimuth Casting Temperature
14	Raster Position Readout (E1) (5)	39	Power Switch Temperature
15	Harvard Electronics Temperature	40	15 Volt Raster Scan Regulator
16	15 Volt Servo Regulator	41	ASC No. 2 Temperature
17	On-Target Signal	42	Raster Position Readout (E1) (8)
18	Raster Position Readout (E1) (6)	43	Harvard +4.3 V and -3 V Monitor
19	15 Volt Pitch Backup Regulator	44	American Science and Engineering +2.4 kv Monitor
20	Azimuth Current Monitor	45	Pitch Automatic-Manual and Backup Arming Relay Monitor
21	Harvard Instrument ΔT	46	Pitch Gas Pressure
22	Solar Intensity Monitor	47	Raster Position Readout (E1) (9)
23	Azimuth Error Signal	48	Sync
24	Raster Position Readout (AZ) (7)		
25	Harvard High Voltage Monitor		

Electronic circuitry allowing storage of 600 bits per inch on the tape permits the tape length to be 300 feet. The shafting configuration consists of a two capstan, single reel device. A two motor approach is employed to bypass clutch problems.

A packaging layout is shown in Figure 4-8. A rectangular configuration is used which requires a gask-o-seal for sealing.

With the conservative two motor approach and with substantial safety factors on torque availability to torque required, the energy consumption for one record/ reproduce cycle is estimated at 130 watt-minutes.

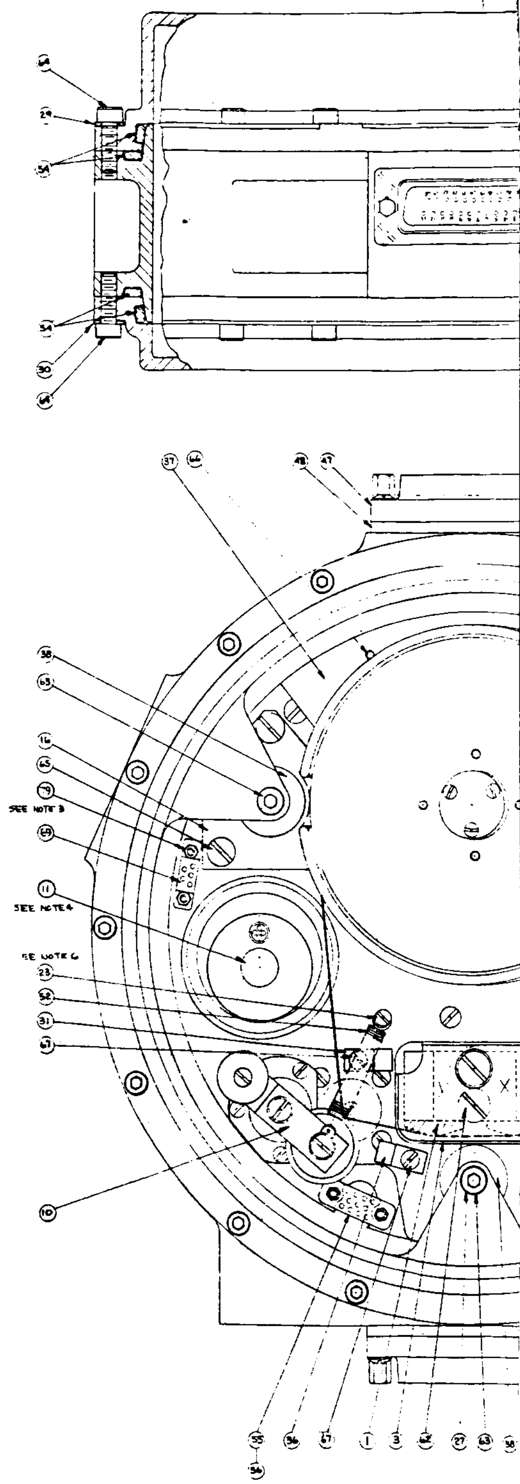
4.4.2 Basic Approach

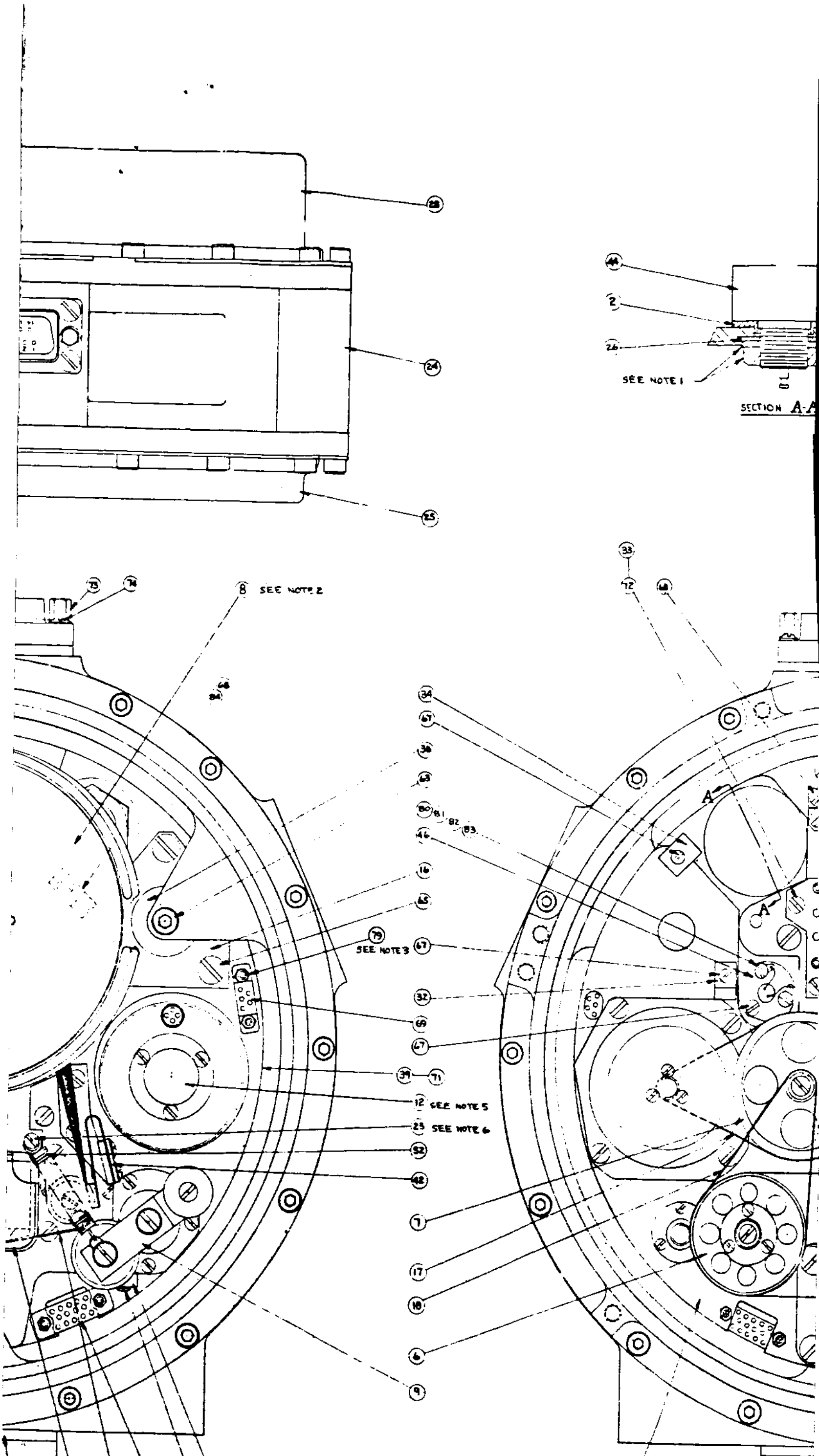
In order to limit the tape length to 300 feet, it is necessary to store the required 2,160,000 bits at a packing density of 600 bits per inch. The electronic system which accommodates this density is shown in Figure 4-9. Tape speed in the record mode is 0.63 inches per second and 12.0 inches per second in the playback mode to provide the 18:1 ratio. The recorder also has a shaft modularization feature which allows for easier recorder disassembly and belt tension adjustment.

The two motor drive configuration strives to bypass problems encountered with solenoid actuated captive spring clutches. The two motor approach involves the use of one motor for record and the other for playback. The record motor is left on continuously and drives the capstans at low speed as long as the playback motor is OFF. However, when the playback motor is turned ON, an overrunning clutch allows the playback motor to override the record motor and drive the capstans at high speed. When the playback motor is turned OFF, the system automatically returns to the record mode.

The recorder incorporates the use of modularized electronics. Each electronic component (record amplifier, playback amplifier, etc.) is made up separately and connected to the general recorder circuitry by internal connectors. The recorder uses 400 cps clock signals which are externally available as synchronizing signals for the recorder's motors.

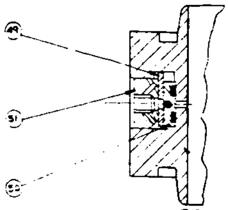
The tape employed is a lubricated LR 1132 tape which was recommended by the Recording Techniques Group at GSFC. It has been life tested by NASA personnel and found to be satisfactory.


SEE NOTE 3
SEE NOTE 4

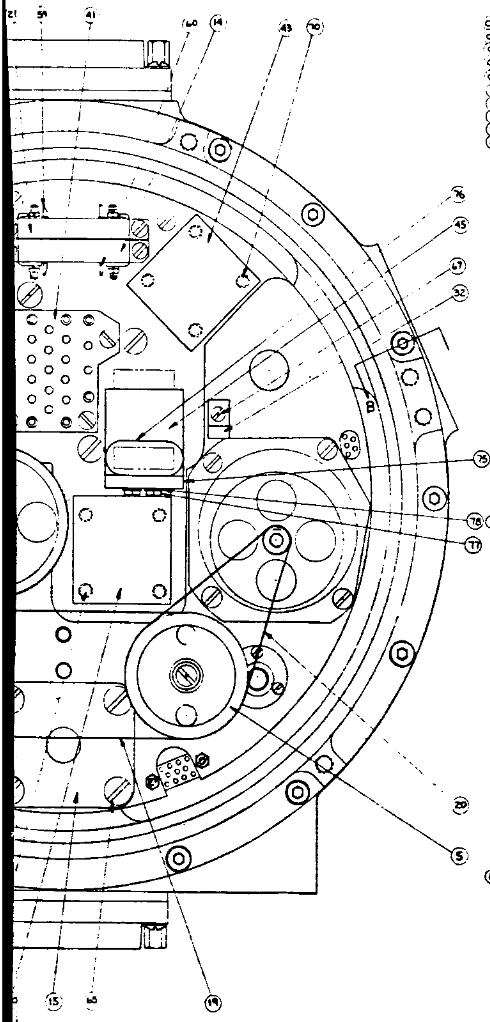


NOTES:

1. ADD LOCKWASHER & LOCTITE "C" TO NUT ON FILTER CAPACITOR #1794-175
2. ADD LOCTITE "C" TO SET SCREWS THAT HOLD ROLLER PINS ON REEL ASSY #1794-52 (4 PLACES)
3. ADD LOCTITE "C" TO HEX NUTS ON SCREW LOCKS FOR CONNECTORS #1360-1-111 (4 PLACES)
4. ADD LOCTITE "C" TO SET SCREW THAT HOLDS PULLEY ON PLAYBACK MOTOR ASSY #1794-55
5. ADD LOCTITE "C" TO SET SCREW THAT HOLDS PULLEY ON RECORD MOTOR ASSY #1794-56
6. ADD LOCKWASHERS & LOCKTITE "C" TO SPRING POST #1794-99 (2 PLACES)



SECTION B-B



C	84	A1794-199	1	CABLE CLAMP
C	83	LL57M2656HQ	2	#2 56 × 7/8 B.H.M.S. (L.L.)
C	82	A1794-198	2	SOLDER LUG
C	81	A1794-197	2	WASHER-THERMISTOR
C	80	A1794-196	2	BUSHING-THERMISTOR
C	79	A1794-86	4	SCREWLOCK CONNECTOR
A	78	A1794-184	4	LOCKWASHER #4
A	77	A1360-45-23	4	NUT, INSTRUMENT #4-40
A	76	A1794-185-2	1	RELAY
A	75	B1794-182	1	BRACKET, RELAY
	74	LL57M4058HQ	8	#4-40 × 1/2 B.H.M.S. (LL)
	73	A1690-81	4	SCREW LOCK
	72	LL57M2658HQ	4	#2-56 × 1/2 B.H.M.S. (LL)
	71	LL57J0084HQ	2	#0-80 × 1/4 F.H.M.S. (LL)
	70	LL57J4054HQ	7	#4-40 × 1/4 F.H.M.S. (LL)
	69	A1360-1-111	2	CONNECTOR, MMS-225S
	68	LL57M2652HQ	5	#2-56 × 1/8 B.H.M.S. (LL)
	67	LL57M2654HQ	7	#2-56 × 1/4 B.H.M.S. (LL)
	66	LL57J2655HQ	2	#2-56 × 5/16 F.H.M.S. (LL)
	65	LL57M6256HQ	10	#6-32 × 3/8 B.H.M.S. (LL)
	64	LL57U628BHQ	28	#6-32 × 1/2 SOC. H.C.S. (LL)
	63	LL57U828BHQ	3	#8-32 × 1/2 SOC. H.C.S. (LL)
	62	LL57M82518HQ	2	#8-32 × 1 1/4 B.H.M.S. (LL)
	61			
	60	B1360-1-116	1	CONNECTOR 20 PIN
	59	B1360-1-115	1	CONNECTOR - 20 PIN
	58	B1360-1-114	1	CONNECTOR 14 PIN
	57	B1360-1-113	1	CONNECTOR 14 PIN
	56	B1360-1-112	1	CONNECTOR 11 PIN
	55	B1360-1-106	1	CONNECTOR 11 PIN
	54	MS29513-261	4	VITON O-RING
	53	3M LR 1220	1	300FT. TAPE (3M)
	52	A1690-50	2	TENSION SPRING
	51	A1738-262	1	SET SCREW - #2-20 × 1/4 LG
	50	A1738-202	1	VENT SEAL
	49	A1738-201	1	WASHER-VENT PLUG
	48	B1733-91	2	GASK-O-SEAL
	47	A1733-89	2	PLUG & ADAPTER ASSEM.
	46	B1631-616	1	THERMISTOR ASSEM.
A	45	A1794-185-1	1	RELAY - K2
	44	A1794-175	1	FILTER CAPACITOR
	43	B1794-171	1	FILTER CHOKE ASSEM
	42	C1794-163	1	WIPER BLOCK ASSEM
	41	A1794-153	1	TERMINAL BOARD ASSEM
	40	C1794-152	1	ELECTRONIC TIMER
	39	A1794-138	1	ASSEM CABLE CLAMP
	38	A1794-129	3	VIBRATION ISOLATOR
	37	B1794-122	1	BALANCE WEIGHT
	36	A1794-121	1	CABLE CLAMP
	35	A1794-119	1	CABLE CLAMP
	34	A1794-118	1	CABLE CLAMP
	33	A1794-117	4	SPACER TERMINAL BD.
	32	A1794-114	2	CABLE CLAMP
	31	A1794-113	1	CABLE CLAMP
	30	C1794-112	1	NUT PLATE
	29	C1794-111	1	NUT CLEATS
	28	E1794-109	1	COVER - BOTTOM
	27	A1794-108	1	SPACER - SHOCK MOUNT
	26	A1794-103	1	WASHER-INSULATING
	25	C1794-101	1	COVER - TOP
	24	E1794-100	1	RING HOUSING
	23	A1794-99	2	POST SPRING
A	22			
	21	B1794-81	1	HOUSING CONNECTOR
	20	A1794-77-4	1	BELT - REC. MOTOR TO CAP.
	19	A1794-77-3	1	BELT - CAP. TO CAP.
	18	A1794-77-2	1	BELT - IDLER TO CAP.
	17	A1794-77-1	1	BELT - PB MOTOR TO IDLER
	16	B1794-75	2	COVER - ISOLATOR
	15	B1794-74	1	COVER - ISOLATOR
	14	B1794-73	1	HOUSING - CONNECTOR
	13	E1794-70	1	PLATE - TRANSPORT
	12	C1794-56	1	RECORD MOTOR ASSEM.
	11	C1794-55	1	PLAYBACK MOTOR ASSEM.
	10	C1794-53-2	1	PRESSURE ROLLER ASSEM.
	9	C1794-53-1	1	PRESSURE ROLLER ASSEM.
	8	C1794-52	1	TAPE REEL ASSEM.
	7	C1794-51	1	IDLER ASSEM.
	6	C1794-50-2	1	CAPSTAN ASSEM.
	5	C1794-50-1	1	CAPSTAN ASSEM.
	4	C1794-40	1	CASE - HEAD SHIELD
	3	B1794-39	1	COVER - HEAD SHIELD
	2	A1794-33	1	SPACER
	1	C1794-7	1	RECORD/REPRODUCE HEAD

E1794-178

C

Figure 4-8–Recorder Packaging Layout

(1)

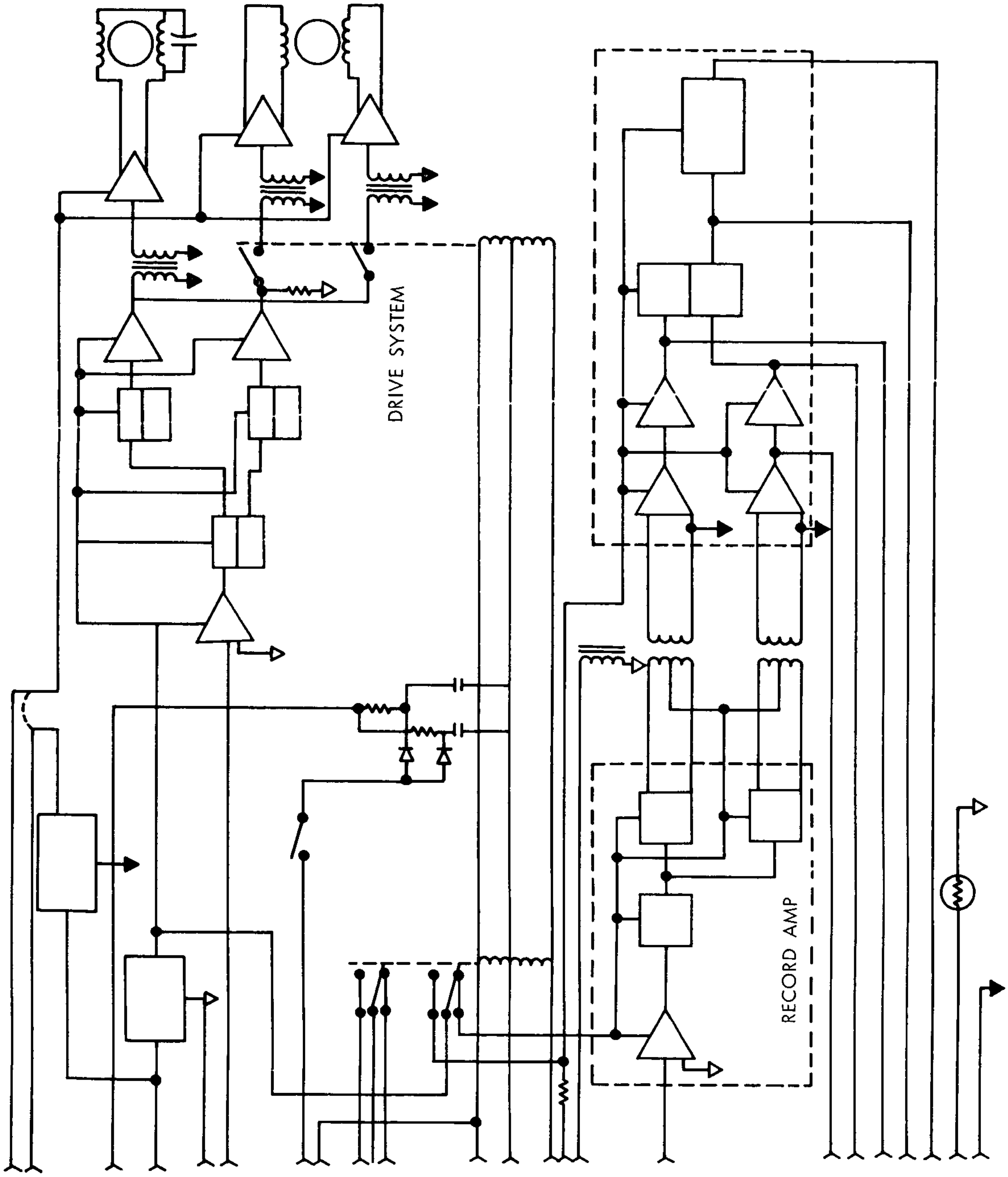


Figure 4-9—Recorder Block Diagram

4.4.3 Electronics

The recorder is required to accept a maximum pulse repetition rate of 400 cycles per second, which at a recording speed of between 0.6 and 0.65 inches per second, results in a packing density of approximately 600 to 650 pulses per inch or 1200 to 1300 flux reversals per inch. Because of the characteristics of the biphase RZ code, the minimum pulse packing will be approximately 600 to 650 flux reversals per inch, which would be the wave from resulting from a chain of successive ones and zeros.

On the OSO-B2, the input coding consisted of two distinct pulse widths, one twice as long as the other, one-shot reconstruction of the output signal was not possible. It was necessary to reproduce pulses representing both the rise and fall of each code bit. Pulses representing these instances could not be put on one channel because of packing density problems. Those representing the rise time were put on one channel by the use of two channel record and playback heads as shown in Figure 4-9. By the aforementioned method, an actual packing density of 1200 to 1300 flux reversals per inch was achieved on magnetic tape. By making use of two channels, the inherent problems of pulse stretching and resulting phase shift were eliminated.

It is believed that any shift due to skew between the channels is eliminated by the use of comparatively low frequencies and the heavy magnetization resulting therein. Any variation in time between the first and second pulses is mainly due to mechanical jitter.

In addition to the components described, the electronics network contains an erase oscillator to provide automatic erasure upon playback. Also because of the rather large fluctuation of the supply voltage, a voltage regulator for the playback and record electronics is necessary to maintain the output voltage within ±10%.

The remaining major electronic subsystem consists of the drive electronics for the record and playback motors which are also shown in Figure 4-9. Because both motors are the two phase, synchronous hysteresis type, it is necessary to provide a transistorized power inverter for each phase.

Because of the availability of synchronous motors for 100 cycle operation, a high degree of speed and ratio stability is obtained by making use of the 400 cycle pulse in the spacecraft. This pulse is applied to the recorder pulse amplifier which has a high input impedance to eliminate any loading on the 400 cycle source, and then to a series of three binaries to provide count down to 100 cps. The output of each binary is then fed to two bridge type power amplifiers, each of which provides power amplification for one phase of the record and playback motors respectively. By making use of the stable clock pulse frequency, exact motor speed control is obtained along with a consistent playback record ratio.

4.4.3.1 Record Electronics

The record electronics circuitry is shown in Figure 4-10. It consists of a single stage pulse amplifier having an input impedance in excess of 20,000 ohms. Transistor T-1 amplifies the input pulse to saturation, and a differentiating network consisting of R-1 and C-1 provides positive and negative spikes for triggering the one-shot circuits through diodes D-1 and D-2 as shown. The latter consists of the standard circuit arrangement, T-3 normally on and T-2 normally off. The single-shot multivibrator for channel 2 works in a similar fashion except that it is triggered upon receipt of a negative pulse which is applied to the base of T-5, thereby turning this NPN transistor off. These circuits have been found to be quite stable under environmental changes and are easily adjustable for different requirements of head current. In addition, the reliability of the circuitry is further enhanced by the fact that the current pulse width can vary considerably without changing the output signal from the reproduce head to any appreciable extent. All that is required to produce the desired results is that the pulse be considerably shorter than the input signal.

4.4.3.2 Reproduce Electronics

The reproduce electronics for the recorder is shown in Figure 4-11. The subsystem consists basically of two class B pulse amplifiers, one four stage and the other five stage, which are designed to amplify the positive half of the sinusoidal signal from the reproduce leads to saturation giving 2 unidirectional square pulses. The additional stage in the channel 2 amplifier is to provide a negative output pulse; other than this the amplifiers are identical.

The supply voltage for the record and playback electronics is regulated to a level of approximately 15 ± 0.2 volts in order to meet the specifications for $\pm 10\%$ stability of output signal voltage.

4.4.3.3 Erase Electronics

The recorder contains an erase facility which may be energized as desired. This recorder uses a separate erase head and erase oscillator in lieu of the permanent magnet type erase head. The circuitry for the erase oscillator is shown in Figure 4-12.

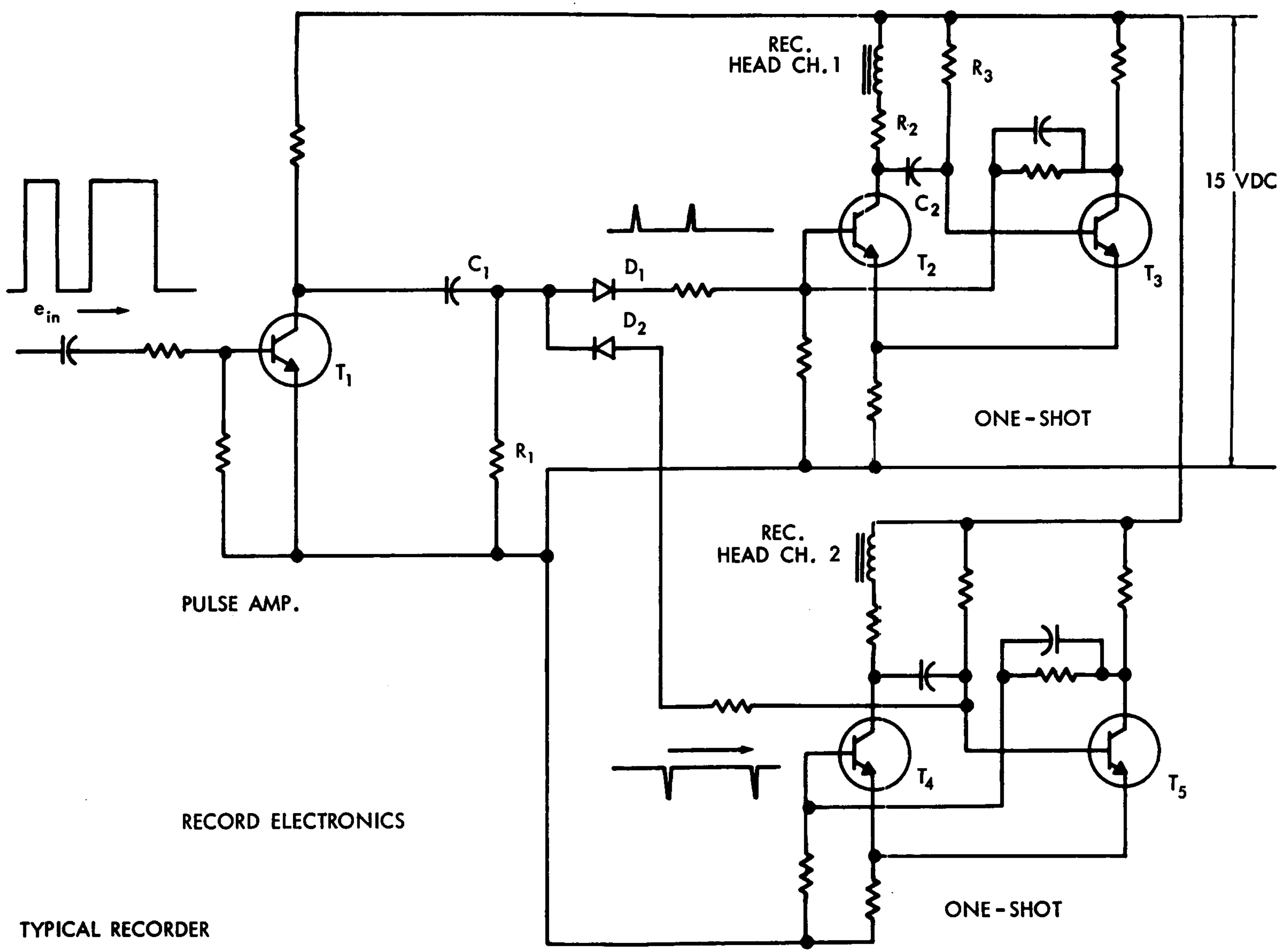


Figure 4-10–Record Electronics

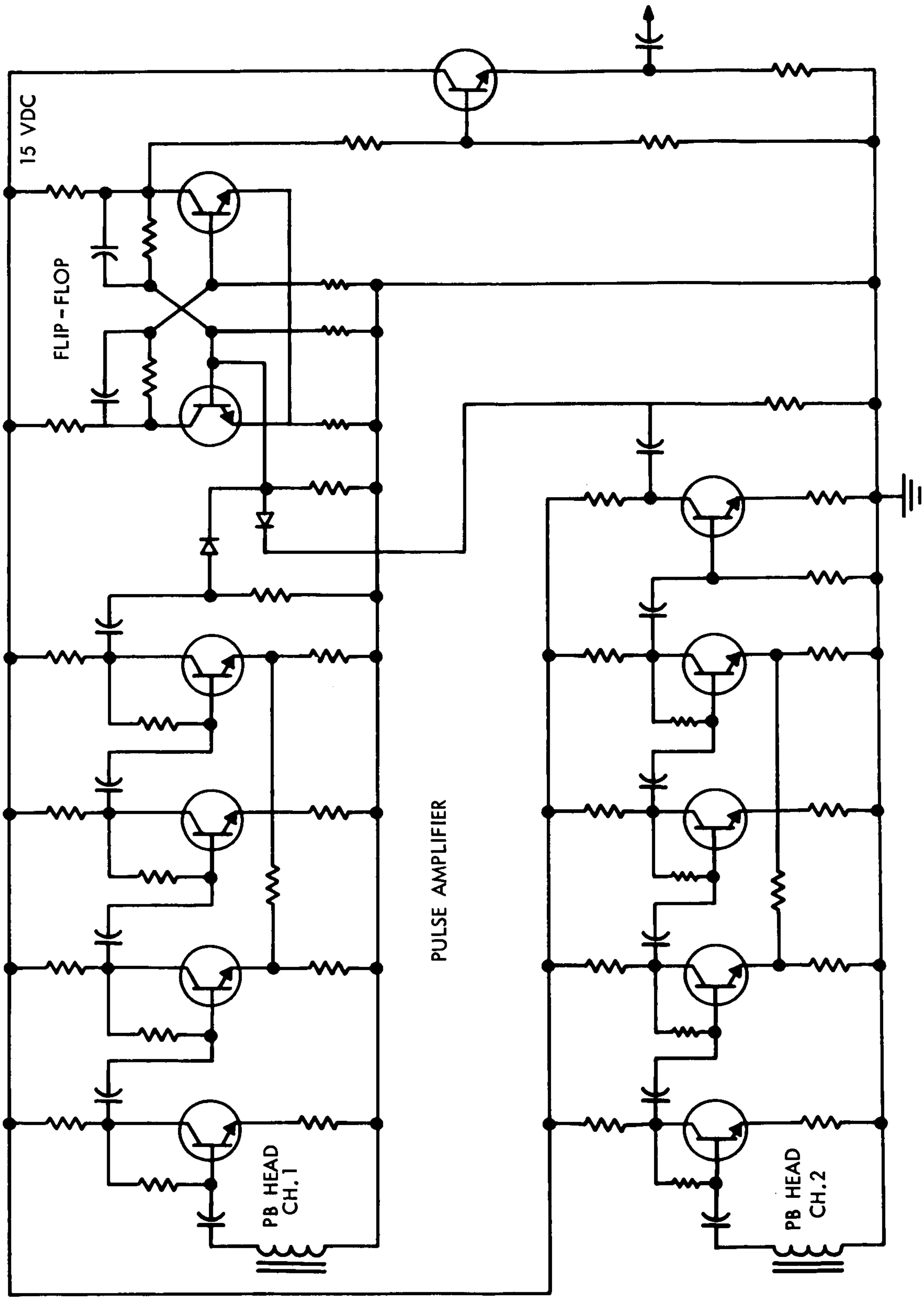
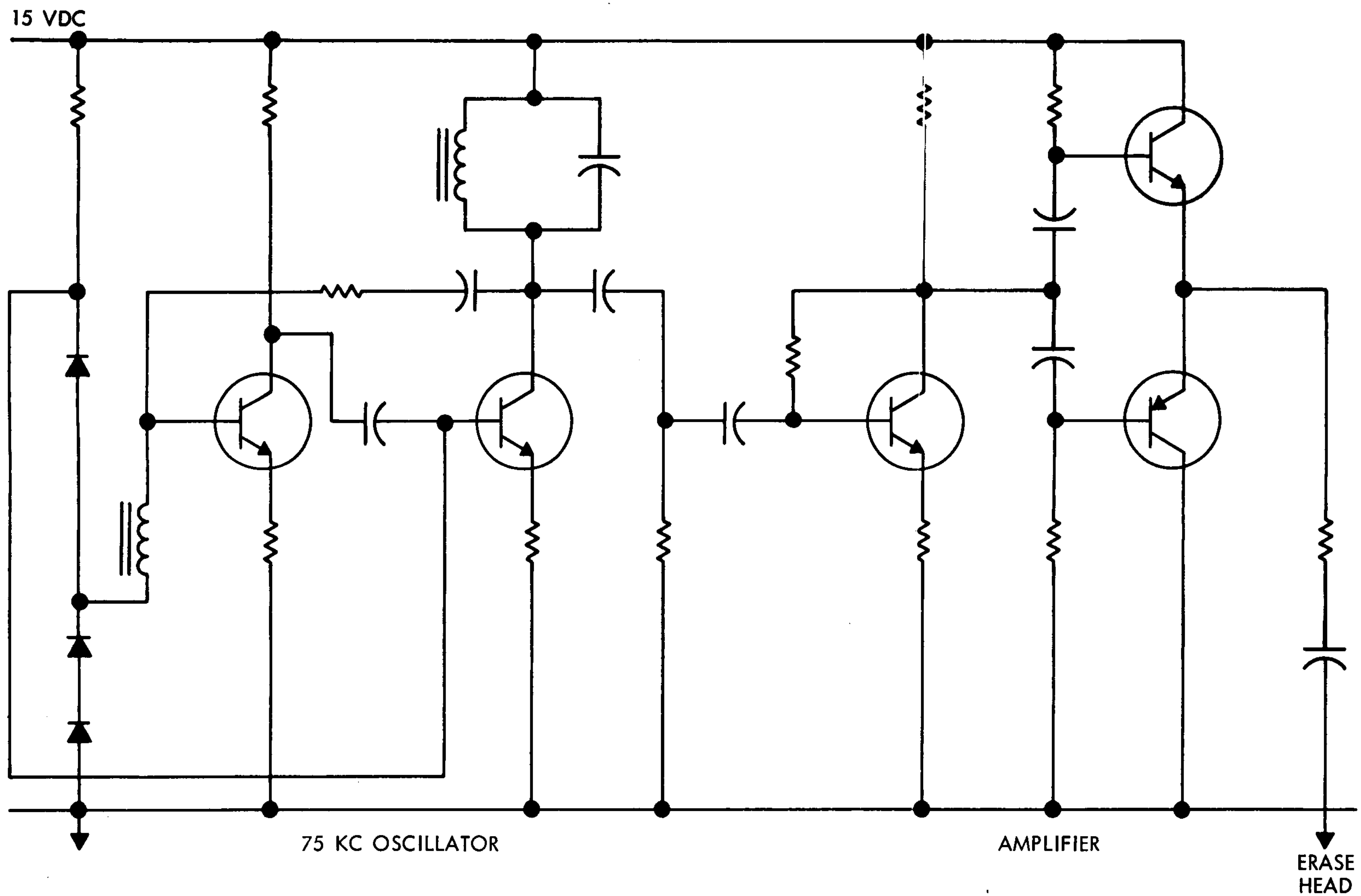


Figure 4-11—Reproduce Electronics



BIAS AND ERASE ELECTRONICS
TYPICAL RECORDER

Figure 4-12–Bias and Erase Electronics

4.4.3.4 Drive System Electronics

The details of the circuitry for the drive system electronics are shown in Figures 4-13 and 4-14 with the overall circuit broken down into two subsystems.

The first consists of an electronics network which converts a 400 cycle clock pulse into two 100 cycle square wave signals one 90 degrees out of phase from the other. This subsystem is shown in Figure 4-13.

The second part of the drive system electronics consists of the drive amplifiers for the two phase synchronous motor, a basic diagram of which is shown in Figure 4-14. Although the system uses a considerable number of transistors, the associated components are quite few and the circuit provides a high degree of reliability and efficiency.

4.4.4 Controls

As seen in the block diagram, Figure 4-9, two latching relays are employed, their main function being to provide the necessary switch closures for playback and record modes. Upon receipt of a command signal, these relays switch the regulated voltage from the record to the playback electronics, and applies unregulated supply voltage to the drive amplifiers for the playback motor.

In addition to the above basic control features the supply voltage leads are brought from the erase oscillator to an external connector in order that the erase oscillator may be used as desired.

4.4.5 Mechanical Configuration

As mentioned previously the mechanical transport will involve modularized shaft assemblies employing duplex pairs. A two capstand, differential speed tape drive is used to drive the endless 300 foot loop. Two motors, one for playback and one for record, provide the drive for the capstans.

The packaging layout is shown in Figure 4-8. Operation of the transport is as follows. During the record mode the record motor drives the left hand capstan flywheel pulley through the jack shaft reduction. The flywheel pulley is free to rotate on the capstan shaft. In the record mode the playback motor does not run and as a consequence, the left capstan assembly overrunning spring clutch transmits torque to the left capstan and to the right capstan through the belt provided. A differential speed between the capstans is affected by a slight difference in pulley diameters. Since the playback motor is not running, the right

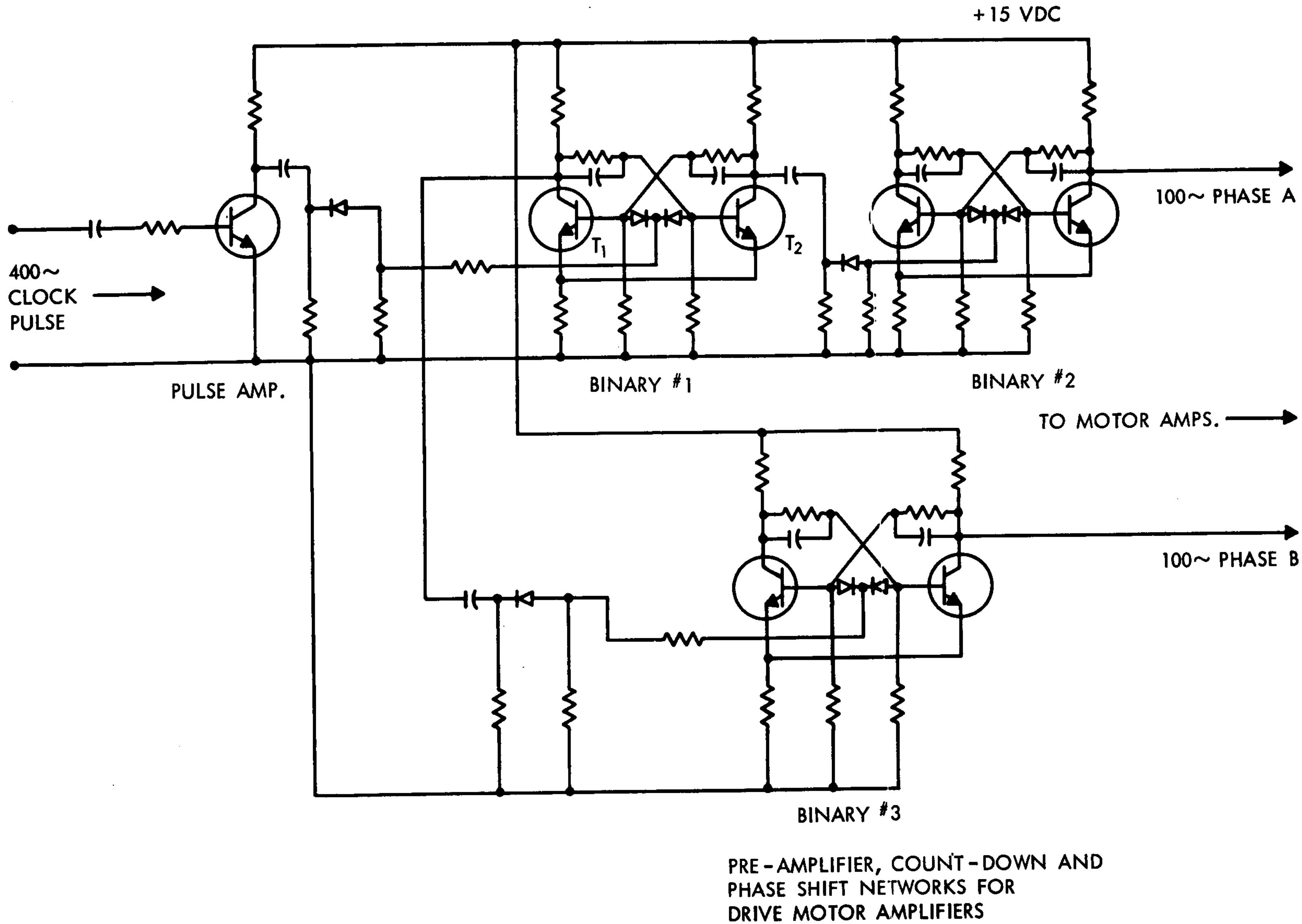


Figure 4-13–Recorder Preamplifier, Count-Down and Phase Shift Networks

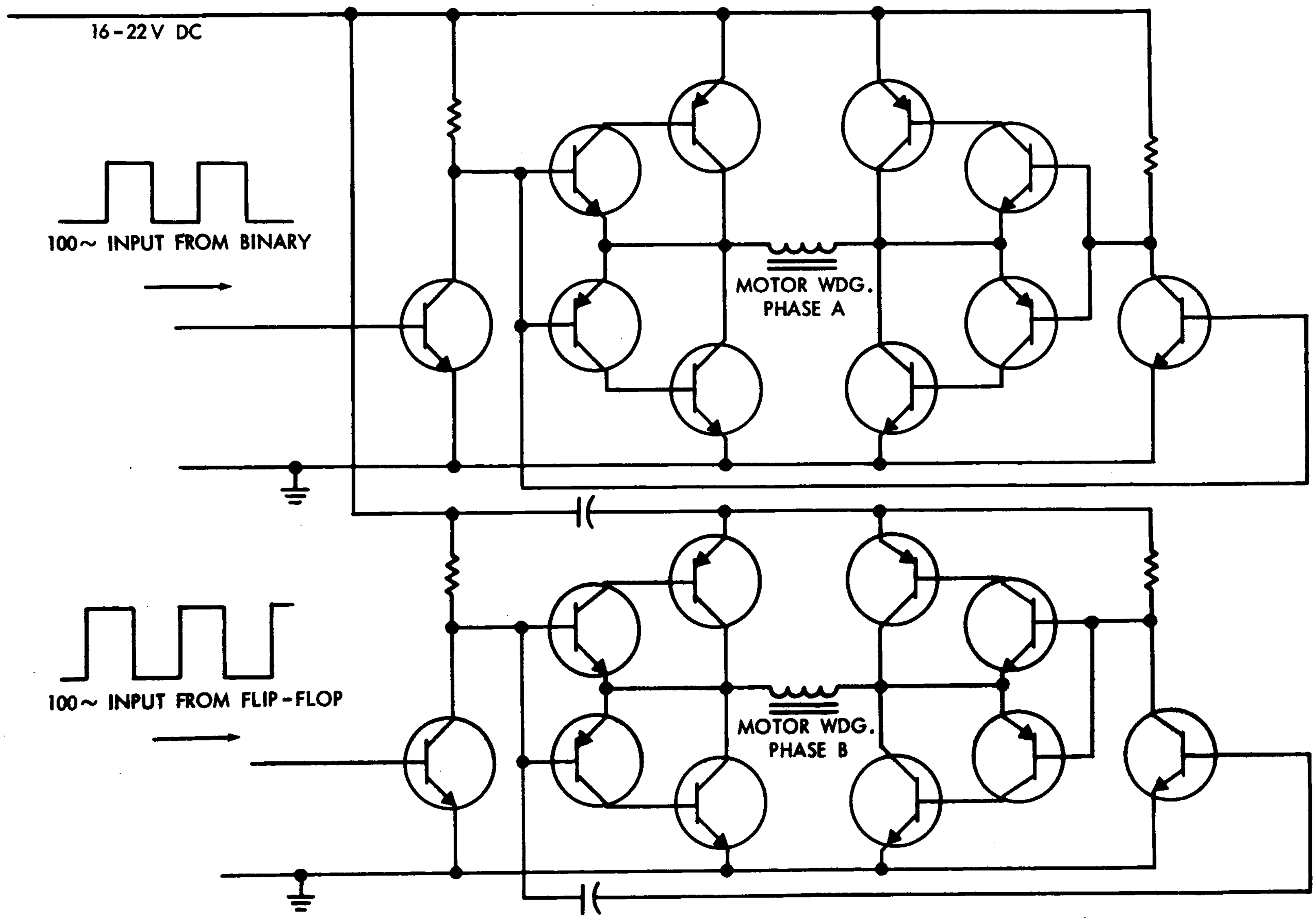


Figure 4-14–Motor Drive Amplifier

capstan assembly overrunning spring clutch slips. When the playback mode is desired, the playback motor is energized. The right spring clutch transmits torque while the left slips. The result is that the capstans are driven at high speed. The record motor continues to run during the playback cycle and never need be turned off after launch.

The timer, consisting of a pulley-driven gear train, is belted directly to the playback motor. One revolution of its output can produce switching operations which turn OFF the playback motor after the five minute playback cycle is complete.

The record motor is an H. C. Roters Co., Model number 113, six pole, hysteresis, synchronous motor operating at a synchronous speed of 2000 rpm from 100 cps, two phase square waves. Its maximum output synchronous torque will be 0.07 inch-ounces against a maximum expected load of 0.02 inch-ounces. Operation at 2000 rpm assures a large safety factor on bearing life.

The playback motor is a Design Engineering Service Model RE, two pole, hysteresis, synchronous motor operating at a synchronous speed of 6000 rpm from 100 cps, two phase square waves. Its maximum output synchronous torque will be 0.22 inch-ounces against a maximum expected load of 0.08 inch-ounces. Operation at 6000 rpm is permissible from a life standpoint because of the relatively short time that the playback motor operates (about 5% of the time that the record motor operates).

Dimensions on the recorder layout drawing indicate a volume of less than 200 cubic inches. Because of the two motor and gasket seal configuration, the weight of the recorder approaches a maximum of 6.5 pounds.

The jitter in the recorder is no greater than 2.0% peak-to-peak, from 0 to 800 cps, and the total jitter from 0 to 10,000 cps is less than 3%.

The recorder warm-up time is three seconds.

4.4.6 Power Considerations

It is conservatively estimated that at 19.0 volts and room temperature, the power consumption in the record mode will not exceed 1.0 watt. Under the same conditions the power consumption in the playback mode will not exceed 7.0 watts. This playback load is broken down as follows:

a. Playback motor and drive electronics: 4.5 watts.

b. AC erase head; 1.5 watts.

c. Record motor and drive electronics (running at playback) and playback signal electronics: 1 watt.

These estimates yield a total energy consumption of 130 watt-minutes during a complete record-reproduce cycle.

4.4.7 Requirements

The following is a list of the major tape recorder requirements:

a. Information rate – 400 bits/second

b. Code – Biphase RZ

c. Record time – 90 minutes

d. Speed ratio – 18

e. Jitter – 3% peak-to-peak, 0-10,000 cps.

f. Supply voltage – 19 ± 3 volts

g. Allowable leak rate – 40 cc/year

h. Vibration

5-50 cps	4.2 g's 0 to peak
50-1000 cps	9.8 g's 0 to peak
1000-2000 cps	14.2 g's 0 to peak

i. Acceleration – 13 g thrust and 7.5 g spin

j. Temperature

Storage – 20°C to 60°C
Operating – 10°C to 35°C

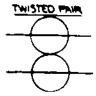
4.4.8 OSO-D Spacecraft Recorder

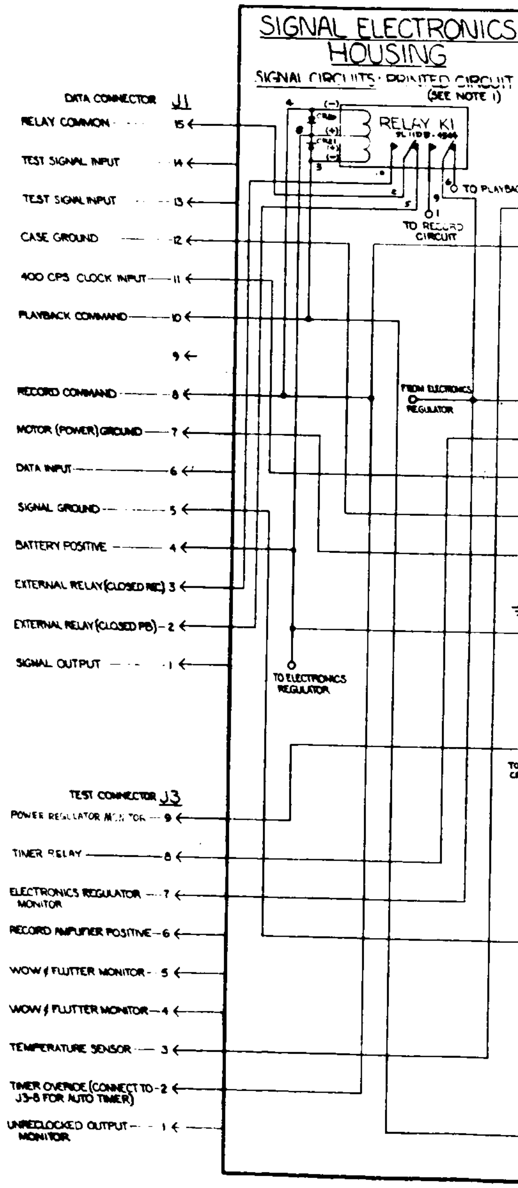
Figures 4-15A and 4-15B show electrical schematics of the actual OSO-D recorder. This recorder is slightly different from the typical recorder explained in this section. Some mechanical differences are: the manner in which the tape is held against the head; the method of recording; the belt drive; and different packaging. There are some minor circuit differences, but basically the operation is the same.

The OSO-D uses a single-channel, high packing density, bi-phase non return to zero recording system utilizing a level detection technique. This system was

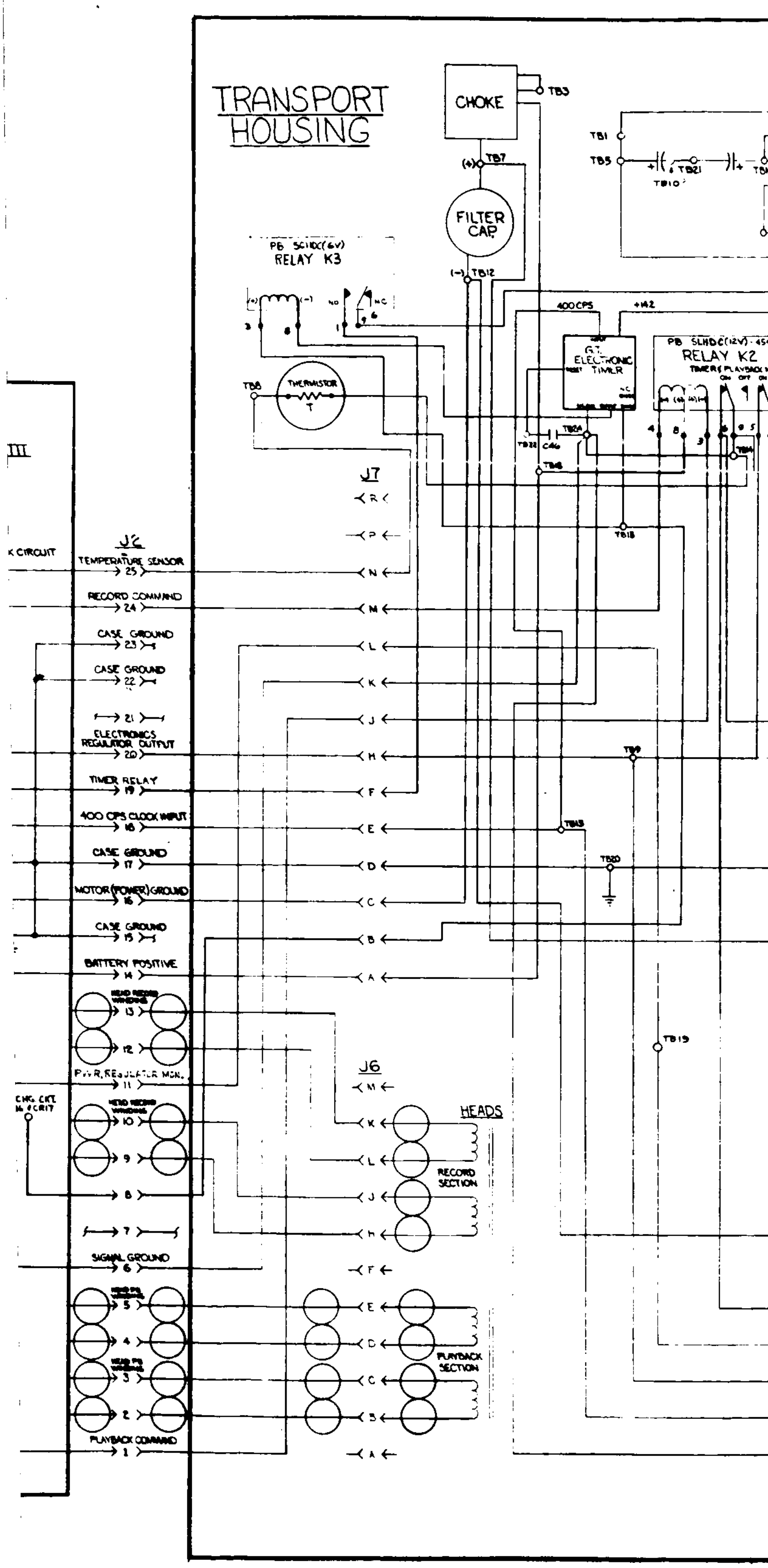
NOTES:

1. SIGNAL CIRCUITS INCLUDE:
   - ELECTRONICS REGULATOR
   - RECORD AMPLIFIER
   - PLAYBACK AMPLIFIER
   - AMPLITUDE DETECTOR
   - RECLOCKING CIRCUIT
   - MODE SWITCHING RELAY





4-33A-1



TRANSPORT HOUSING
CHOKE
TB3
TB7
FILTER CAP
TB12
PB 5C1IDC(6V) RELAY K3
THERMISTOR
TB8
G.T. ELECTRONIC TIMER
400 CPS
PB SLHDC(12V) RELAY K2
TB1
TB5
TB21
TB10
TB24
C46
TB22
TB16
TB18
TB14
TB9
TB13
TB20
TB19
J7
J6
TEMPERATURE SENSOR
RECORD COMMAND
CASE GROUND
CASE GROUND
ELECTRONICS REGULATOR OUTPUT
TIMER RELAY
400 CPS CLOCK INPUT
CASE GROUND
MOTOR (POWER) GROUND
CASE GROUND
BATTERY POSITIVE
SIGNAL GROUND
PLAYBACK COMMAND
HEADS
RECORD SECTION
PLAYBACK SECTION

4-33A 0

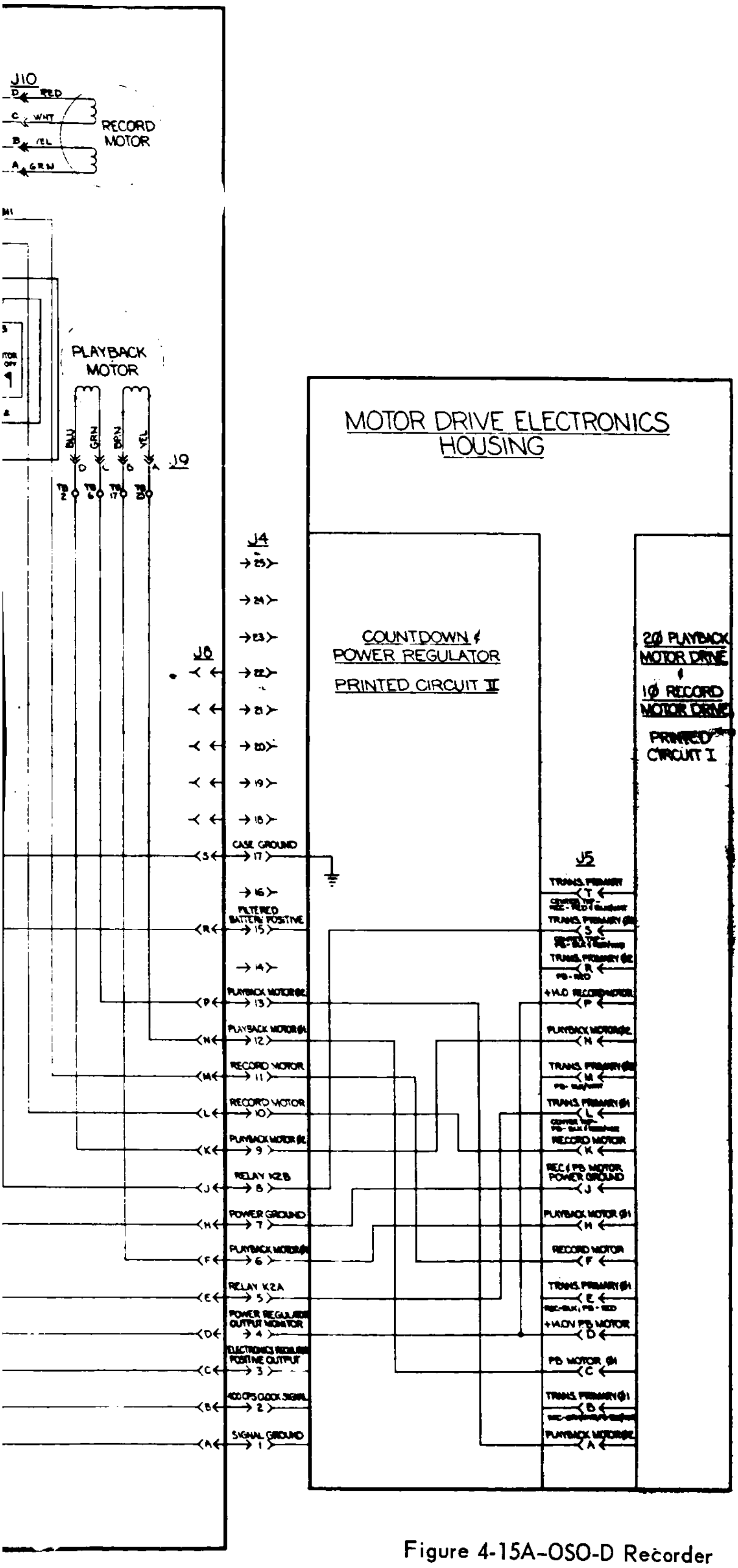
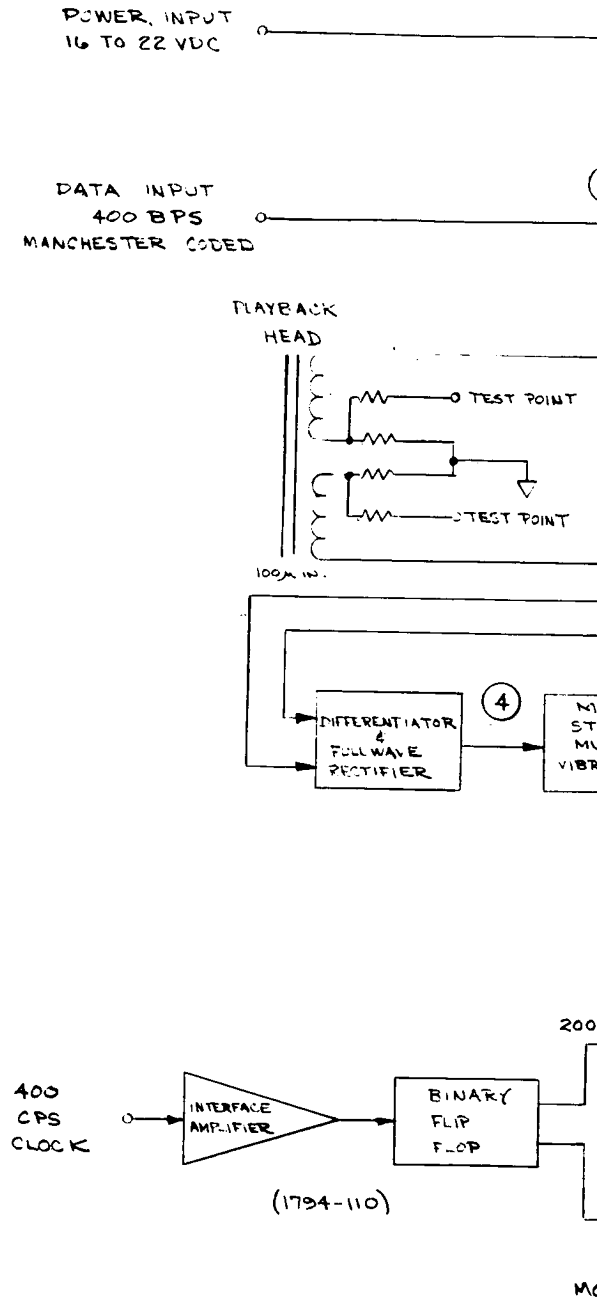
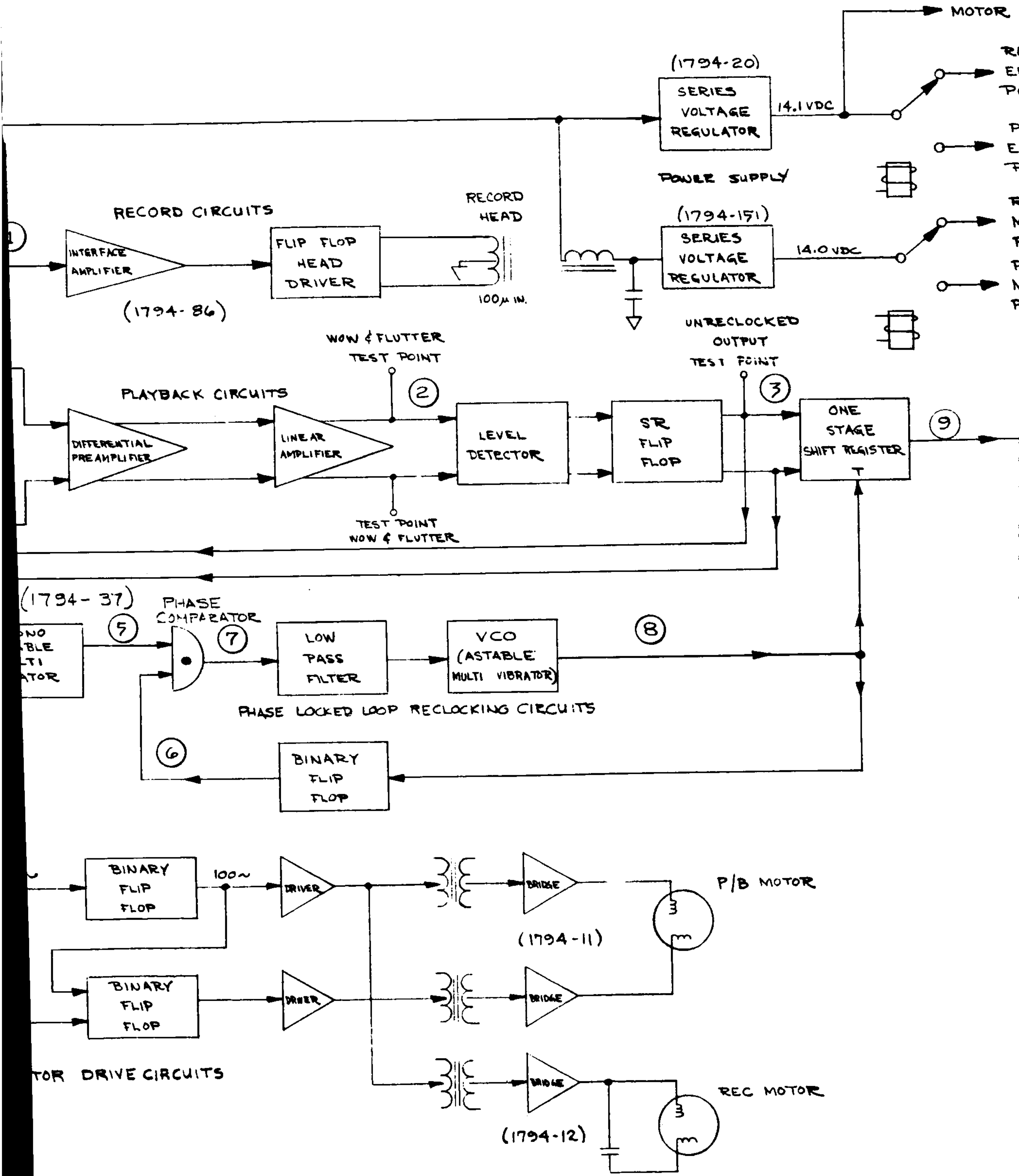


Figure 4-15A–OSO-D Recorder


POWER INPUT
16 TO 22 VDC
DATA INPUT
400 BPS
MANCHESTER CODED
PLAYBACK
HEAD
TEST POINT
TEST POINT
100μ IN.
DIFFERENTIATOR
&
FULLWAVE
RECTIFIER
4
400
CPS
CLOCK
INTERFACE
AMPLIFIER
(1794-110)
BINARY
FLIP
FLOP

4-33-B-1


MOTOR
(1794-20)
SERIES VOLTAGE REGULATOR
14.1 VDC
POWER SUPPLY
(1794-151)
SERIES VOLTAGE REGULATOR
14.0 VDC
RECORD CIRCUITS
INTERFACE AMPLIFIER
FLIP FLOP HEAD DRIVER
RECORD HEAD
100μ IN.
(1794-86)
UNRECLOCKED OUTPUT TEST POINT
WOW & FLUTTER TEST POINT
PLAYBACK CIRCUITS
DIFFERENTIAL PREAMPLIFIER
LINEAR AMPLIFIER
LEVEL DETECTOR
SR FLIP FLOP
ONE STAGE SHIFT REGISTER
TEST POINT WOW & FLUTTER
(1794-37)
PHASE COMPARATOR
LOW PASS FILTER
VCO (ASTABLE MULTI VIBRATOR)
PHASE LOCKED LOOP RECLOCKING CIRCUITS
BINARY FLIP FLOP
BINARY FLIP FLOP
100~
DRIVER
BRIDGE
P/B MOTOR
(1794-11)
BINARY FLIP FLOP
DRIVER
BRIDGE
TOR DRIVE CIRCUITS
BRIDGE
REC MOTOR
(1794-12)

4-33B2

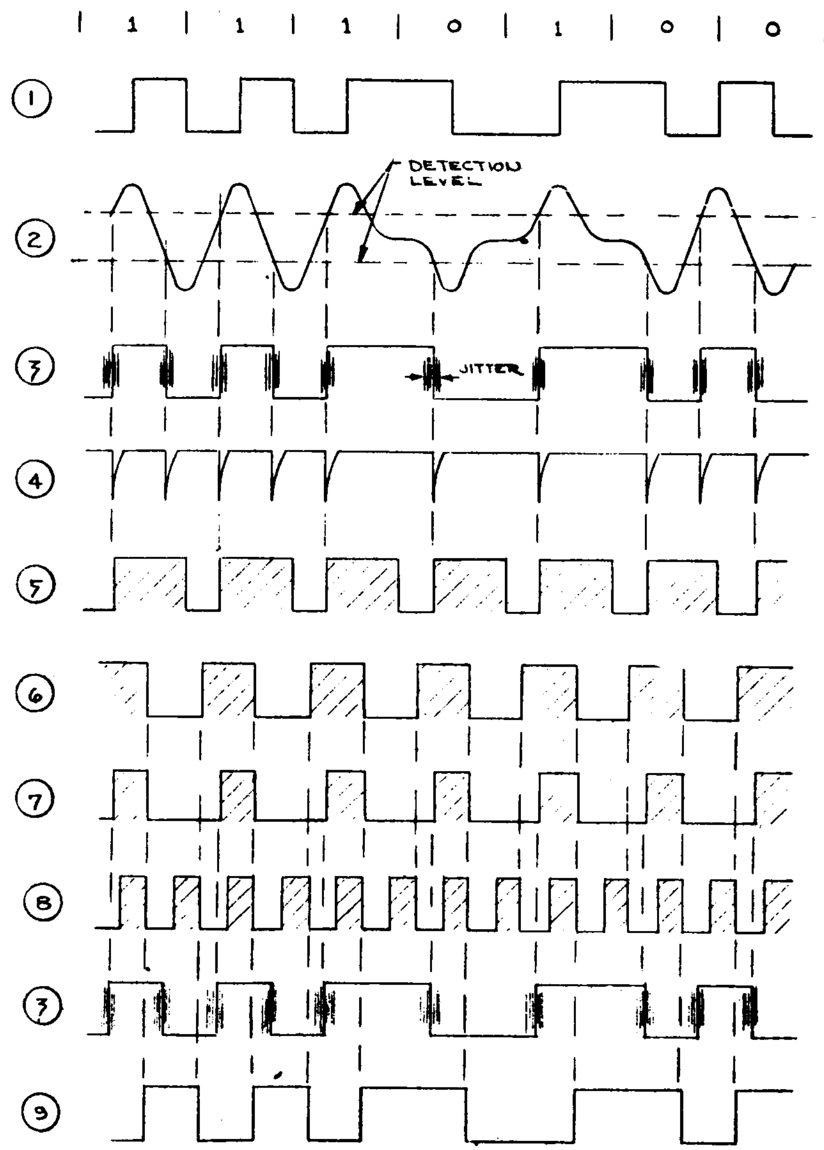


Figure 4-15B–OSO-D Recorder/Reproducer Signal Electronics System Diagram made feasible by the development of a phase-locked loop reclocking system which enables retiming of the pulses and reduces jitter caused by tape motion irregularity and noise.

4.5 DATA TRANSMISSION

The transmitter for the OSO-D spacecraft is a phase-shift keyed type employing all solid state circuitry. Transmission is made in two modes. Mode one is continuous real time transmission, throughout the orbit. Mode two is an interruption of real time resulting in the command playback of tape recorders. During the second mode, the recorded data are transmitted to the controlling station.

This transmission requires approximately five minutes, and will take place during the period of time the spacecraft is within radio range of the surface station.

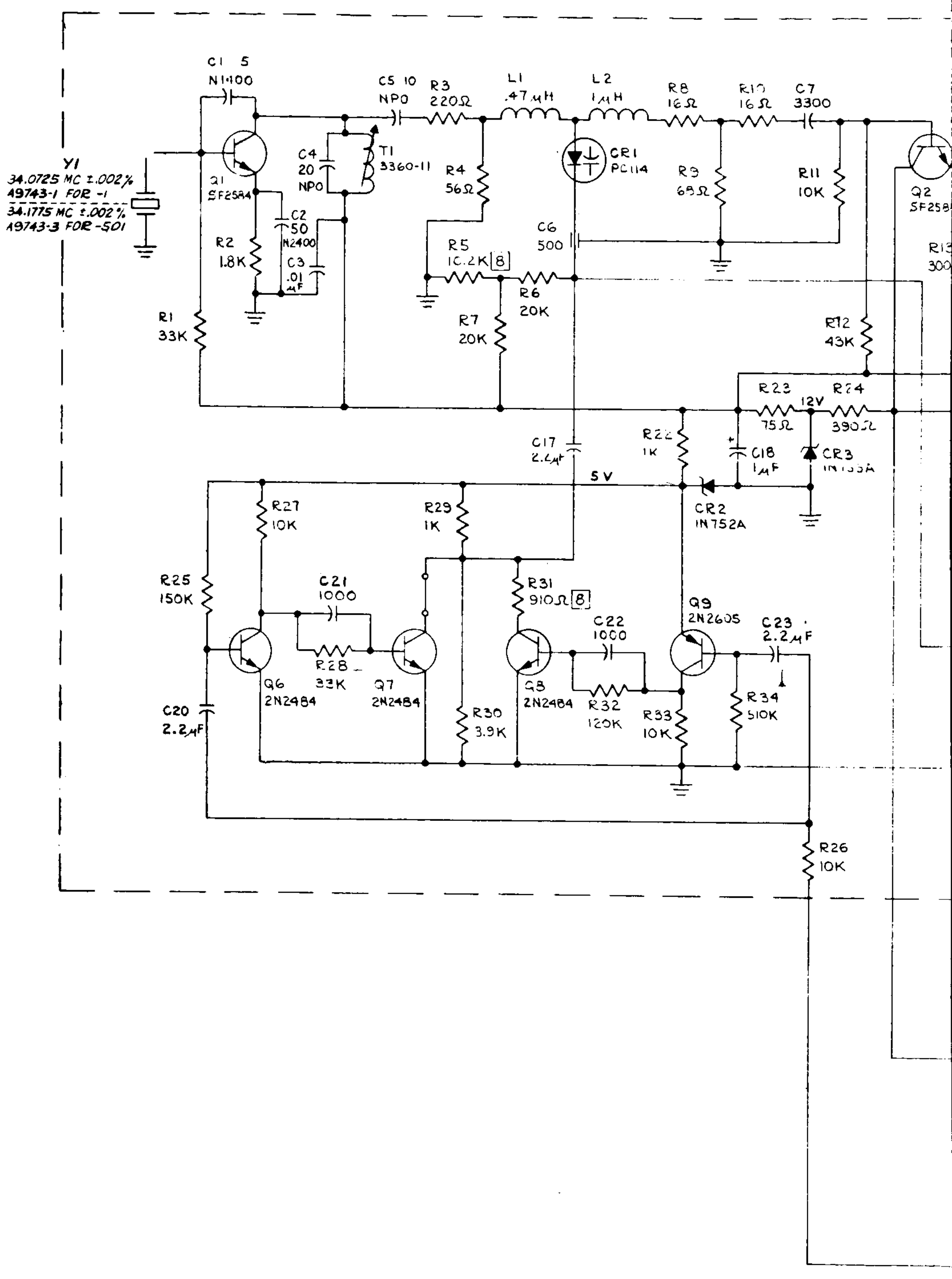
The real time transmission can only be received and recorded when the spacecraft is in radio view of a surface station equipped for such acquisition.

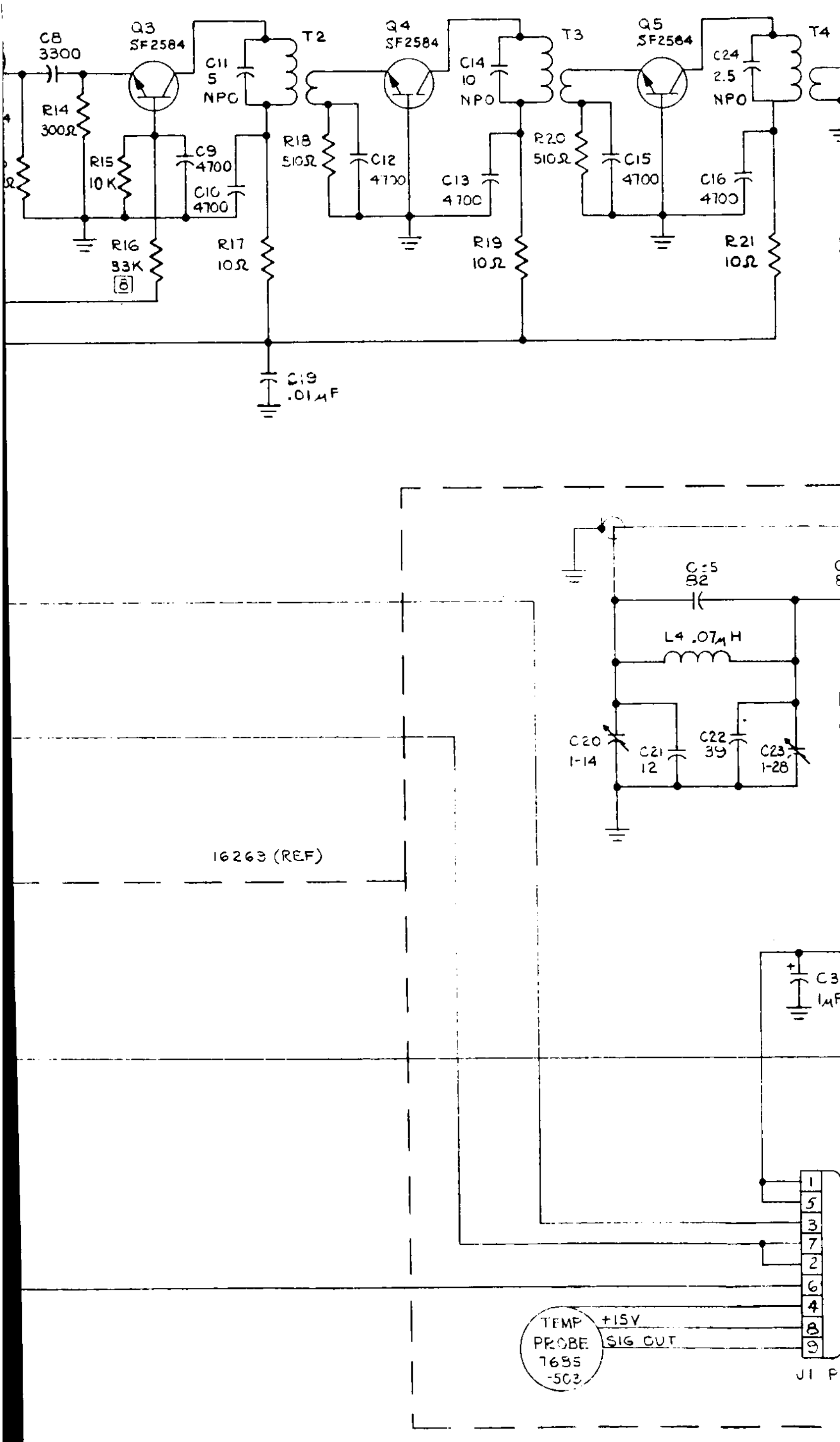
The transmitters are physically located in the wheel of the spacecraft in compartment number 8. The unit is rectangular in shape and occupies a volume of less than 20 cubic inches. The weight is approximately 13 ounces.

The transmitter consists of a phase modulated crystal oscillator, a driver unit, and a power amplifier. Figure 4-16 is a block diagram of the unit. The unit delivers a nominal 600 mw of power to the antenna system. The power input requirements are 19 volts ±3 volts. The maximum total input current is 210 milliamperes at 22 volts.

Typical characteristics of the transmitter follow. The peak deviation is selectable throughout the range of 10 to 90 degrees. A digital input signal amplitude of 1.75 to 6 volts peak-to-peak will cause the specified phase deviation. The data bit rate is 400 to 15,000 bits per second. The output impedance is a nominal 50 ohms resistive. The transmitter frequency is 136 mc; frequency stability is no more than ±5 Kc from center frequency under all environmental conditions. The transmitter tunes into a 2 to 1 VSWR. The spurious outputs are 40 db below the output carrier power level and no spurious outputs are present in the command frequency band (approximately 149 mc).

Phase modulation has been utilized in the transmitter design because it is inherently possible to achieve a more optimum design of a crystal controlled transmitter than by the use of frequency modulation. The phase modulated signal can be received by a conventional FM receiving system.


Y1
34.0725 MC ±.002%
49743-1 FOR -1
34.1775 MC ±.002%
49743-3 FOR -501
C1 5 N1400
Q1 SF2584
R1 33K
R2 1.8K
C2 50 N2400
C3 .01 μF
C4 20 NPO
T1 3360-11
C5 10 NPO
R3 220Ω
R4 56Ω
L1 .47μH
L2 1μH
CR1 PC114
R5 10.2K [8]
R6 20K
R7 20K
C6 500
R8 16Ω
R9 68Ω
R10 16Ω
C7 3300
R11 10K
R12 43K
Q2
R23 75Ω
R24 390Ω
12V
C18 1μF
CR3
R22 1K
C17 2.2μF
5V
CR2 1N752A
R27 10K
R29 1K
R25 150K
C21 1000
R28 33K
Q6 2N2484
Q7 2N2484
C20 2.2μF
R30 3.9K
R31 910Ω [8]
C22 1000
Q8 2N2484
R32 120K
R33 10K
Q9 2N2605
C23 2.2μF
R34 510K
R26 10K



C8 3300
Q3 SF2584
T2
C11 5 NPO
R14 300Ω
R15 10K
C9 4700
C10 4700
R16 33K
8
R17 10Ω
C19 .01μF
Q4 SF2584
C14 10 NPO
T3
R18 510Ω
C12 4700
C13 4700
R19 10Ω
Q5 SF2584
C24 2.5 NPO
T4
R20 510Ω
C15 4700
C16 4700
R21 10Ω
C15 82
L4 .07μH
C20 1-14
C21 12
C22 39
C23 1-28
16263 (REF)
TEMP PROBE 7695 -503
+15V
SIG OUT
1
5
3
7
2
6
4
8
9
J1

4-37 0

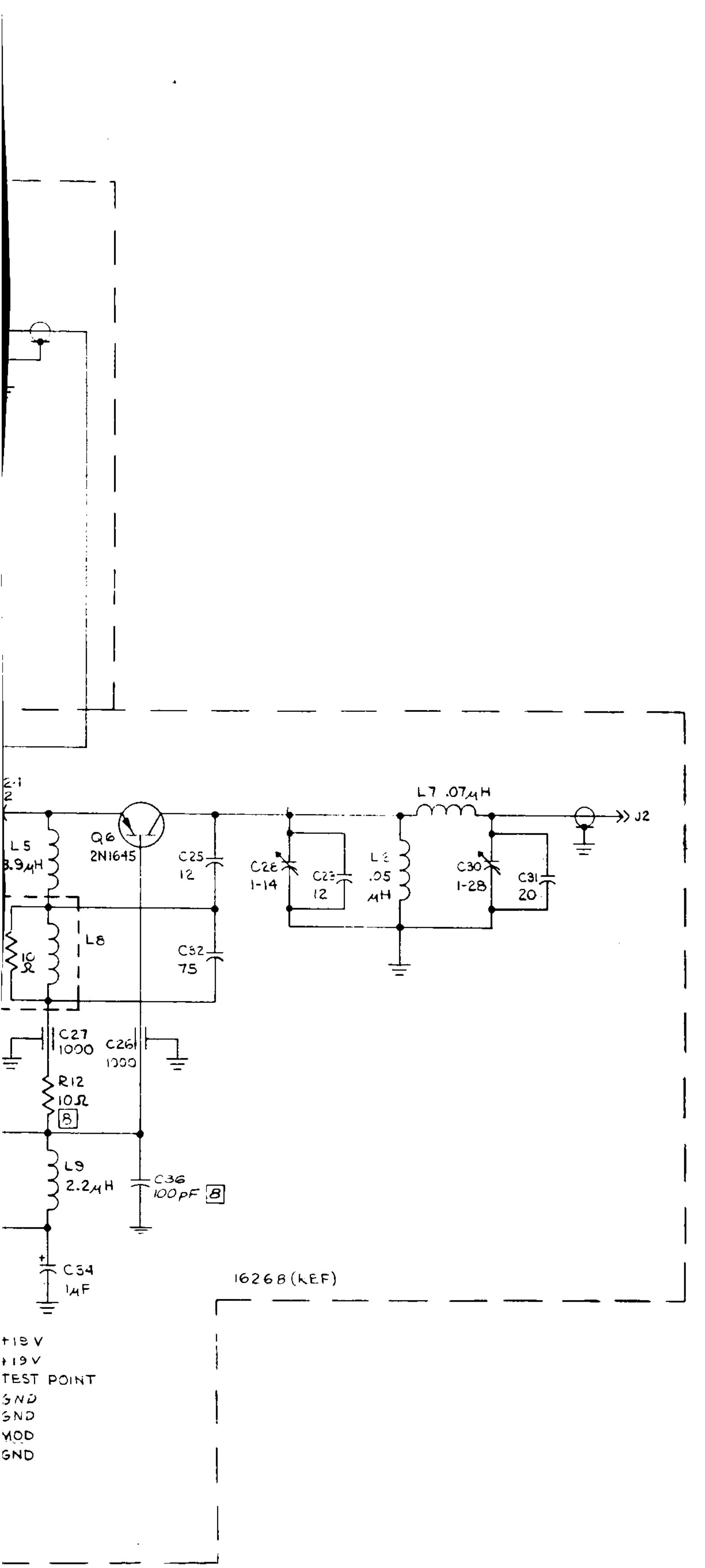


Figure 4-16–OSO-D Transmitter

Section 5

COMMAND SYSTEM

5.1 INTRODUCTION

The command system is a PDM/AM/AM digital type capable of executing 140 commands. The receiver is an AVCO part number 185012 which operates at 149.52 mc. There are two receivers connected in parallel whose inputs come from a hybrid circulator in the antenna system. Both command receivers operate continuously as protection against a single receiver failure during the acquisition and command period. The output of the receivers is a pulse duration modulated 7 kc audio tone. It is fed to three decoders in parallel to be processed for command execution. See Figure 5-1 for the command system block diagram.

Two of the decoders are located in the wheel to process the wheel commands. They are connected in parallel. The third decoder is located on an experiment in the sail to process the sail commands. The decoders each require a different address code. The two wheel decoders are capable of processing the same 70 commands, but must be properly addressed to accept these commands. The sail decoder is capable of processing the balance of 70 commands, but must be properly addressed to accept these commands. The output of the decoders actuates a latching type relay when a command is executed. The relays are distributed about the spacecraft external to the decoders. They are 12v dc dual-coil type relays. Therefore a total of 70 relays can be used to execute 140 commands.

The system uses digital techniques, wherein the commands are made up of unique combinations of bits and words. A command word is made up of ten bits and the typical command frame includes two words for address and three words for instruction. The allocation of the command words for both decoder subsystems is given in Table 5-1 for the OSO-D spacecraft. The commands are used for the following purposes: (1) for normal command operations of the spacecraft telemetry systems; (2) for failure or trouble analysis control of the spacecraft, known as backup control; (3) and for experiment control.

5.2 COMMAND RECEIVER

The receiver is a single-conversion super-heterodyne AM receiver featuring high reliability, low power consumption and high dynamic range capability

OSO-D DIGITAL COMMAND AIRBORNE RECEIVING SYSTEM

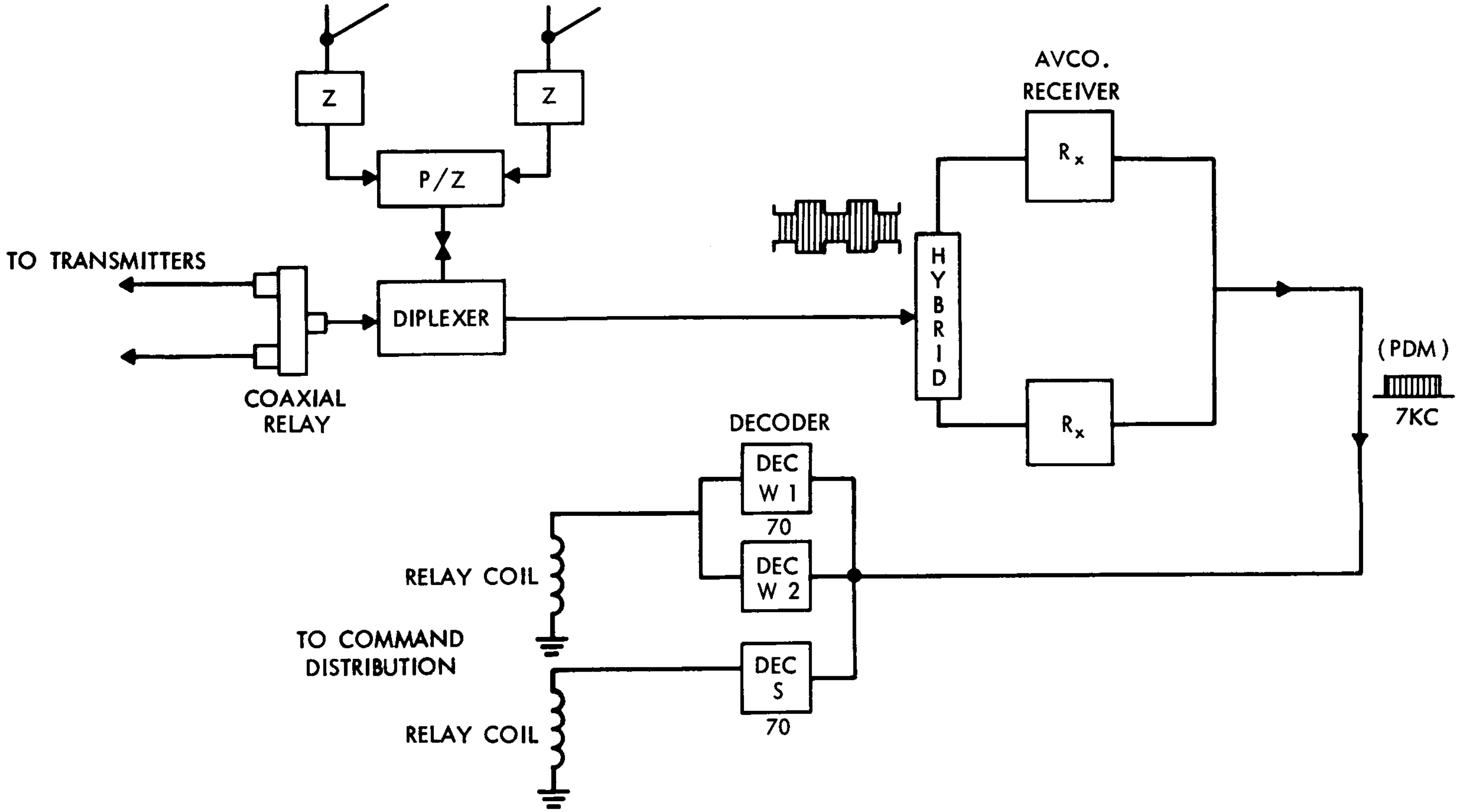


Figure 5-1—Command System Block Diagram

Table 5-1
OSO-D Command Allocation

Command Number	Wheel Function	Command Number	Sail Function	Code* Format
1	Playback On	71	Raster Mode	0015
2	Spin Up	72	HCO Low Voltage On	0107
3	ASE X-Ray Off	73	Pitch Manual	0111
4	Tape Recorder No. 2	74	Spare	0113
5	DME No. 1	75	NRL Off	0114
6	UVS Bypass Open	76	HCO Position Sel. 1	0207
7	Day Power Sail On	77	HCO Position Sel. 2	0211
8	NRL Lyman Alpha On	78	HCO Position Sel. 3	0213
9	XMTR No. 1	79	HCO Position Sel. 4	0214
10	Day Night Bypass Closed	80	HCO Position Sel. 5	0303
11	UCL 304 Å Squib Comm.	81	HCO Position Sel. 6	0305
12	UCL X-Ray Off	82	HCO Position Sel. 7	0306
13	ASE X-Ray Door Open and F. W. Disable	83	HCO Position Sel. 8	0309
14	ASE X-Ray F. W. Auto	84	HCO Position Sel. 9	0310
15	NRL X-Ray Peak Reader Off	85	Spare	0312
16	RF On	86	Spare	0407
17	Tape Recorder – Power On	87	HCO High Voltage On	0411
18	NRL X-Ray Peak Reader On	88	Spare	0413
19	LRL P-E Detector On	89	Pitch Down	0414
20	NRL X-Ray Calib. Off	90	ASE Aperture Wh. 01	0503
21	Day Night Bypass – Open	91	ASE Aperture Wh. 10	0505

Table 5-1
OSO-D Command Allocation (cont.)

Command Number	Wheel Function	Command Number	Sail Function	Code* Format
22	LRL Squib Comm.	92	ASE Filter Wheel 00	0506
23	UCL X-Ray Calib. On	93	ASE Filter Wheel 01	0509
24	UCL X-Ray Calib. Off	94	ASE Filter Wheel 10	0510
25	UCL X-Ray Low Sensitivity	95	ASE Wheel Reset	0512
26	UCL X-Ray On	96	ASE Post Acc. On	0603
27	NRL X-Ray Wheel Pos. 1	97	ASE Post Acc. Off	0605
28	NRL X-Ray Wheel Pos. 2	98	ASE Chamber Door Open	0606
29	NRL X-Ray Wheel Pos. 3	99	HCO Position Sel. 10	0609
30	Exp. Squib. Pwr. Reset	100	HCO Position Sel. 11	0610
31	NRL X-Ray Calib. On	101	HCO Position Sel. 12	0612
32	Spin Down	102	HCO Power OFF	0701
33	UVS Bypass Closed	103	HCO Position Sel. 13	0702
34	UCL 304 Å He Lyman Alpha On	104	HCO Position Sel. 14	0704
35	NRL X-Ray Off	105	ASE Power ON	0708
36	NRL X-Ray On	106	ASE Power OFF	0807
37	UCL 304 Å Calib. On	107	HCO Mech. Ref.	0811
38	UVS Security Closed	108	HCO Optical Ref.	0813
39	Spin Auto	109	HCO Wavelength	0814
40	Orbit Power Bypass On	110	HCO Reset Override	0903
41	Playback Off	111	HCO Wavelength Reset	0905
42	NRL X-Ray & Lyman Alpha Motor Power On	112	HCO Motor Start	0906
43	UCL 304 Å On	113	Spare	0909

Table 5-1
OSO-D Command Allocation (cont.)

Command Number	Wheel Function	Command Number	Sail Function	Code* Format
44	NRL X-Ray & Lyman Motor Power Off	114	Spare	0910
45	Exp. Squib Power Set	115	Spare	0912
46	NRL Lyman Alpha Wh. Pos. #1	116	Spare	1003
47	NRL Lyman Alpha Wh. Pos. #2	117	Spare	1005
48	NRL Lyman Alpha Wh. Pos. #3	118	Spare	1006
49	NRL Lyman Alpha Calib. On	119	Spare	1009
50	NRL Lyman Alpha Calib. Off	120	Spare	1010
51	NRL Lyman Alpha Alter. Mode	121	Spare	1012
52	ASE X-Ray On	122	Pitch Auto	1101
53	Day Power Sail Off	123 NRL	LV Pwr. Sup. No. 1	1102
54	Tape Recorder Power Off	124 NRL	LV Pwr. Sup. No. 2	1104
55	RF Off	125 NRL	HV Pwr. Sup. No. 1	1108
56	LRL PE Det. Shutter Advance	126 NRL	HV Pwr. Sup. No. 2	1203
57	Orbit Power Bypass Off	127 NRL	In Line S/R Select	1205
58	NRL Lyman Alpha 2×10^{-12} Range	128 NRL	Cross S/R Select	1206
59	NRL Lyman Alpha 5×10^{-12} Range	129 NRL	Speed Select	1209
60	Spare	130 NRL	Speed Select	1210
61	UCL 304 Å Off	131 NRL	Motor Driver No. 1	1212

Table 5-1
OSO-D Command Allocation (cont.)

Command Number	Wheel Function	Command Number	Sail Function	Code* Format
62	XMTR No. 2	132 NRL	Motor Driver No. 2	1301
63	NRL Lyman Alpha Off	133	**NRL No. 11 Not Used	1302
64	LRL PE Det Shutter Stop	134	**NRL No. 12 Not Used	1304
65	UVS Security Open	135	**NRL No. 13 Not Used	1308
66	DME No. 2	136	NRL On	1401
67	Tape Recorder No. 1	137	NRL No. 14 Not Used	1402
68	LRL PE Det Off	138	Pitch Up	1404
69	Spin Manual	139	Spare	1408
70	Redundant Playback On	140	Point Mode	1500

* Command Code format is the same for indicated wheel and sail.

** Experimenter allocated but not utilized

Spare - unassigned commands.

(2 uv to 0.1 v). It operates at 149.52 mc. The receiver is packaged in approximately 19 cubic inches and weighs approximately 19 ounces. The two receivers are located in wheel compartment number 7.

The reliability of the receiver has been obtained by the use of premium components throughout. All transistors and diodes are silicon types. A complete report on the measures taken to assure reliability can be obtained by referring to NASA document titled "Command Receiver for Gamma Ray Satellite (S-15)," Report No. MTP-M-G & C-12, by H. P. Lowery.

Typical performance characteristics are given in Table 5-2. Figure 5-2 is a block diagram of the receiver.

Table 5-2
Typical Receiver Characteristics

*Frequency	100-150 mcs. (AM)
Input Impedance	50 ohms
6 db bandwidth	35-40 kc
60 db bandwidth	100 kc maximum
Sensitivity (for Decoder relay closure)	2 uv maximum (75% modulation)
Overload	100,000 uv minimum
Image rejection	80 db
Spurious response rejection	60 db minimum
Local oscillator radiation	200 u uw (100 uv) maximum
Local oscillator stability	±2 kc
Audio amplifier response	±1.5 db from 5 kc to 9 kc
Temperature range	-20° to +70°C
Output signal	50 mw (5 v rms across 500 ohm load)
Standby power	250 milliwatts (maximum)
Interrogate power	330 Milliwatts (maximum, including 50 mw output)
Weight	19 ounces
RMS random vibration	20 g's (20-2000 cps)
Shock	50 g's-11 milliseconds

*Tuning fixed to specified frequency at the factory before shipment.

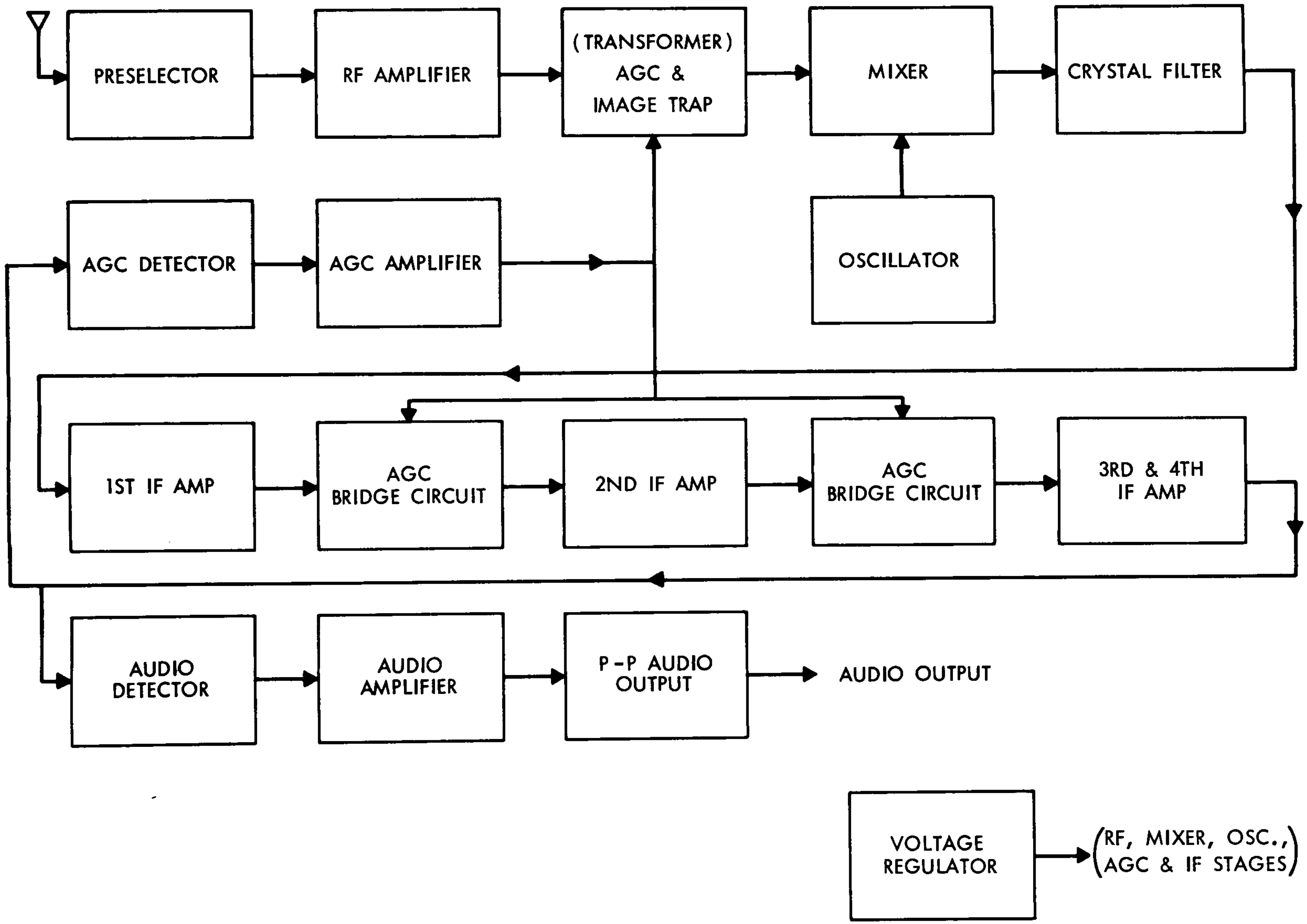


Figure 5-2—Command Receiver Block Diagram

With an rf input signal of 5 microvolts and 30 percent modulation, or 2 microvolts and 75 percent modulation, receiver sensitivity is more than adequate to operate the digital decoder. The signal-plus-noise-to-noise ratio at 1.5 microvolts is 10 db minimum.

The i-f bandwidth, as determined by a crystal filter following the mixer, is 36 kc at 6 db and 100 kc at 60 db.

The crystal filter gives a stable selectivity characteristic, along with high adjacent signal rejection. An overall receiver response curve is shown in Figure 5-3.

Two resistors in a "fixed-resistor" volume control are factory selected for 50 milliwatts audio output with a 5 microvolt input signal modulated 75 percent. The audio amplifier is designed to operate into a load impedance of 500 ohms. With this load, the audio frequency response is flat within 2 db from 1 kc to 10 kc as shown in Figure 5-4.

An unusual feature of the receiver is the use of varicap-diode automatic gain control which gives sufficient agc to maintain the audio output within 3 db as the rf input varies from 2 microvolts to 0.1 volts. The audio power output vs rf input curve is shown in Figure 5-5.

5.2.1 Power Consumption

The supply voltage is 15.6 volts ± 10 percent, positive above ground. Low current drain is obtained by connecting various stages in a series-parallel arrangement across the supply voltage as shown in Figure 5-6. Power consumption is 250 milliwatts maximum during standby and 330 milliwatts maximum during interrogation.

An investigation conducted to determine minimum voltage and current requirements of the vhf amplifier, mixer, and oscillator circuits resulted in the following arrangement: the oscillator (requiring 4 volts at 2 ma) is connected in series with the parallel combination of the vhf amplifier and mixer (9.3 volts and 1 ma each) across the 13.3 vdc regulated supply voltage. Thus the total supply current required for the three stages is 2 ma compared to perhaps 3.5 ma in a conventional arrangement.

For additional information concerning the operation of the receiver, refer to the AVCO manual, vhf Command Receiver, dated 1 September 1964 (80045XRW 11/964).

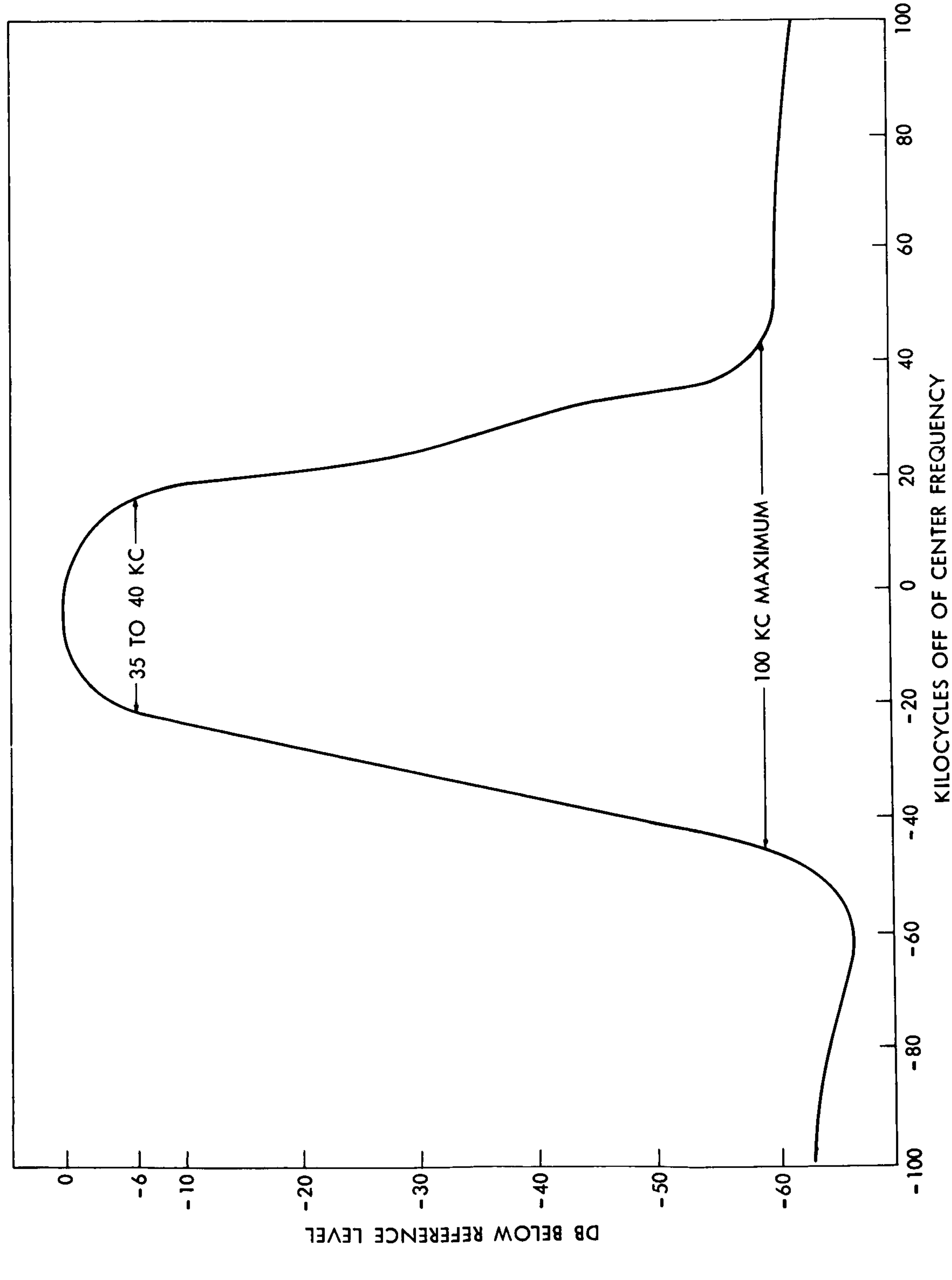


Figure 5-3–Command Receiver Selectivity

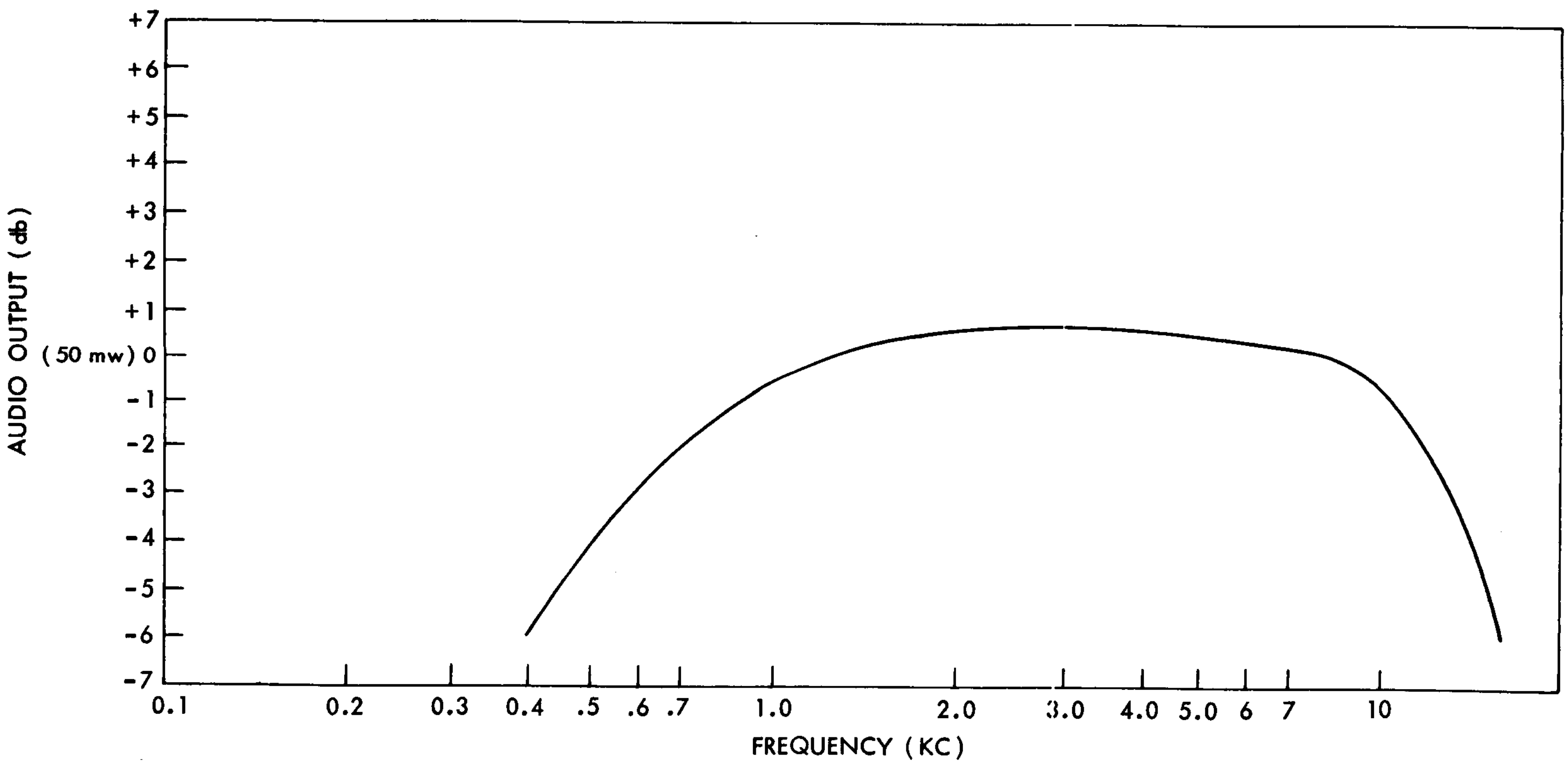


Figure 5-4–Typical Command Receiver Frequency Response

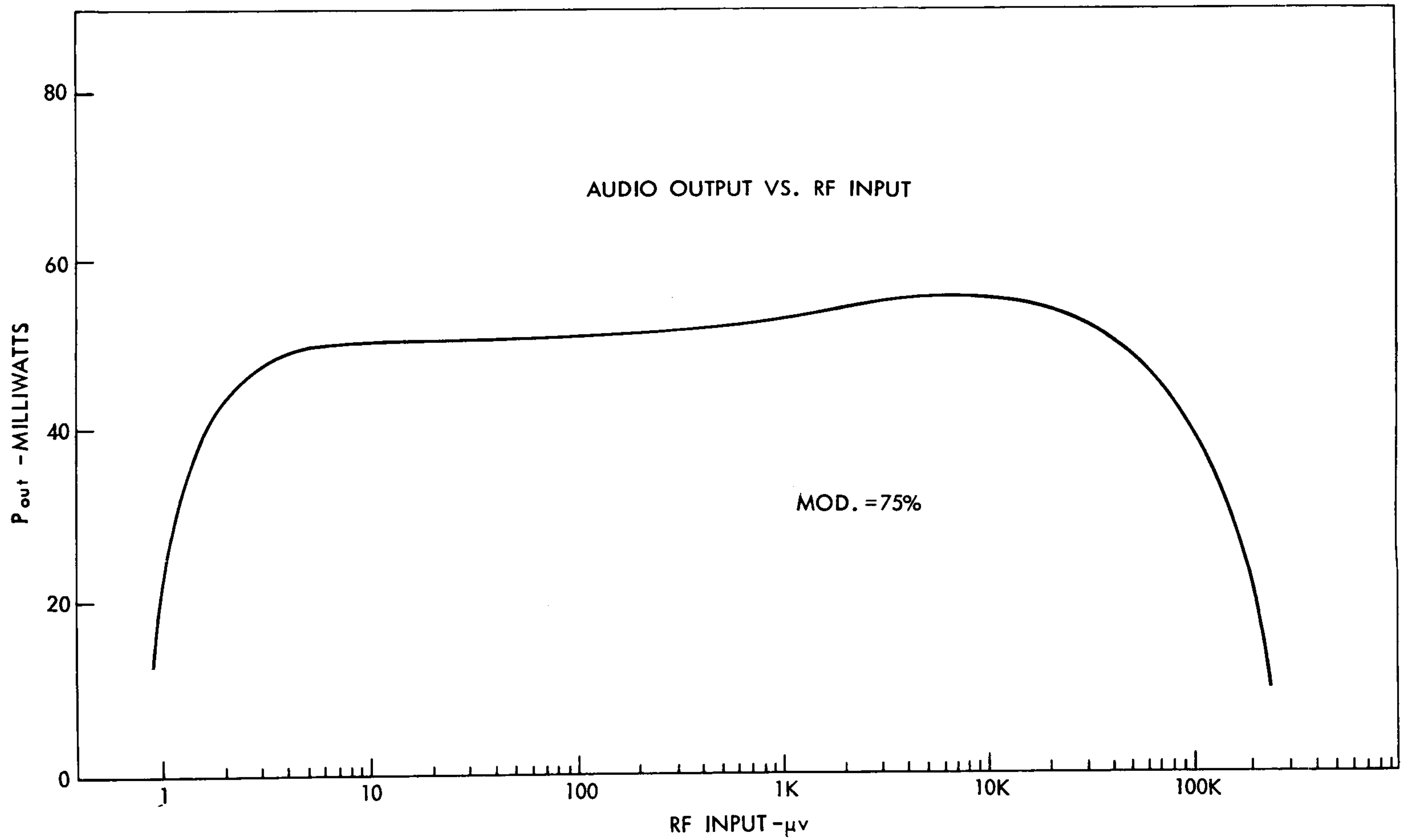


Figure 5-5–Power Output vs Rf Input

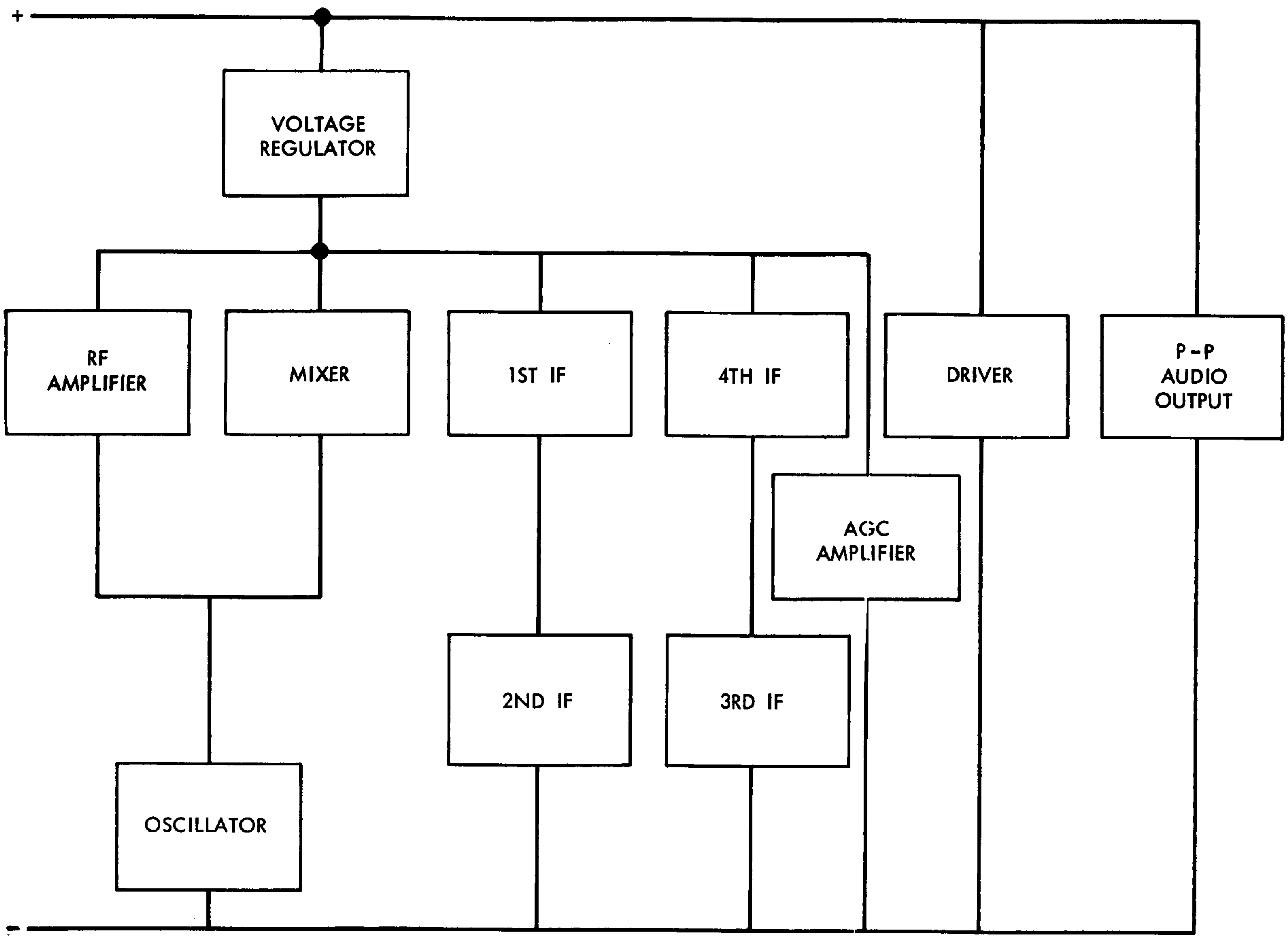


Figure 5-6–Command Receiver Power Distribution Diagram

5.2.2 Mechanical Design

Basic mechanical design was determined by the overall satellite packaging concept. A standard packaging configuration was adopted by NASA to permit stacking all of the various satellite equipments. The unit is 5-7/8 inches long, 3-5/8 inches wide, and one inch thick. See Figure 5-7.

Mechanical isolation of the five modules permits operation of the receiver in high-level vibration environments. The receiver is also completely encapsulated in Eccofoam FP Polyurethane potting foam.

5.3 COMMAND DECODER

The decoder receives a series of PDM tone bursts from the command receiver. These serial tone bursts are transmitted in a frame of five words, each word containing eight data bits, a sync and a blank bit. The first two words of a typical frame contain the address of a specific decoder. The last three words contain a function command to be performed by this decoder. System reliability is increased by transmitting the address twice, and the function command three times. One correctly received address and command code is sufficient to achieve the proper output function.

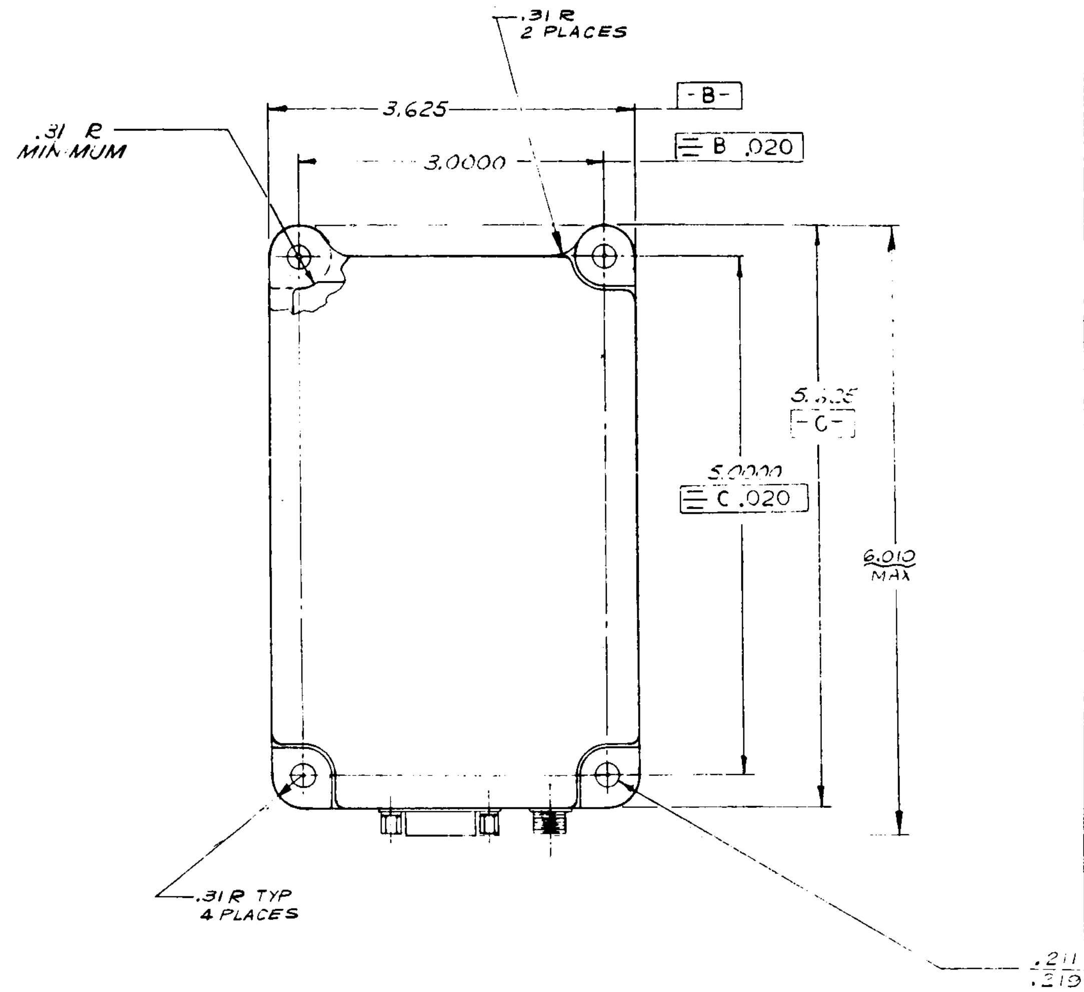
The decoder reads in all data presented to it from the command receiver. Each serial train of pulses is shifted, bit-by-bit, into the magnetic core shift register. The sync bit succeeding each word causes the decoder to interrogate the contents of the shift register. If, at this time, the shift register contains the prewired address for this decoder, the decoding position of the unit is enabled. The succeeding words of the same frame are read into the shift register, and the contents are interrogated by each sync bit. When a valid function command word is recognized by the enabled decoding section, this command is generated at the decoder output. (See Figure 5-8.)

The input tone bursts consist of three time durations, all prescribed as an integral number of cycles of the subcarrier, or command frequency. They are defined as follows:

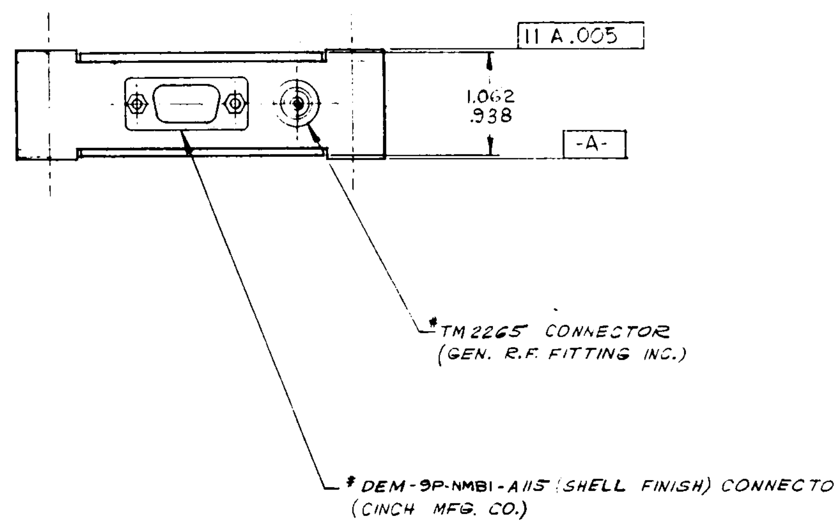
a. Binary 0 = 18 cycles of subcarrier frequency

b. Binary 1 = 26 cycles of subcarrier frequency

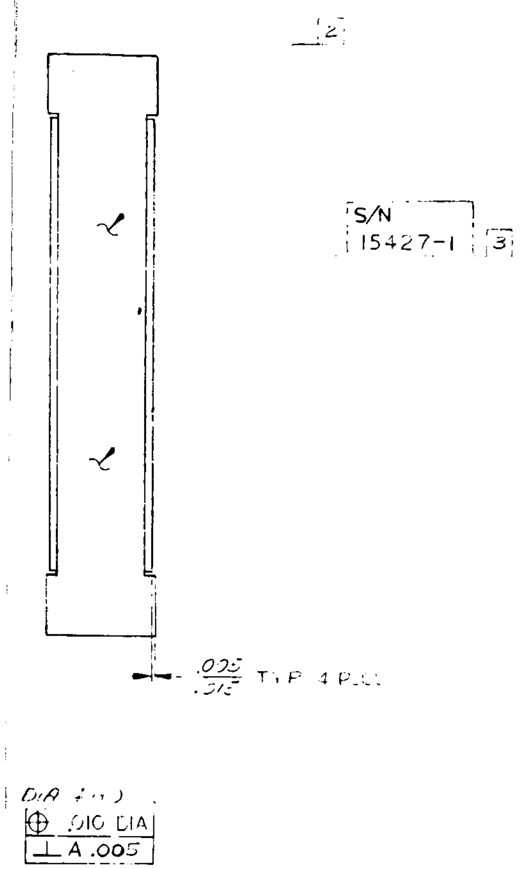
c. Sync Bit = 54 cycles of subcarrier frequency



.31 R
2 PLACES
-B-
3.625
.31 R
MINIMUM
3.0000
B .020
5.625
-C-
5.0000
C .020
6.010
MAX
.31 R TYP
4 PLACES
.211
.219



A .005
1.062
.938
-A-
*TM 2265 CONNECTOR
(GEN. R.F. FITTING INC.)
* DEM-9P-NMB1-A115 (SHELL FINISH) CONNECTO
(CINCH MFG. CO.)



GEN. NOTES UNLESS OTHERWISE SPECIFIED

APPROVED SOURCE: AVCO CORP. CINCINNATI, OHIO
AVCO PART NO. 185012

[2] VENDOR IDENTIFICATION PERMITTED IN NOTED AREA. (NO NAMEPLATES OR DECALCOMANIAS PERMITTED)

[3] MARK PER BPS 19.00-8-12

4. FINISH: 32√ POLISHED ON ALL OUTSIDE SURFACES. PART TO BE CLEANED AND ALL TRACES OF POLISH COMPOUND REMOVED.

5. REF. A 15327 DES SH. SPEC.

6. PIN CONNECTIONS

PIN NO.	FUNCTION
1	CHASSIS GROUND
2	B+
3	AGC JOINING
4	AUDIO (HIGH SIDE)
5	AUDIO (LOW SIDE)
6	AUDIO TEST POINT
7	REGULATED B+ TEST POINT
8	AGC TEST POINT
9	SPARE

7. EQUIPMENT SHALL BE BUILT IN ACCORDANCE WITH NASA QUALITY PUBLICATION NPC 200-4 & MSFC 154

Figure 5-7–Receiver Outline Drawing

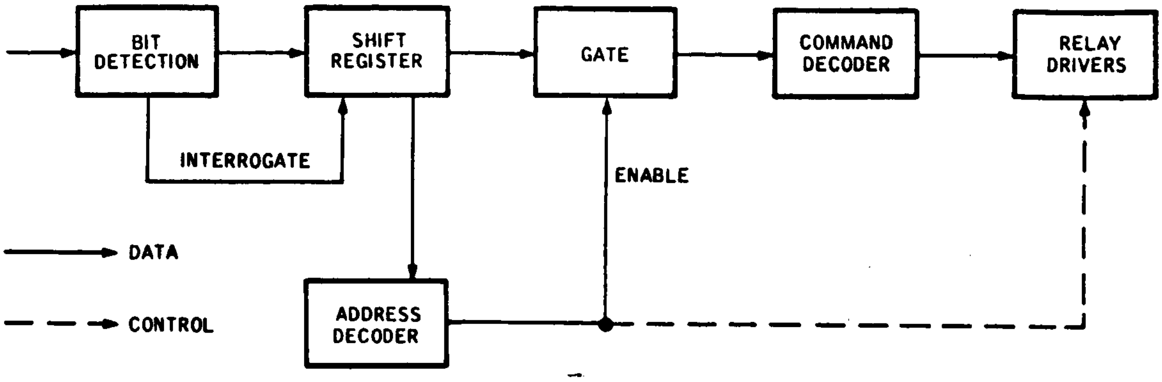


Figure 5-8—Command Decoder Block Diagram

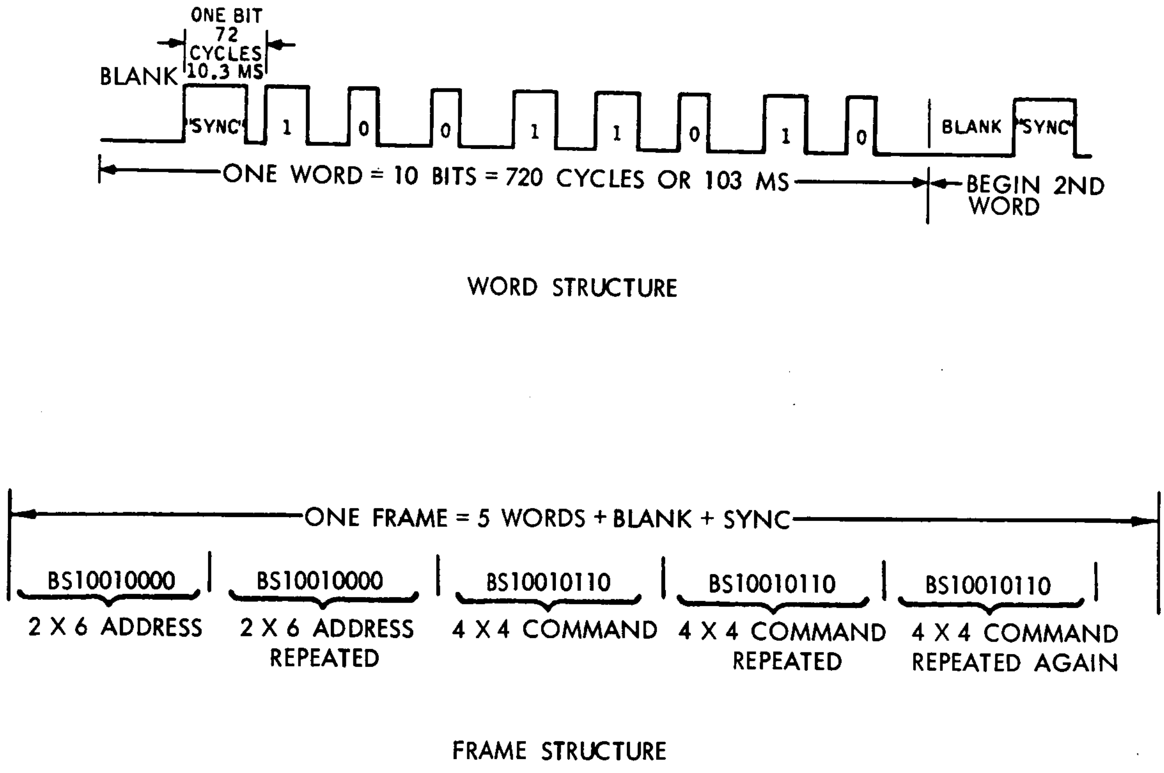


Figure 5-9—Word and Frame Structure

A complete bit time is defined as 72 cycles of the subcarrier; therefore, there is always a blank interval during each bit time.

5.3.1 Word Structure

As shown in Figure 5-9, a word consists of 10 bit times (720 cycles). A blank interval for 1 bit time is followed by a sync bit, and then eight data bits consisting of 1's and 0's. There are two types of words: address words and command words.

The eight-bit data portion of an address word always contains a combination of two 1 bits and six 0 bits, or six 1 bits and two 0 bits. There are 56 such combinations.

The eight-bit data portion of a command word always contains a combination of four 1 bits and four 0 bits. There are 70 such 4 × 4 combinations available. The decoder detects all 70 of these combinations.

5.3.2 Frame Structure

For most reliable operation in a high noise environment, a frame structure having the first two words as identical address codes and the last three words as identical command codes may be used. Figure 5-9 shows such a frame structure. The decoder generates the desired output signal if either address word and any one of the three command words are received correctly. The decoder is also capable of operating properly with a frame structure consisting of one address word followed by one to four different command words. In this mode, bit errors in the address word will result in no commands being executed. A bit error in one command will result in that command not being executed. This format may be used in less noisy conditions or when the transmission of a large number of commands per given time is required.

5.3.3 Bit Detection

The purpose of the bit detection circuitry is to determine the information content of each input tone burst. An integrating detection technique is used for this purpose. (See Figures 5-10 and 5-11.) The input signal from the receiver is applied to the bandpass filter. The center frequency of this filter is set for the subcarrier frequency of the PDM signal.

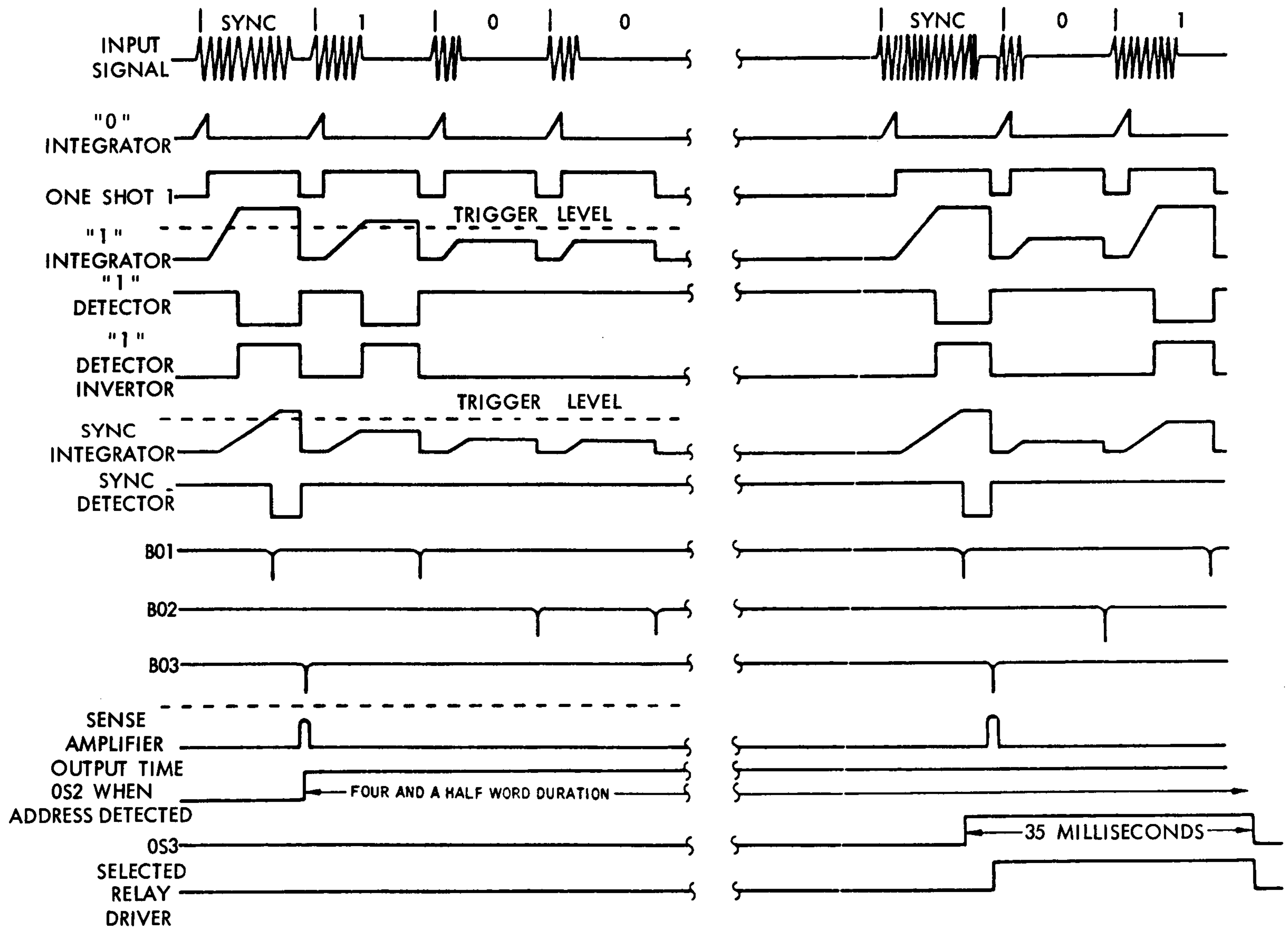


Figure 5-10–Decoder Timing Diagram

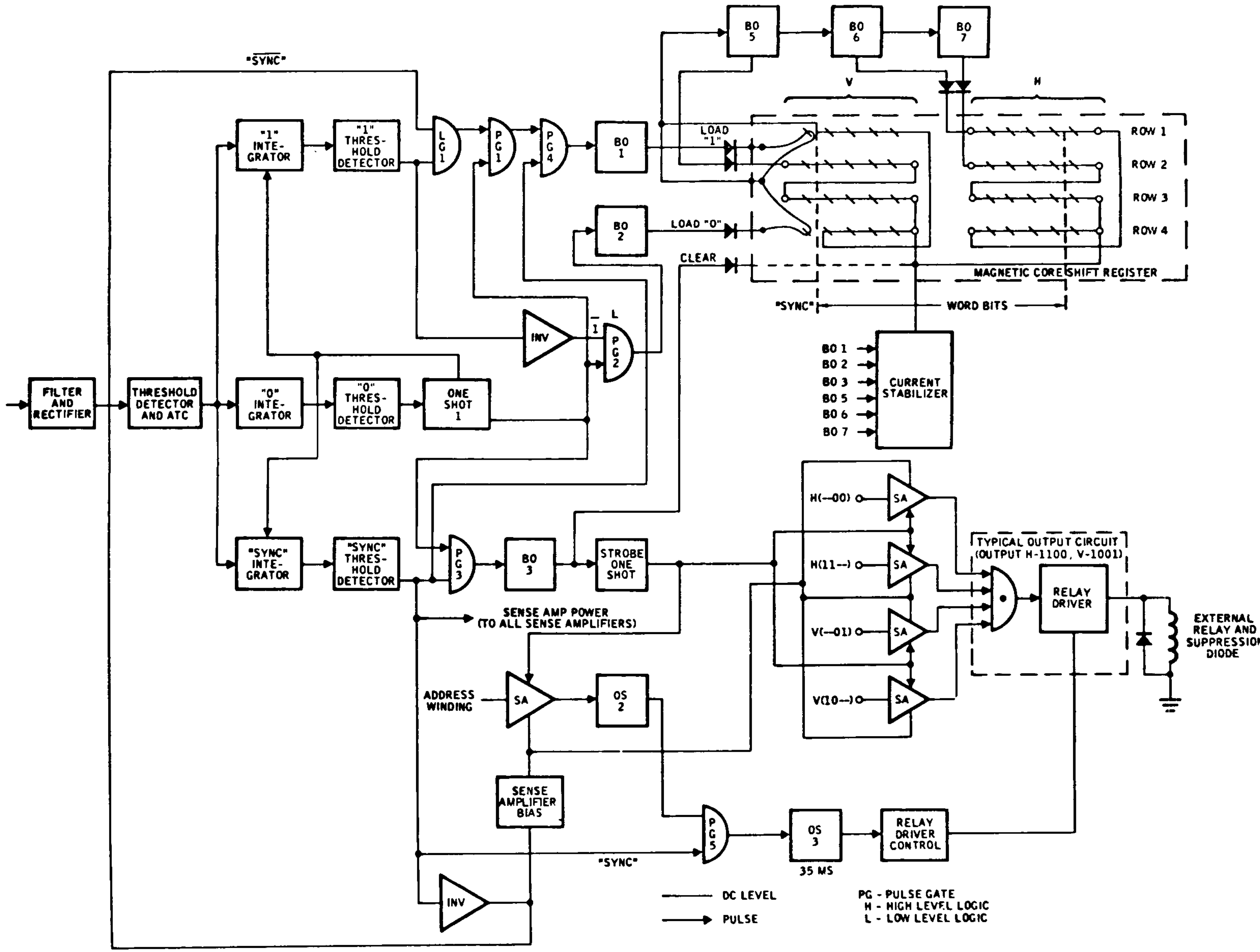


Figure 5-11–Decoder Block Diagram

5.3.4 Input Threshold Detector

The output of the filter is connected to a threshold detector. This device triggers when the filter output signal amplitude has reached a given threshold.

Once the threshold has been reached, the threshold detector circuit presents unit amplitude pulses to the three integrator circuits.

There is an integrator and an associated threshold detector for detecting each type of data; i.e., a sync bit, binary 1, or binary 0. When a tone burst appears at the filter output, the capacitor in the 0 integrator begins charging to the power supply voltage. The 1 and sync integrators obtain their charging current from one-shot 1 (OS1); these integrators operate only when OS1 is ON. Therefore, at the beginning of a tone burst, the 0 integrator will be the only one of the three to begin charging.

As shown in the timing diagram (Figure 5-10) when the 0 integrator reaches the preset level, its threshold detector triggers OS1. This is set to occur approximately in the middle of the 0 signal. Once the incoming burst has been detected, the 1 and sync integrators begin operating. The charging rates of these two integrators are different; each is set to reach its full charge approximately at the end of its associated tone burst. The threshold detectors for each of these integrators are set to trigger approximately in the middle of the unique portion of the 1 and sync signals, extending beyond the 0 and 1 signals, respectively. These two integrators remain at the charging level reached until they are reset by OS1.

5.3.5 Threshold Detectors

The 1 threshold detector provides the logic level indicating that a binary 1 PDM signal has been received. This level is inverted to provide a similar logic level for a binary 0. The levels are connected to AND (gates) pulse gate 1 and pulse gate 2 (PG1 and PG2 on Figure 5-11).

The sync detector signals AND (gate) pulse gate 3 that a sync pulse has been detected. It also triggers blocking oscillator 1 (BO1) to effect the shifting of a 1 into the cores prior to clearing them. This aligns the data correctly in the cores for the clearing and decoding operation. The same detector also turns on the sense amplifier 4-volt bias circuit. This prepares the address sense amplifier to read the output from the core memory address sense winding.

One-shot 1 is triggered ON when a 0 bit has been detected. The one-shot is set to time out during the blank interval between each data bit. The trailing edge of OS1 interrogates the three AND (gates) pulse gates 1, 2, and 3, to determine which blocking oscillator (BO1, BO2, or BO3) is to be fired.

In this manner, a 0 or 1 is loaded into the magnetic core shift register; or, a clear pulse to the cores is generated, when a sync bit is detected. OS1 supplies the charging current for the 1 and sync integrators, and also discharges all three integrators at the proper time.

5.3.6 Magnetic Core Shift Register

The magnetic core shift register serves as a serial-to-parallel code converter and as a decoding matrix. It stores the serial input code until the sync bit arrives at the end of the code word. Then the stored code is read out in parallel. Part of the address and command decoding is determined by the manner in which the sense windings are wound through the register.

The shift register stores 20 bits of information. It stores 1 for the sync bits at the beginning and at the end of a word, and 1's or 0's for the eight bits of the word itself. These 10 bits are stored in row 2 of the register, as shown in Figure 5-11. The second set of 10 bits is the complement of the first set, and these bits are stored in row 3. Each bit of the second set is stored in the register at the same time as its complement in the first set. The second set of bits is required by the output decoding logic.

The magnetic core shift register consists of 40 tape-wound memory cores, arranged in a two-core-per-bit fashion. The tape-wound cores are constructed from a molybdenum nickel iron alloy wound on a stainless steel bobbin.

To store the information described above (rows 2 and 3 of Figure 5-11) 20 of the cores are used. The other 20 cores are required for temporary storage during the shifting operation (rows 1 and 4 of Figure 5-11). BO1 and BO2 load the register and shift held information already in the register. BO5, BO6, and BO7 shift information in the register. BO6 and BO7 are logically redundant, but are required because of the limited supply voltage available.

Information is shifted from left to right (see Figure 5-11). BO1 sets the flux in the first core of row 1 and shifts the information in the first five bit positions of rows 2 and 3 one position to the right into rows 1 and 4, respectively. BO2 performs the same shift operation, but sets the first core in row 4. When BO1 or BO2 times out, it triggers BO5. BO5 shifts the information in the first five bit positions of rows 1 and 4 one position to the right into rows 2 and 3, respectively. At the trailing edge of BO5, BO6 is triggered. BO6 shifts the information in the second five bit positions of rows 2 and 3 into rows 1 and 4 one position to the right. BO7 then shifts the information back into rows 2 and 3 in the second five bit positions. When the sequence of BO firings is complete, the information entered by BO1 or BO2 is in the first position of row 2 or 3; all the old information has been shifted one position to the right in rows 2 and 3. There is no information in the cores of rows 1 and 4.

5.3.7 Command Decoding

Command decoding consists of translating the eight bits of the command word to a signal of one of the command outputs. Command decoding is done in two stages.

A valid code is first translated to signals on four of the 16 sense amplifiers. The outputs of the sense amplifiers are then combined in 4-legged AND gates. Each AND gate serves to trigger one relay driver; this occurs only when all four inputs to the gate are simultaneously true.

Each of the 16 sense amplifiers is fed by a sense winding. Each sense winding represents a particular 2-bit code. It is wound through the sync core (the right-most core in row 2) and through two of the 8-data-bit cores. Figure 5-12 shows eight of these windings. Although only one winding is shown going through the sync core, the other 15 also go through it.

The sense windings operate the sense amplifiers in the following manner. When a valid command in memory is read out, the sync core generates a positive voltage pulse on all 16 command sense windings. This pulse is sufficient to turn on the sense amplifiers. However, an opposing negative voltage pulse, sufficient to cancel the positive pulse, is simultaneously generated by each bit core containing a 1.

One or more negative pulses will cancel out the positive pulse from the sync core. Therefore, only the sense windings passing through bit cores containing 0's will have the necessary positive pulse at clearing time to energize the sense amplifier.

The 16 command sense amplifiers also receive signals from the strobe one-shot and sense amplifier 4-volt bias circuits. An amplifier produces an output signal only when the sense winding signal is positive at strobe time.

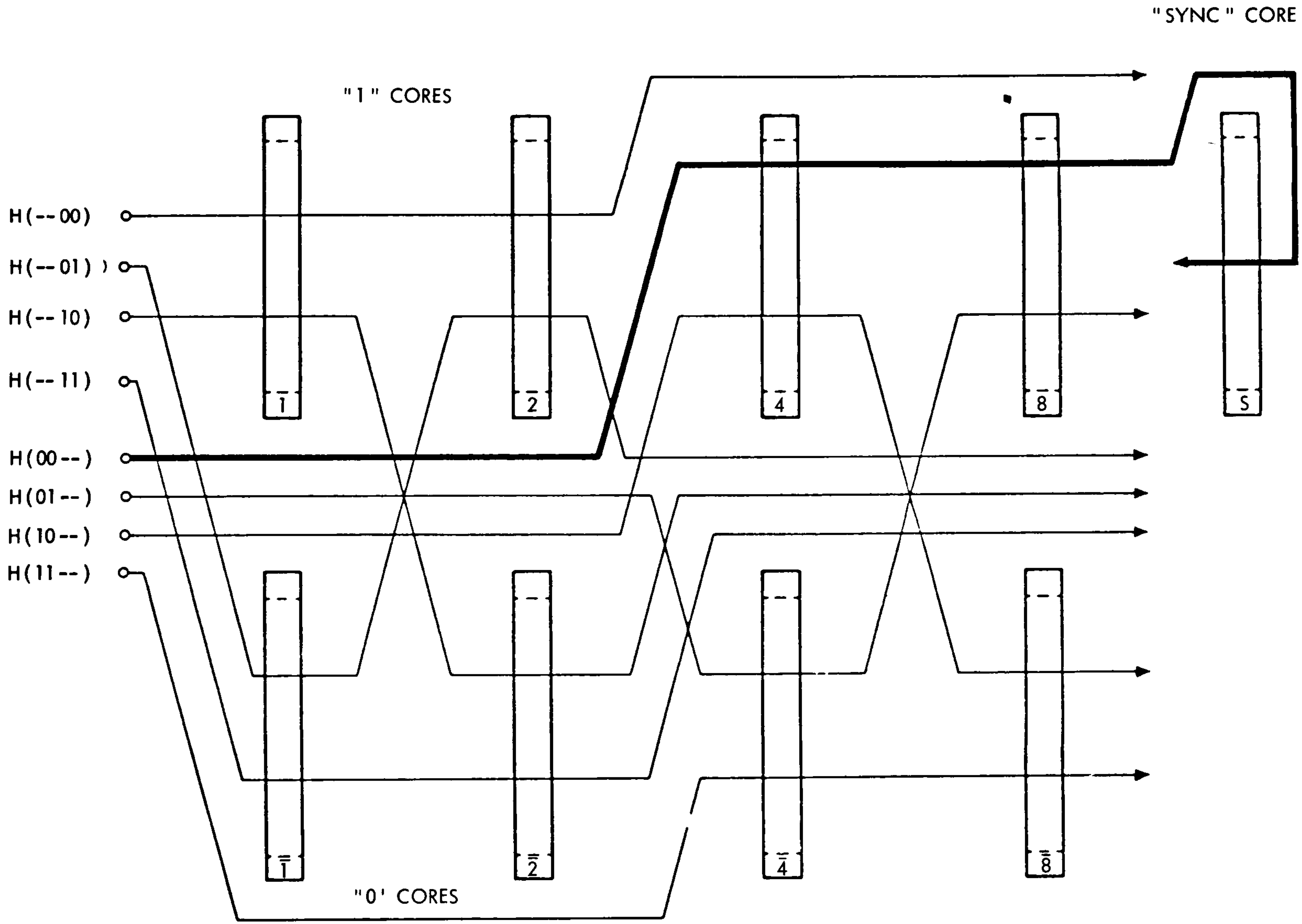


Figure 5-12–Core Decoding

5.3.8 Address Decoding

The address word decoding is accomplished in the same manner as the command word, with one exception. The address sense winding is threaded through all eight data cores as well as the sync cores. In this manner, a positive signal will be generated on this wire only when the complete address is available in the cores. (See Figure 5-13.)

Each decoder is furnished with preselected address sense wires. These wires are brought to the input connector in order to provide for a selection of one of these as the address to be detected by the decoder. When the positive address signal is detected by the address sense amplifier, OS2 is triggered ON. The timing of this one-shot is set to last for the duration of the next four words of the frame being transmitted. With OS2 on, the AND gate PG5 may now operate the OS3, whenever the sync bit is detected. OS3 applies power to the relay drivers. The selected driver turns on for 35 ± 5 milliseconds when a command has been detected. Once the frame of data has expired, OS2 times out and will not be triggered on again until the selected address is detected. Until this occurs, PG5 and OS3 are inoperative, and no relays may be energized.

5.3.9 Relay Driver Matrix

The sense amplifier outputs are arranged in a 16 × 16 matrix as depicted in Figure 5-14. The horizontal lines are derived from the two right-hand groups of cores shown in Figure 5-13. These are the most significant four bits. The vertical lines are derived from the two left-hand groups of cores, which are the least significant four bits of the 8-bit command word.

This full matrix forms 256 intersections; however, only the 70 intersections which produce the codes containing four 1's and four 0's are used for decoding command words.

Located at each of the 70 selected intersections is an AND gate and a relay driver. When four sense amplifier output pulses occur simultaneously at the inputs to the AND gate, the associated relay driver is triggered ON. For example, a relay is to be energized when the command word 01010101 is transmitted. The relay must be connected to the relay driver located at intersection 21 on the matrix shown in Figure 5-14. When this command word is received and decoded, the four sense amplifiers, (V_1 (01--), V_2 (--01), H_1 (01--), and H_2(--01), will generate a pulse, triggering ON relay driver 21 and energizing relay 21.

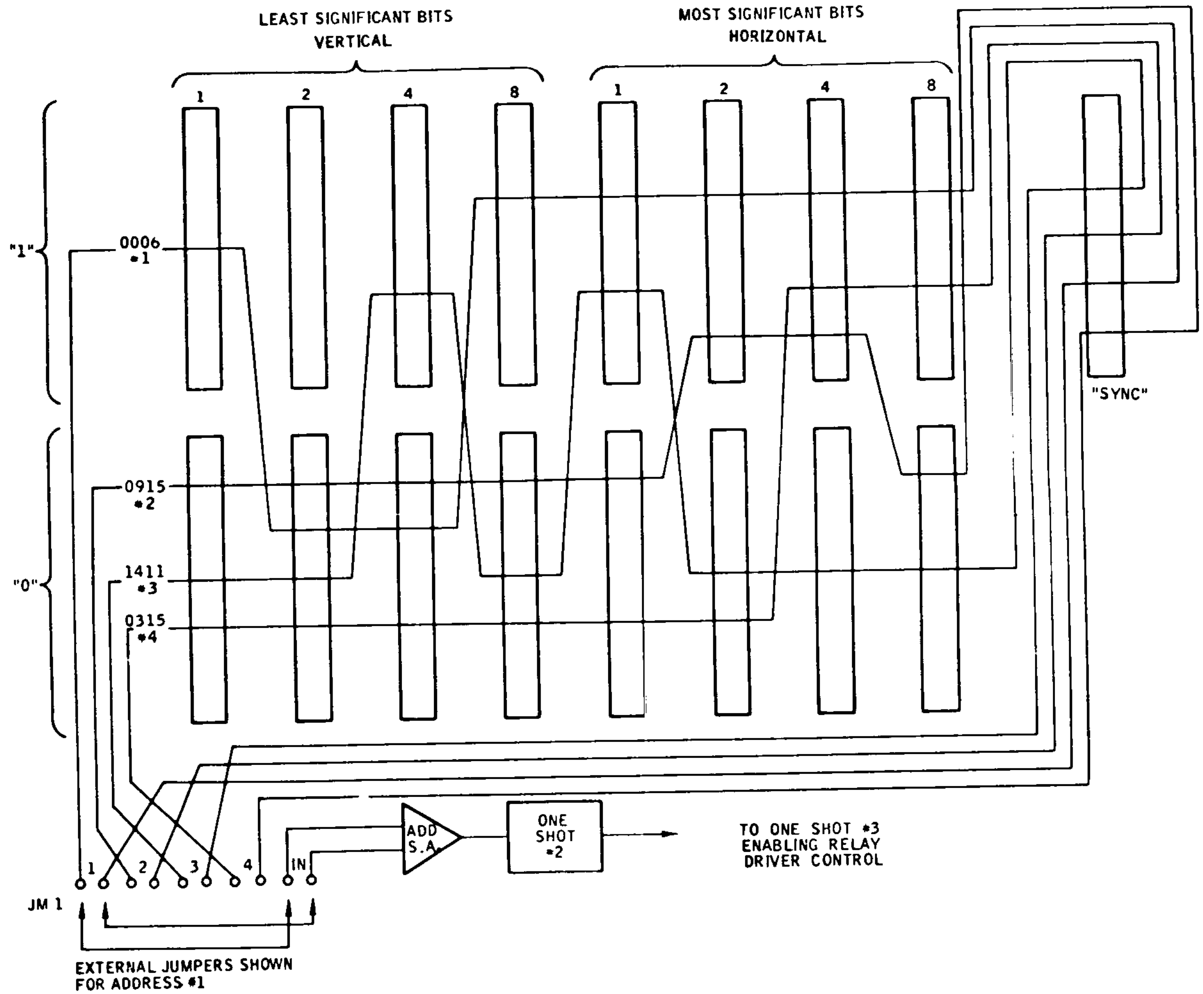


Figure 5-13–Address Sense Winding

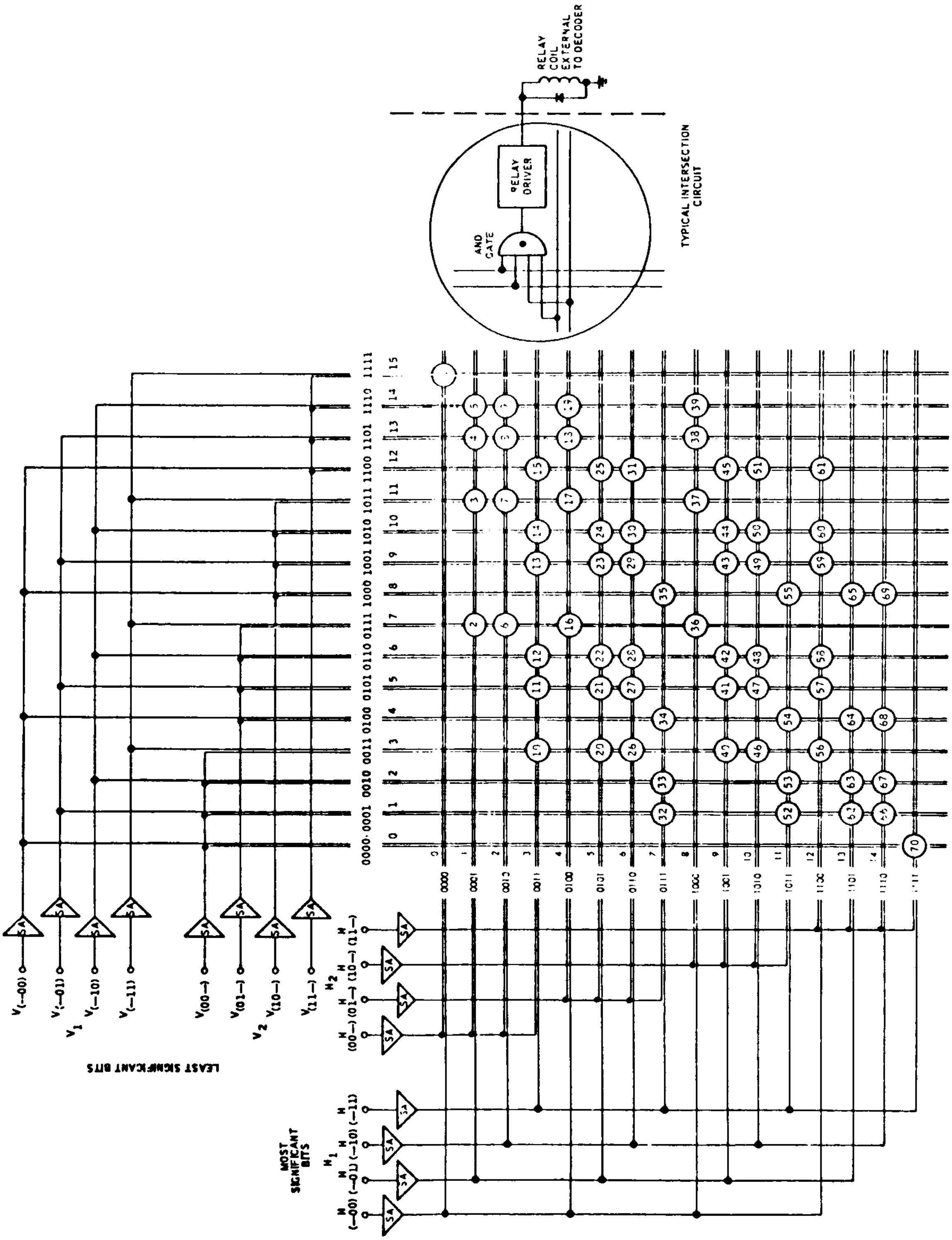


Figure 5-14—Relay Driver Matrix

5.4 SYSTEM OPERATION

5.4.1 Normal Command Operation

The commands used for normal spacecraft operation are primarily to operate the telemetry systems during the acquisition and tracking periods.

5.4.2 Command Backup of Automatic Functions

Various command words are used for backup control of the spacecraft during orbital operation. This backup system could extend the life of the spacecraft.

Those functions which lend themselves to manual control or backup are (1) spin control, (2) pitch control, (3) undervoltage switching, and (4) the sequencing timer. The functions of spin and pitch are described in Section 3; the undervoltage switch circuit is described in Section 6; and the sequencing timer is discussed in Section 10.

5.4.3 Experiment Control

The experiment control command allocations for the OSO-D spacecraft are listed in Table 5-1.

Section 6

POWER SUPPLY AND DISTRIBUTION

6.1 INTRODUCTION

Power for the spacecraft and the experiments is supplied by a battery pack. This battery pack is recharged while the spacecraft is in the sunlight by an array of solar cells that are mounted on the sail. Power is distributed to several electrical busses that are either energized or de-energized depending upon the state of battery charge and whether or not the spacecraft is in sunlight. The system diagram for the power supply and distribution is Figure 6-1.

6.2 SOLAR CELL ARRAY

The solar cell array is mounted on the front face of the sail. A honeycomb panel on the back of the array acts as a heat sink. The array is shown in Figure 1-1.

The solar cell array converts solar energy into electrical power which charges the battery pack and also furnishes electrical power during daylight operation. There are approximately 2016 silicone cells arranged in 36 parallel strings of 56 cells each, which cover an area of 3.8 square feet. The power output available from the solar array is 38 watts. There is reverse current diode protection to prevent the batteries from discharging through the solar cells.

6.2.1 Solar Cell

Each solar cell is an N/P shingled silicone cell with a resistivity of 10 ohm/cm. The solar cells each have a blue reflecting filter with a response between 0.410 microns and 2 microns. For radiation purposes, a 20 mil cover sheet of Corning Fused Silica is applied with LTV 602 GE cement. An anti-reflective coating with a transmissibility which peaks at 0.625 microns is applied to the cover sheet.

6.3 BATTERY PACK

The battery pack consists of 42 nickel-cadmium, F size cells, These 42 cells are distributed in six packs of seven cells; two packs are located on the rim of the spacecraft in compartments 1, 4, and 7. To produce an 18.9 volt dc supply, the 14 cells in each compartment are connected in series; and the three groups are connected in parallel to provide the necessary power capacity. The battery pack voltage ranges from 16 volts at a nearly discharged state to 22 volts at a fully charged state.

There is no prime supply voltage or current regulator in the spacecraft; however, there is an undervoltage switch to prevent the batteries from being completely discharged and a regulator that supplies voltage for critical spacecraft functions and experiments. A temperature probe is attached to the battery pack in compartment 1; this probe detects changes in the battery case temperature and feeds this change as an input to channel 16 of ASC number 1.

6.3.1 Batteries

Each individual battery is capable of taking a 0.45 ampere charge for at least 96 hours with an end-point voltage of 1.49 volts or less. This cell is capable of providing 0.76 ampere for 5 hours at 1.2 or more volts after undergoing the following schedule.

a. Charge at 0.45 ampere for 16 to 96 hours

b. Discharge at 0.76 ampere for 5 hours

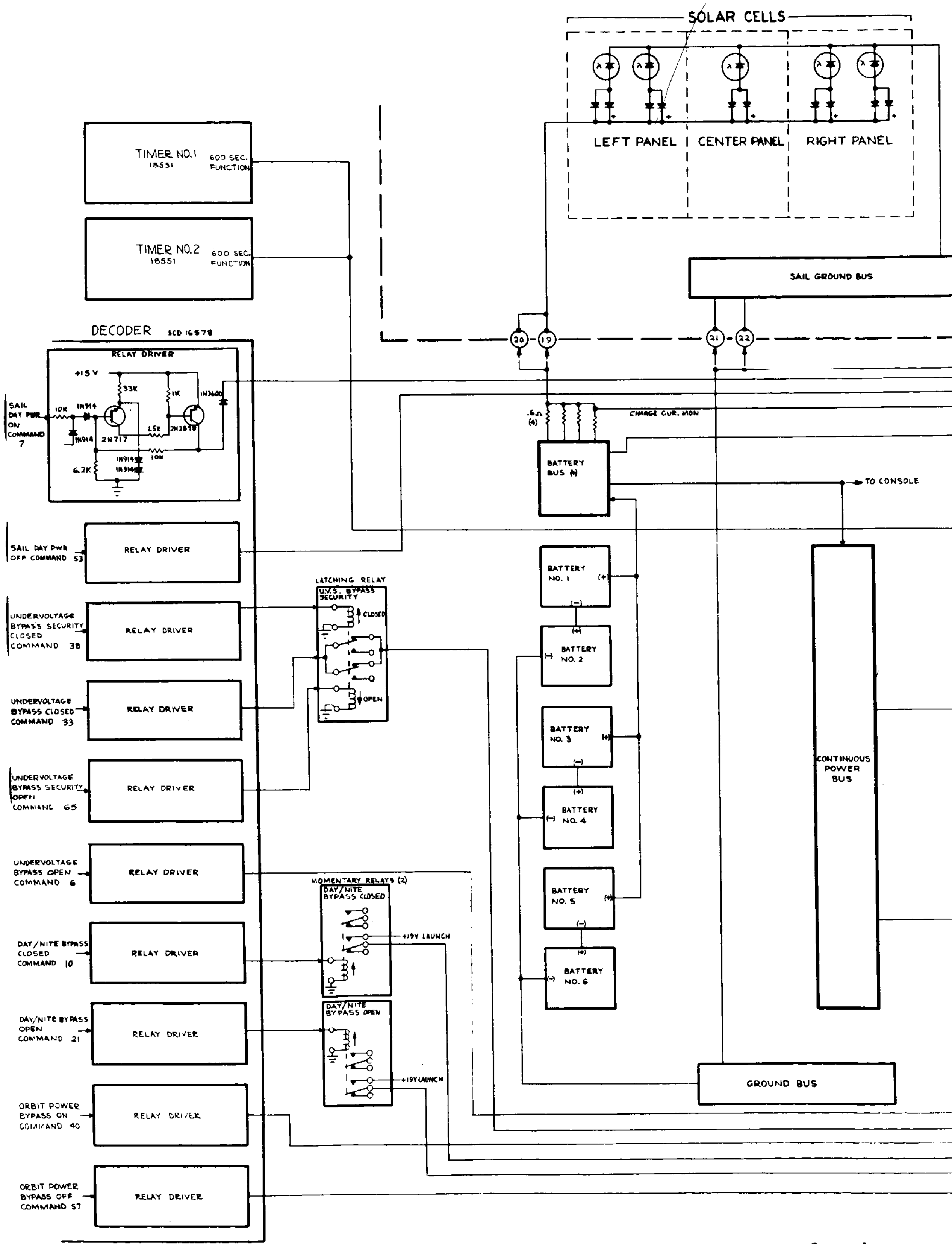
c. Charge at 0.45 ampere for 16 to 17 hours

d. Repeat b and c until four discharge-charge cycles have been completed.

6.3.2 Charge Rate Monitor

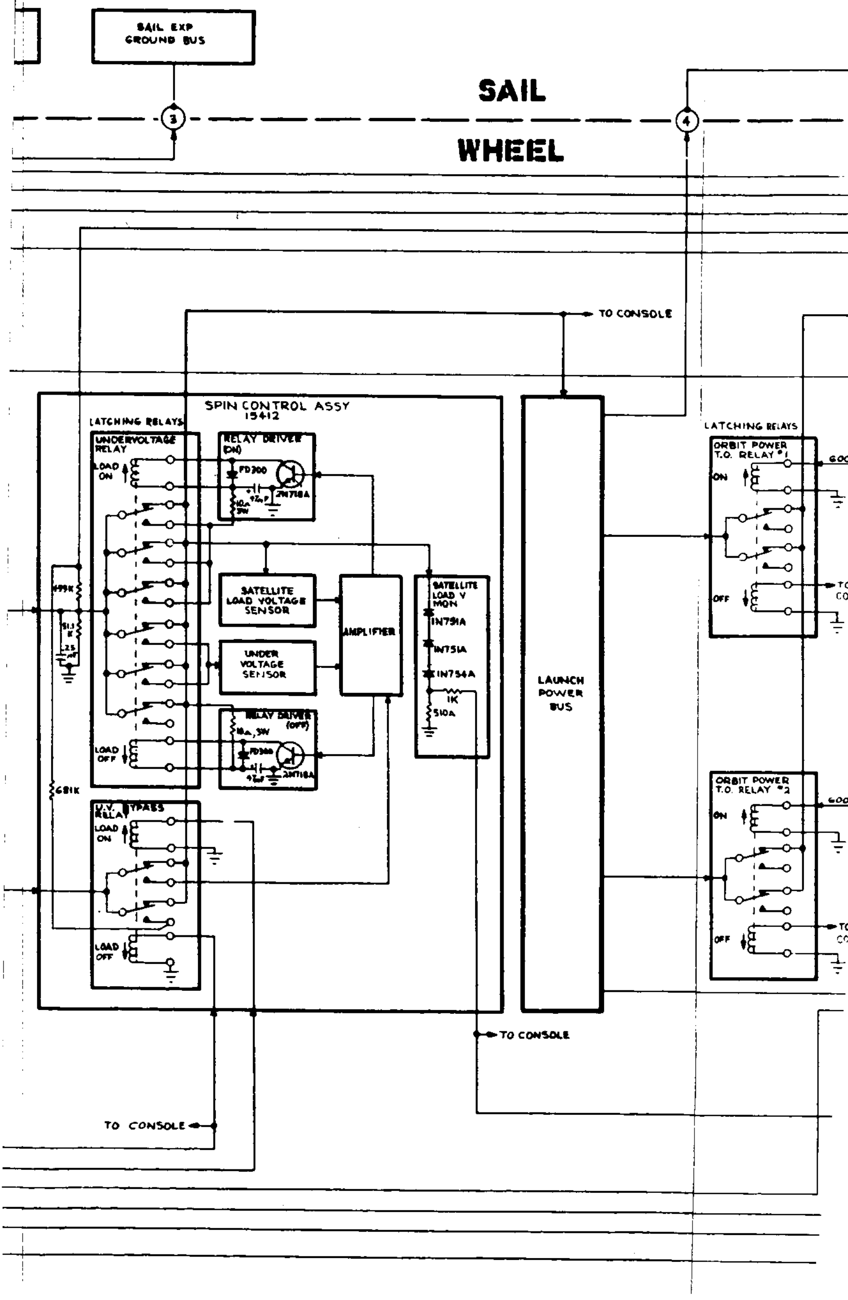
The charge rate monitor delivers a voltage to channel 41 of ASC number 2 proportional to the output current of the solar cell array. The monitor amplifies the voltage drop across four paralleled 0.6 ohm resistors in the positive solar cell array lead. The solar array current monitored is between 0 and 2.67 amperes. Power for operation of the monitor is taken directly from the batteries.

This three stage transistorized monitor products an output between 0 and 5 volts dc (nominally 1.87 volts per ampere of current being monitored) with a load of 100 k ohms.

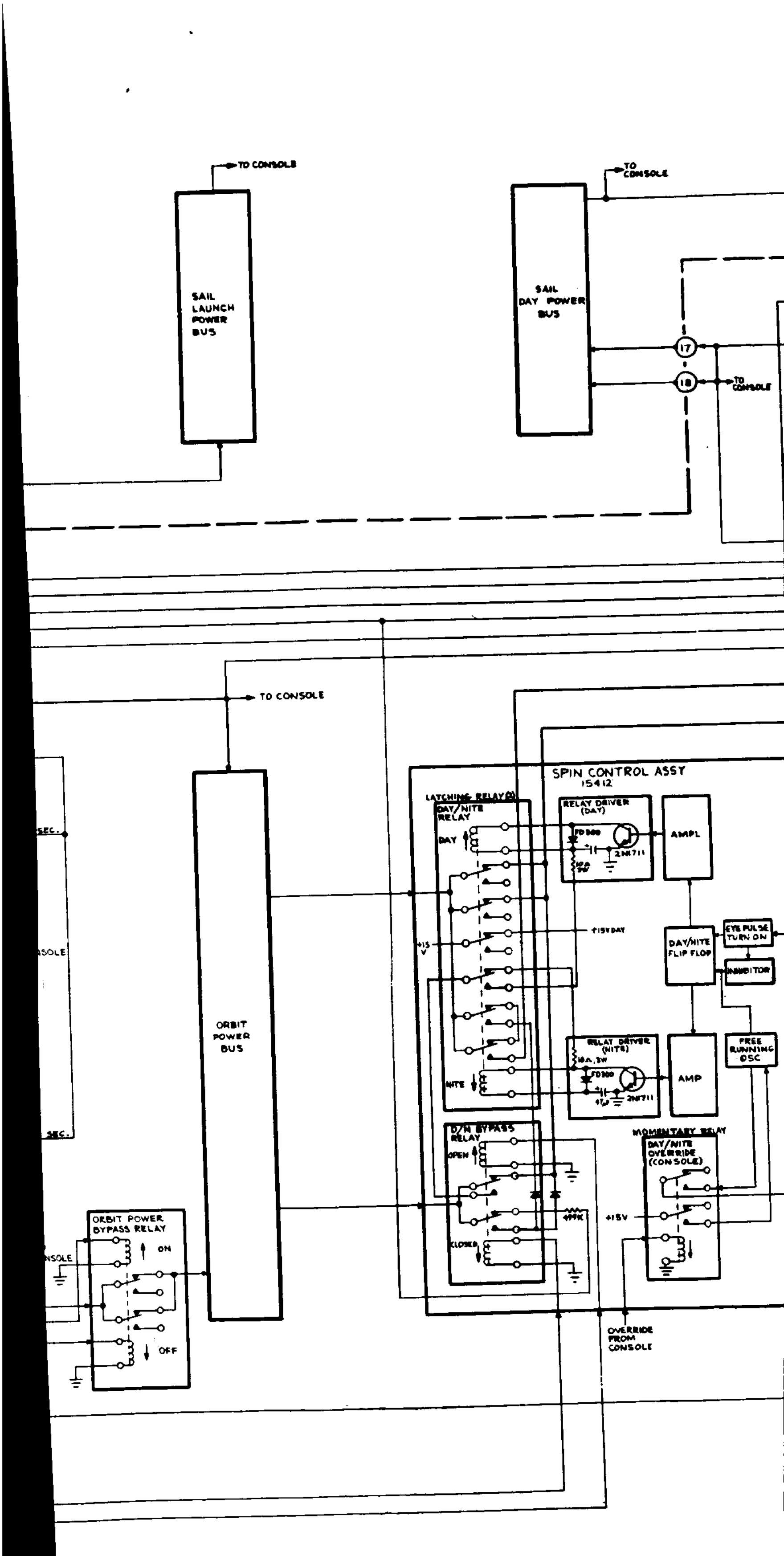


SOLAR CELLS
LEFT PANEL
CENTER PANEL
RIGHT PANEL
TIMER NO.1
18551
600 SEC. FUNCTION
TIMER NO.2
18551
600 SEC. FUNCTION
SAIL GROUND BUS
DECODER SCD 16578
RELAY DRIVER
+15 V
SAIL DAY PWR ON COMMAND 7
2N717
2N2838
SAIL DAY PWR OFF COMMAND 53
UNDERVOLTAGE BYPASS SECURITY CLOSED COMMAND 38
UNDERVOLTAGE BYPASS CLOSED COMMAND 33
UNDERVOLTAGE BYPASS SECURITY OPEN COMMAND 65
UNDERVOLTAGE BYPASS OPEN COMMAND 6
DAY/NITE BYPASS CLOSED COMMAND 10
DAY/NITE BYPASS OPEN COMMAND 21
ORBIT POWER BYPASS ON COMMAND 40
ORBIT POWER BYPASS OFF COMMAND 57
RELAY DRIVER
LATCHING RELAY
U.V.S. BYPASS SECURITY
CLOSED
OPEN
MOMENTARY RELAYS (2)
DAY/NITE BYPASS CLOSED
DAY/NITE BYPASS OPEN
+19V LAUNCH
CHARGE CUR. MON
BATTERY BUS (+)
TO CONSOLE
BATTERY NO. 1
BATTERY NO. 2
BATTERY NO. 3
BATTERY NO. 4
BATTERY NO. 5
BATTERY NO. 6
CONTINUOUS POWER BUS
GROUND BUS

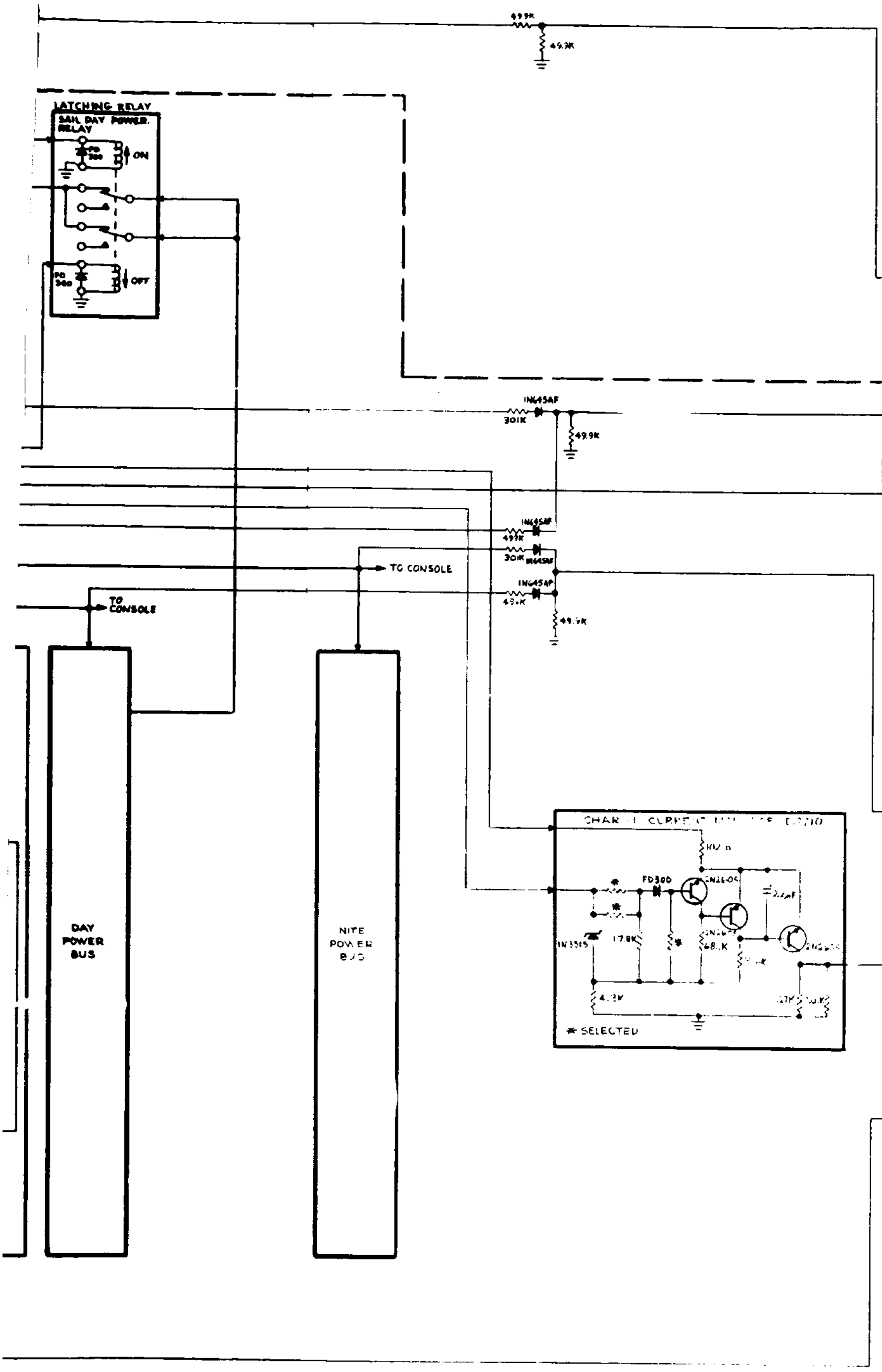
6-3, 1



SAIL EXP
GROUND BUS
3
SAIL
WHEEL
4
TO CONSOLE
SPIN CONTROL ASSY
15412
LATCHING RELAYS
UNDERVOLTAGE
RELAY
LOAD
ON
LOAD
OFF
RELAY DRIVER
(ON)
FD300
2N718A
10Ω
3W
47μF
SATELLITE
LOAD VOLTAGE
SENSOR
UNDER
VOLTAGE
SENSOR
AMPLIFIER
SATELLITE
LOAD V
MON
1N751A
1N751A
1N754A
1K
510Ω
RELAY DRIVER
(OFF)
10Ω, 3W
2N718A
47μF
499K
51.1
K
2.5
μF
681K
U.V. BYPASS
RELAY
LOAD
ON
LOAD
OFF
LAUNCH
POWER
BUS
LATCHING RELAYS
ORBIT POWER
T.O. RELAY #1
ON
OFF
ORBIT POWER
T.O. RELAY #2
ON
OFF
TO CONSOLE
TO CONSOLE


TO CONSOLE
SAIL LAUNCH POWER BUS
TO CONSOLE
SAIL DAY POWER BUS
17
18
TO CONSOLE
TO CONSOLE
SPIN CONTROL ASSY
15412
LATCHING RELAY
DAY/NITE RELAY
DAY
NITE
RELAY DRIVER (DAY)
FD300
2N711
AMPL
+15V DAY
DAY/NITE FLIP FLOP
EYE PULSE TURN ON
INHIBITOR
RELAY DRIVER (NITE)
FD300
2N711
AMP
FREE RUNNING OSC
+15 V
ORBIT POWER BUS
D/N BYPASS RELAY
OPEN
CLOSED
499K
MOMENTARY RELAY
DAY/NITE OVERRIDE (CONSOLE)
+15V
ORBIT POWER BYPASS RELAY
ON
OFF
SEC.
SEC.
OVERRIDE FROM CONSOLE

63, R (3)



49.9K
49.9K
LATCHING RELAY
SAIL DAY POWER RELAY
FD 300
ON
OFF
1N645AF
301K
49.9K
TO CONSOLE
TO CONSOLE
DAY POWER BUS
NITE POWER BUS
FD300
17.8K
68.1K
4.3K
* SELECTED

GEN NOTES UNLESS OTHERWISE SPECIFIED:
1. ABBREVIATIONS OTHER THAN THOSE LISTED IN MIL-STD-12 ARE:
U.V.S. UNDERVOLTAGE SWITCH
U.V. UNDERVOLTAGE

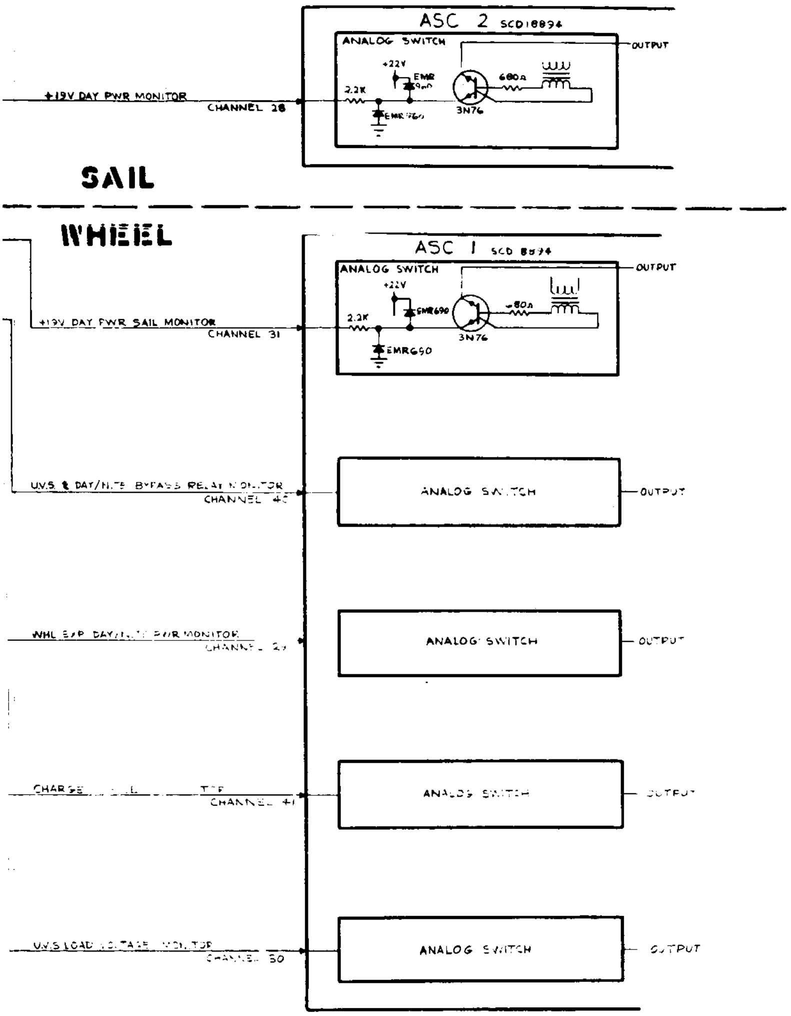


Figure 6-1—Power Supply and Distribution

6.4 CONTINUOUS POWER BUS

The batteries are connected directly to the continuous power bus. Circuits that receive power from this bus are shown in Figure 6-2. The continuous power bus is connected to the launch power bus through the undervoltage switch (relay) and the undervoltage bypass switch (relay). The voltage (satellite load voltage) on the continuous power bus is monitored on channel 30 of ASC number 2.

6.4.1 Undervoltage Switch (Relay)

The spacecraft batteries are nickel-cadmium cells which have a rather flat discharge curve until they become almost fully discharged. Near the fully discharged state, the voltage falls abruptly and the impedance increases and very little power can be drawn from them. When the batteries become almost fully discharged, they will not be able to deliver the current necessary to allow the servo to be activated and orient the sail toward the sun. This condition will result in a disabling of the spacecraft. By utilizing ground command, sections of the spacecraft can be turned off to conserve power so the undervoltage condition is not expected to occur. However, if the command system is not operative and the batteries are discharged to the point where the voltage drops abruptly, a final means is available in the spacecraft to prevent the loss of the vehicle. This is the undervoltage switch (relay) which shuts down the entire spacecraft and permits the batteries to charge from the rotating solar cell array. When the batteries are about 10 percent charged, the undervoltage switch turns on the spacecraft again. A diagram of the undervoltage switch is shown in Figure 6-1.

All the power for spacecraft operation goes through a 6-pole double-throw latching relay. Five of the poles carry the spacecraft power and one is used for switching in the undervoltage switch.

When the voltage is high and the batteries are charged, the relay is as shown in the diagram. Power is applied to the turn-off voltage reference and to the coil of the relay that will turn off the spacecraft. The driver for the coil is shut off, however, so the relay cannot operate. Power for a regenerative switch that controls the driver is fed directly from the batteries. When the battery voltage drops to 15.5 volts, the regenerative switch operates and changes state. This in turn fires the driver for the "off" coil causing the relay to be activated and place the batteries in a charge state. As the contacts leave their "on" position, power is removed from the "off" coil of the relay and from the "off" voltage reference. A time delay in the regenerative switch keeps the "off" coil driver saturated so the energy stored in the 47 microfarad capacitor across the "off" coil can flow through the relay and complete the contact transfer.

When the relay has transferred, power is removed from the spacecraft except for the undervoltage sensor. The battery voltage is now connected to the "on" voltage reference and the "on" relay coil. The "on" voltage reference is set so it will not fire the regenerative switch until the battery voltage rises to 19 volts. Therefore, the "on" coil driver is not energized and the relay cannot transfer. When, due to charging from the solar cell array the voltage rises to 19 volts, the regenerative switch changes back to its original state and fires the "on" coil driver. The relay contacts are now transferred back to their original state, aided by the capacitor across the "on" coil.

Sufficient hysteresis is built into the undervoltage switch so the servo can catch and orient the solar cells for efficient battery charging after it has again been turned on.

6.4.2 Undervoltage and Security Bypass Relays

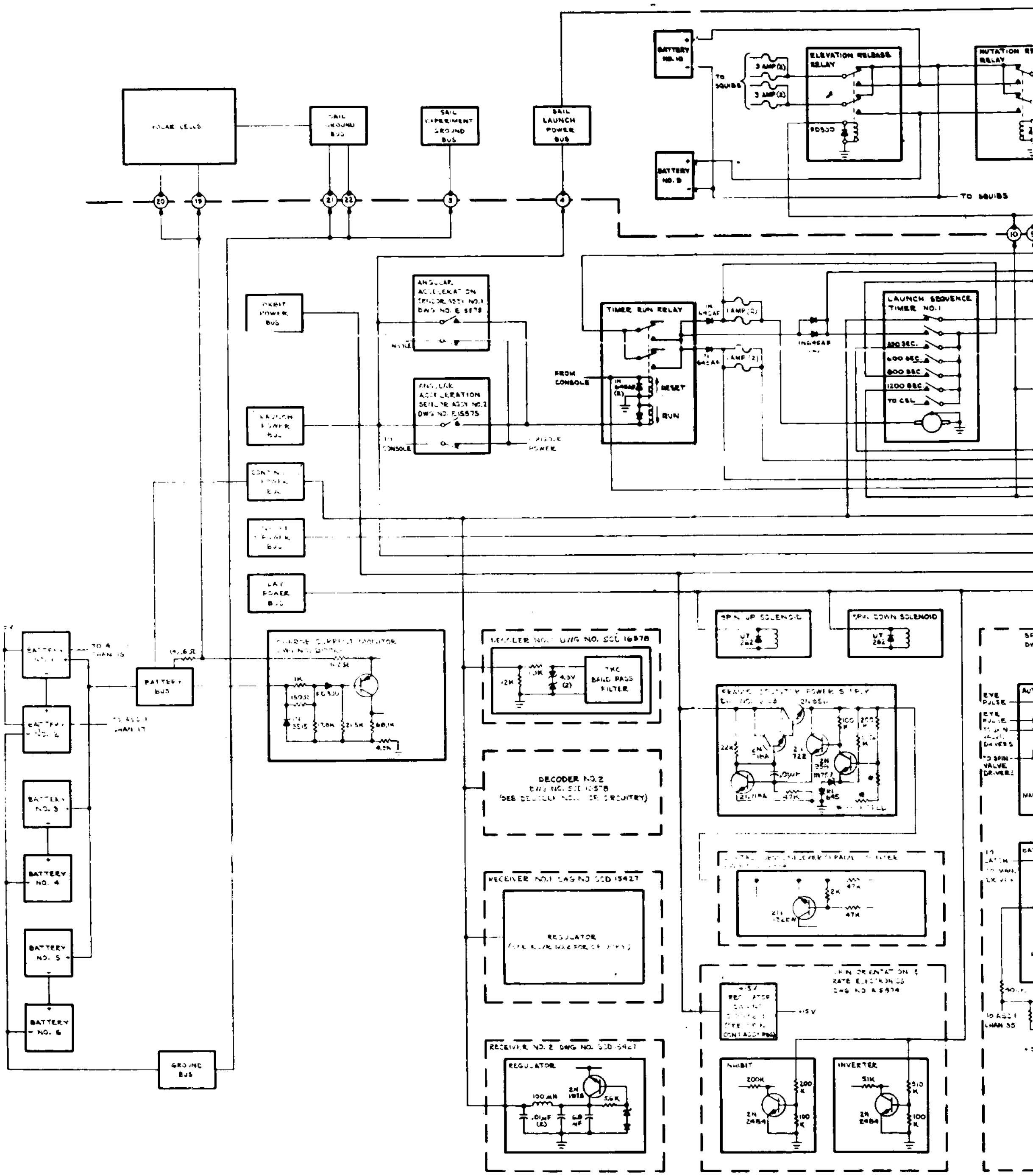
The operation of the undervoltage and u.v.s. bypass security relay serves as a command back up function when failure occurs to the undervoltage relay. If the undervoltage switch fails to open when the voltage is low the "load off" coil of the undervoltage bypass relay (latching type) must be energized by an alternate means. This is accomplished by the undervoltage bypass open command number 6 signal. With this coil ("load off") energized, the continuous power bus will then be applied as the input to the undervoltage relay amplifier. (See Figure 6-1.)

To shunt the undervoltage switch after the voltage has risen to a sufficiently high level it is necessary to energize the "load on" coil of the undervoltage bypass relay. To energize this coil the u.v.s. bypass security relay (latching type) must be in the closed position. The undervoltage bypass security closed command number 38 and the undervoltage bypass security open command number 65 signals control the position of this relay. With the security bypass relay in the closed position, the undervoltage bypass closed command number 33 signal may then be applied to energize the "load on" coil of the undervoltage bypass relay.

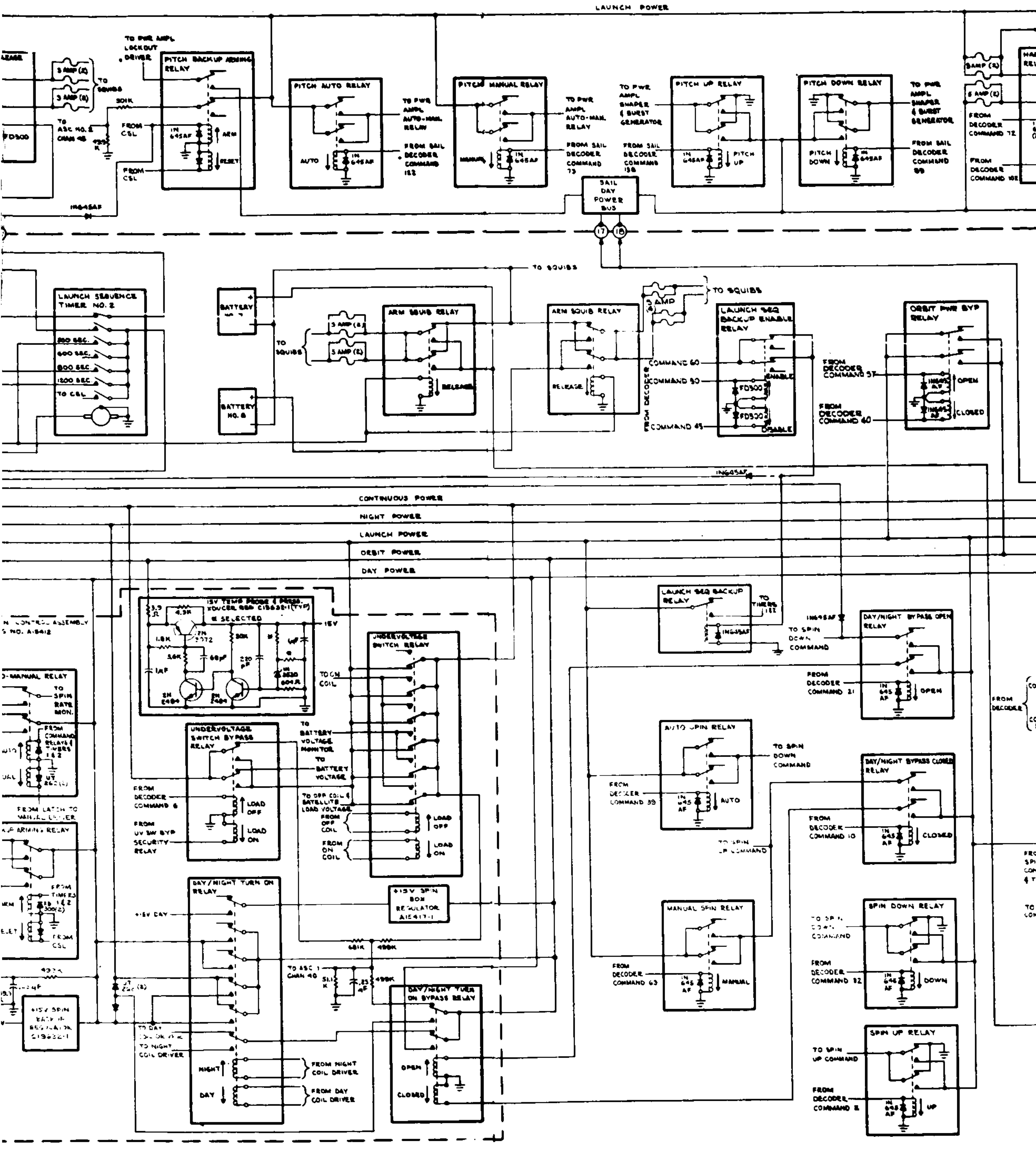
Once this backup system is in operation, care must be taken to monitor the state of the spacecraft. Telemetry points indicate the state of the shunt and series undervoltage command system.

6.5 LAUNCH POWER BUS

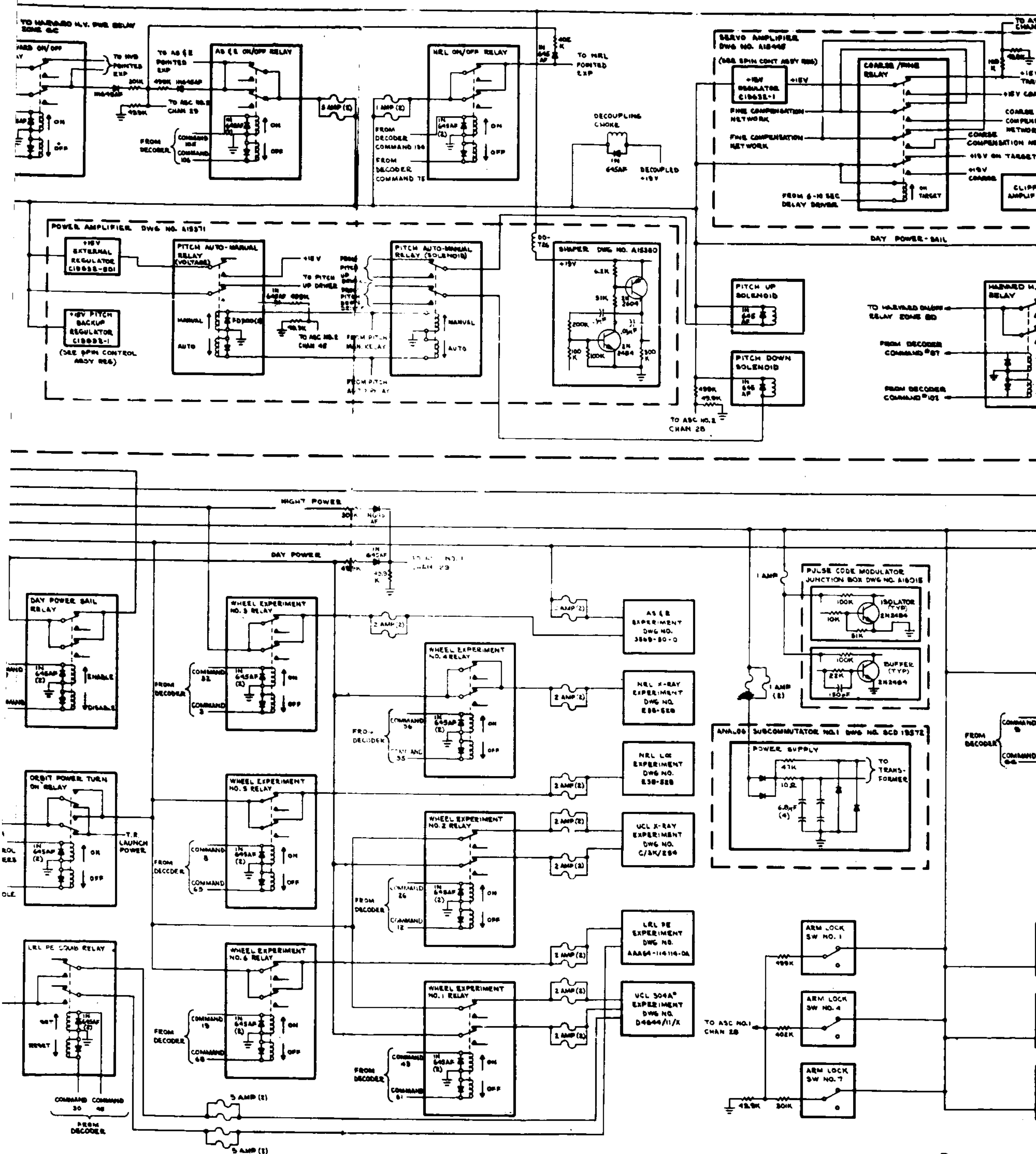
The launch power bus receives dc voltage from the continuous power bus through the undervoltage and undervoltage bypass relay. Launch power is


BATTERY NO. 10
BATTERY NO. 9
ELEVATION RELEASE RELAY
3 AMP (2)
TO SQUIBS
SOLAR CELLS
SAIL GROUND BUS
SAIL EXPERIMENT GROUND BUS
SAIL LAUNCH POWER BUS
TIMER RUN RELAY
RESET
RUN
FROM CONSOLE
LAUNCH SEQUENCE TIMER NO. 1
300 SEC.
600 SEC.
900 SEC.
1200 SEC.
TO CSL
BATTERY BUS
BATTERY NO. 3
BATTERY NO. 4
BATTERY NO. 5
BATTERY NO. 6
GROUND BUS
DECODER NO. 2
REGULATOR
INHIBIT
INVERTER
SPIN UP SOLENOID
SPIN DOWN SOLENOID

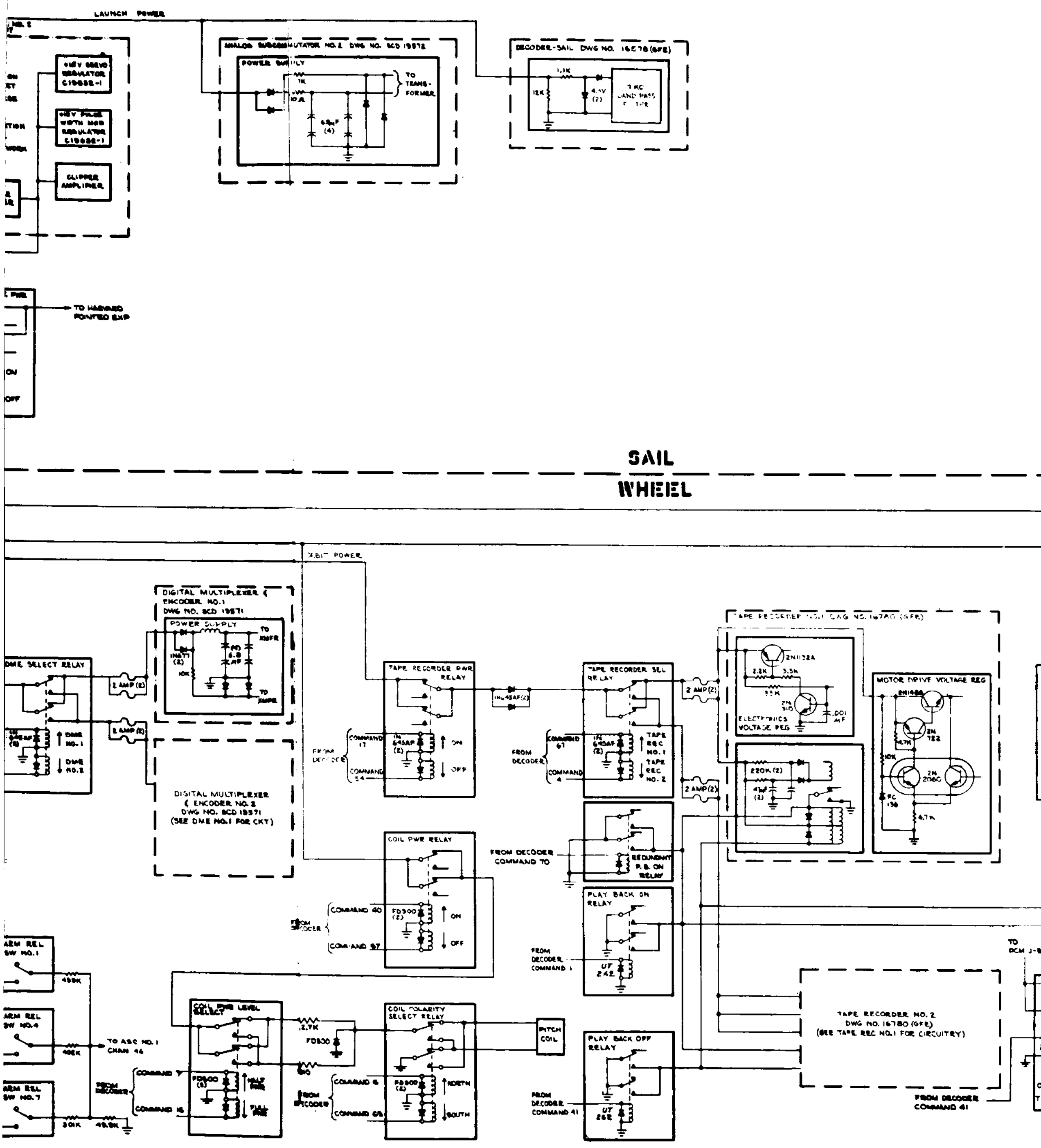
6-7,1


LAUNCH POWER
PITCH BACKUP ARMING RELAY
PITCH AUTO RELAY
PITCH MANUAL RELAY
PITCH UP RELAY
PITCH DOWN RELAY
SAIL DAY POWER BUS
TO SQUIBS
LAUNCH SEQUENCE TIMER NO. 2
ARM SQUIB RELAY
LAUNCH SEQ BACKUP ENABLE RELAY
ORBIT PWR BYP RELAY
CONTINUOUS POWER
NIGHT POWER
LAUNCH POWER
ORBIT POWER
DAY POWER
LAUNCH SEQ BACKUP RELAY
DAY/NIGHT BYPASS OPEN RELAY
UNDERVOLTAGE SWITCH RELAY
UNDERVOLTAGE SWITCH BYPASS RELAY
AUTO SPIN RELAY
DAY/NIGHT BYPASS CLOSED RELAY
DAY/NIGHT TURN ON RELAY
MANUAL SPIN RELAY
SPIN DOWN RELAY
DAY/NIGHT TURN ON BYPASS RELAY
SPIN UP RELAY

6-7,2



AS & E ON/OFF RELAY
NRL ON/OFF RELAY
TO NRL POINTED EXP
DECOUPLING CHOKE
DECOUPLED +15V
SERVO AMPLIFIER
COARSE /FINE RELAY
FINE COMPENSATION NETWORK
DAY POWER - SAIL
POWER AMPLIFIER
PITCH AUTO-MANUAL RELAY (VOLTAGE)
PITCH AUTO-MANUAL RELAY (SOLENOID)
SHAPER
PITCH UP SOLENOID
PITCH DOWN SOLENOID
TO ASC NO.2 CHAN 28
NIGHT POWER
DAY POWER
DAY POWER SAIL RELAY
WHEEL EXPERIMENT NO. 3 RELAY
WHEEL EXPERIMENT NO. 4 RELAY
WHEEL EXPERIMENT NO. 5 RELAY
WHEEL EXPERIMENT NO. 2 RELAY
WHEEL EXPERIMENT NO. 6 RELAY
WHEEL EXPERIMENT NO. 1 RELAY
AS & E EXPERIMENT
NRL X-RAY EXPERIMENT
NRL Lα EXPERIMENT
UCL X-RAY EXPERIMENT
LRL PE EXPERIMENT
UCL 304A° EXPERIMENT
PULSE CODE MODULATOR JUNCTION BOX
ISOLATOR (TYP)
BUFFER (TYP)
ANALOG SUBCOMMUTATOR NO.1
POWER SUPPLY
TO TRANS-FORMER
ORBIT POWER TURN ON RELAY
T.R LAUNCH POWER
LRL PE SQUIB RELAY
ARM LOCK SW NO. 1
ARM LOCK SW NO. 4
ARM LOCK SW NO. 7
TO ASC NO.1 CHAN 28
FROM DECODER
5 AMP (2)


LAUNCH POWER
ANALOG SUBCOMMUTATOR NO. 2 DWG NO. SCD 19572
POWER SUPPLY
TO TRANS-FORMER
DECODER-SAIL DWG NO. 16578 (GFE)
7 KC BAND PASS FILTER
+15V SERVO REGULATOR C19682-1
+15V PULSE WIDTH MOD REGULATOR C19682-1
CLIPPER AMPLIFIER
TO HARVARD POINTED EXP
SAIL
WHEEL
XBIT POWER
DIGITAL MULTIPLEXER & ENCODER NO. 1 DWG NO. SCD 19571
POWER SUPPLY
DME SELECT RELAY
2 AMP (2)
DIGITAL MULTIPLEXER & ENCODER NO. 2 DWG NO. SCD 19571 (SEE DME NO. 1 FOR CKT)
TAPE RECORDER PWR RELAY
FROM DECODER
COMMAND 17
COMMAND 54
TAPE RECORDER SEL RELAY
COMMAND 67
COMMAND 4
TAPE REC NO. 1
TAPE REC NO. 2
TAPE RECORDER NO. 1 DWG NO. 16780 (GFE)
ELECTRONICS VOLTAGE REG
MOTOR DRIVE VOLTAGE REG
COIL PWR RELAY
COMMAND 40
COMMAND 57
FROM DECODER COMMAND 70
REDUNDANT P.B. ON RELAY
PLAY BACK ON RELAY
FROM DECODER COMMAND 1
ARM REL SW NO. 1
ARM REL SW NO. 4
ARM REL SW NO. 7
TO ASC NO. 1 CHAN 46
COIL PWR LEVEL SELECT
COMMAND 9
COMMAND 16
HALF PWR
FULL PWR
COIL POLARITY SELECT RELAY
COMMAND 6
COMMAND 65
NORTH
SOUTH
PITCH COIL
PLAY BACK OFF RELAY
FROM DECODER COMMAND 41
TAPE RECORDER NO. 2 DWG NO. 16780 (GFE) (SEE TAPE REC NO. 1 FOR CIRCUITRY)
FROM DECODER COMMAND 41
TO PCM J-8

6-7,4

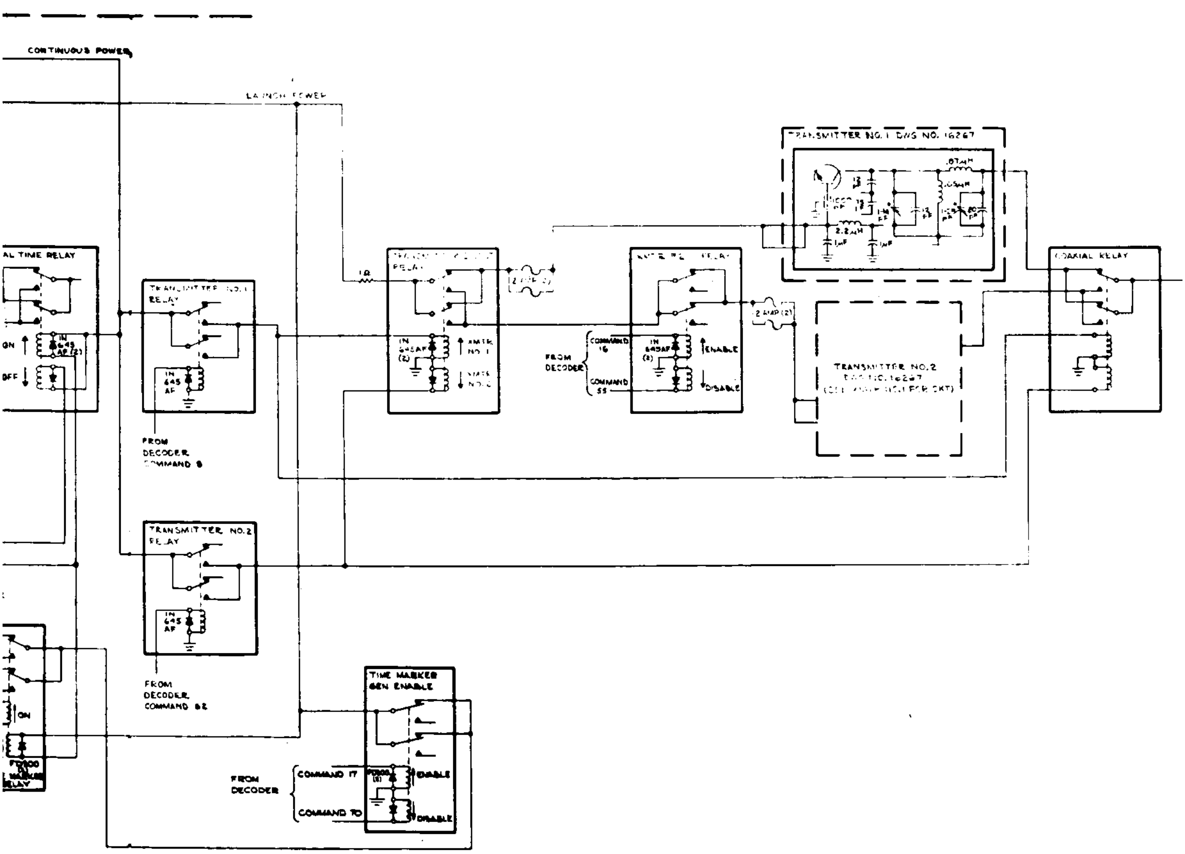


Figure 6-2–Power Distribution

applied through relay contacts to the spin up and spin down circuits; day/night circuits; and to the contacts of the orbit power turn on relay. This power is also utilized as power supply voltage for the analog subcommutator, digital multiplexer and encoders, and the transmitters. The arm lock and arm release switches also make use of this power.

6.6 ORBIT POWER BUS

The orbit power bus is energized by the orbit power turn on relays approximately 600 seconds after launch. These relays transfer power from the launch power bus to the orbit power bus; the power is then distributed to either the day power bus or the night power bus as determined by the day/night or day/night bypass relay. The orbit power bus in the sail is connected to the sail day power bus through the contacts of the NRL On/Off relay. Orbit power is monitored on telemetry channel 31, ASC number 1. Refer to Section 10, Launch Sequence, for the operation of the orbit power relays.

6.6.1 Day/Night Relay

During the dark portion of the orbit, certain of the components in the spacecraft are not operative. To conserve power, the pointing control, the pointed experiments and the spin up system are turned off. A pair of solar sensors feeds the day/night relay circuit. The output of each sensor is a fixed current between 1 and 2 ma when the sun is in the sensor's field of view, and zero when the sun is outside the field of view.

All the orbit power goes through the day/night relay (Figure 6-1) which is a 6-pole double-throw latching type relay. The solar sensor current controls the position of this relay. Sensor current is applied as base-emitter bias to the spin eye amplifier which in turn is applied to a pulse shaper that drives a flip-flop. When the flip-flop receives a turn on pulse signal, it changes to a state which applies a signal to the day relay driver through an amplifier. The night relay driver is then cut off. As the contacts leave their night position, power is removed from the day coil of the relay. A time delay keeps the day-coil driver saturated so the energy stored in the 47 microfarad capacitor can flow through the relay and complete the contact transfer.

After the relay has transferred, orbit power is applied to the day power bus. The relay will remain in this state until a dark-current signal is received from the sensor. This signal will change the position of the flip-flop, energize the night-coil of the relay and remove orbit power from the day power bus and apply it to the night power bus. The day/night relay is monitored on telemetry channel number 29, ASC number 1.

6.6.2 Day/Night Bypass Relay Circuit

The day/night bypass relay (Figure 6-1) is a two pole double-throw latching type. This relay operates as a command backup function when failure occurs in the day/night relay. Both coils of the day/night bypass relay are operated by 19 volts launch power that is applied through the contacts of the day/night bypass closed or open relays. The day/night bypass closed command number 10 controls the closed relay and day/night command number 21 controls the open relay. In the normally open position, the day/night bypass relay shunts the day/night relay, applying orbit power to the day power bus. When commanded to the closed position, the day/night bypass relay will apply orbit power through its closed contacts to the night coil of the day/night relay which will then apply orbit power to the night power bus.

The telemetry channels for the day/night bypass relay are channel number 40 and channel number 29, ASC number 1.

6.6.3 Day/Night Override Relay

The day/night override relay (Figure 6-1) is a momentary type relay that is operated as a ground function only. This relay is energized by a override signal from the ground console. Once energized the day/night override relay applies 15 volts power to the free running oscillator which is timed at 2.4 seconds. The oscillator time is approximately the spin rate of the wheel. This signal is then applied to the eye-pulse-on circuit in the spin control assembly. The day/night relay will then be switched to the day condition without the aid of a sun pulse.

6.7 DAY POWER BUS

The day power bus when energized by the position of the day/night turn-on relay supplies power to the spin-up and spin-down solenoids, the SORE, and the spin control assembly. Also receiving power from this bus are the wheel experiments and the contacts of the day-power-sail relay. The day-power-sail relay is a latching type that can be turned on by command number 7 and off by command number 53. When in the on position, day power is supplied to the sail-day-power bus. This bus supplies power to the sail pointing system and the pointed experiments. These systems can be removed from the day power bus, should the need arise, by energizing the off coil of the day power sail relay.

The telemetry channels for monitoring the day power and sail day power are channel number 29, ASC number 1, and channel number 31, ASC number 1, respectively.

6.8 NIGHT POWER BUS

The night power bus is controlled by the day/night turn-on relay. Night power is supplied to the spin control assembly and to the required wheel experiments. Power to the wheel experiments is supplied through separate relays so each experiment may be turned on and off by command, as desired.

6.9 15-VOLT REGULATOR ASSEMBLY

The output of the regulator is maintained at 15.0 volts ± 20 mv with an input from 16.2 to 22 vdc and a regulator load from 0 ma to 50 ma. Quiescent current with 19 volts input at room temperature is less than 4 milliamperes.

The regulator (Figure 6-3) consists mainly of 3 transistor stages and a 12 volt zener diode. A 3.9 ohm resistor and 1 microfarad capacitor provide surge protection.

When the situation exists where the 15 volt output decreases, the voltage at the CR1 and R7 junction will decrease causing less conduction of CR1. Transistor Q3 will then conduct less which will cause its collector voltage to raise. This voltage is applied to the base of Q2. Q2 will then conduct more, requiring more base current from Q1. The voltage at junction R2 and R4 will decrease, which will cause a heavier conduction of Q1 causing the output voltage to increase to 15 volts.

When the voltage output increases, the voltage at the CR1 and R7 junction will increase causing zener CR1 to conduct more. Transistor Q3 will then conduct more which will cause its collector voltage to decrease. This voltage is applied to the base of Q2. Q2 will then conduct less, requiring less base current from Q1. The voltage at junction R2 and R4 will increase which will cause less conduction of Q1. The output voltage will then be reduced to 15 volts.

Regulation is required for the SORE, temperature probes and transducers, power amplifier, backup, and the spin control assembly. The spin box regulator is included in the undervoltage switch assembly, but the circuit is the same as described except the component designations are different.

6.10 AZIMUTH SHAFT ASSEMBLY

The wheel structure and sail structure are connected by an aluminum shaft which runs from the base of the sail, through the center of the wheel and terminates

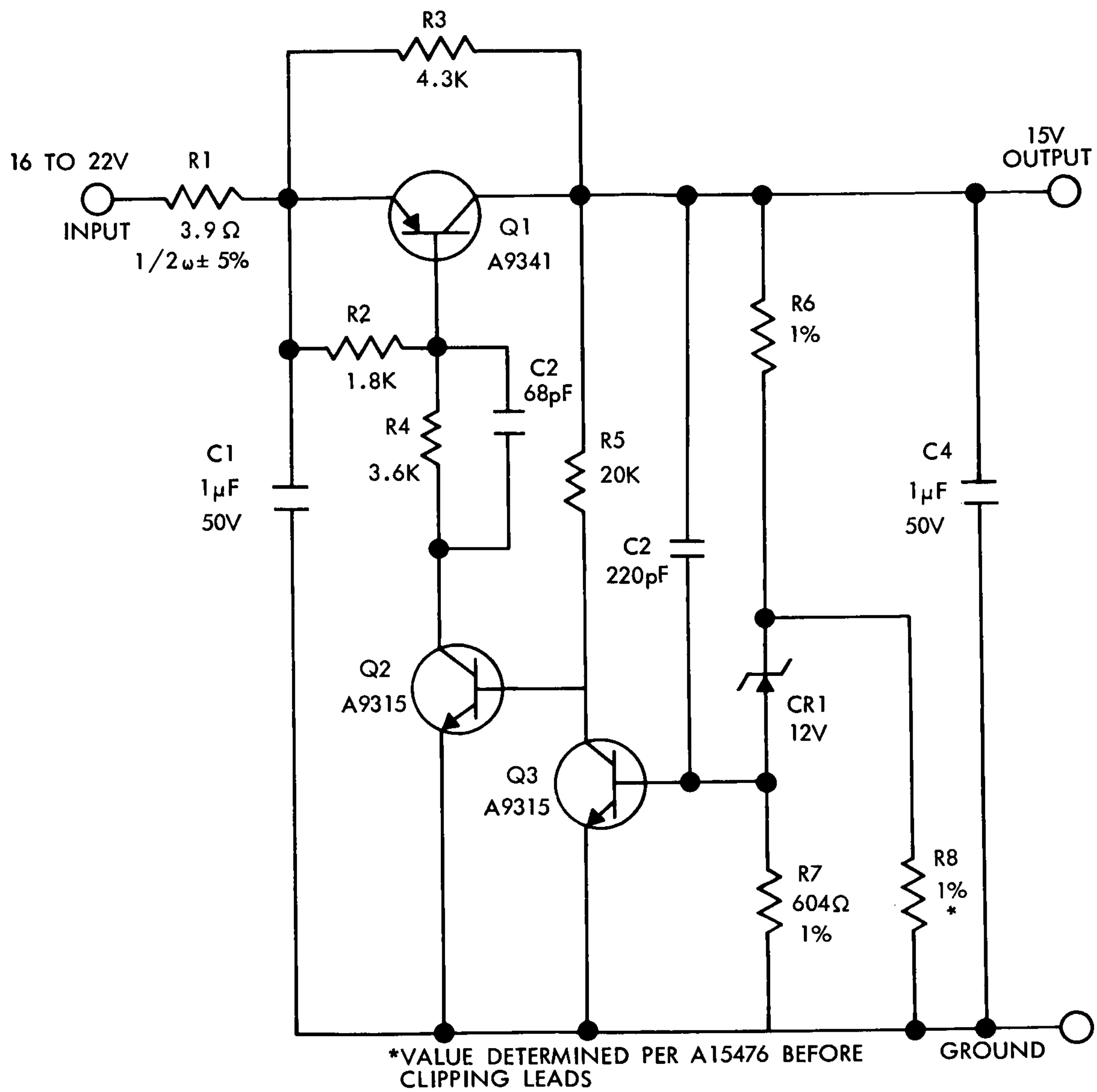


Figure 6-3–15-Volt Regulator

in a support ring structure on the underside of the wheel. This shaft is held in place by two bearing, one on top and one on the bottom of the wheel. Mounted on the shaft between the two bearings is a high pressure nitrogen gas tank for pitch precession jets located on the sail structure. A torque motor mounted on the top of the shaft, controls the azimuth position of the sail while the spacecraft is in daylight. On the base of the shaft is a slip ring assembly which allows transmission of power, telemetry signals, and control signals between the sail section and the wheel. Figure 6-4 illustrates the azimuth shaft assembly.

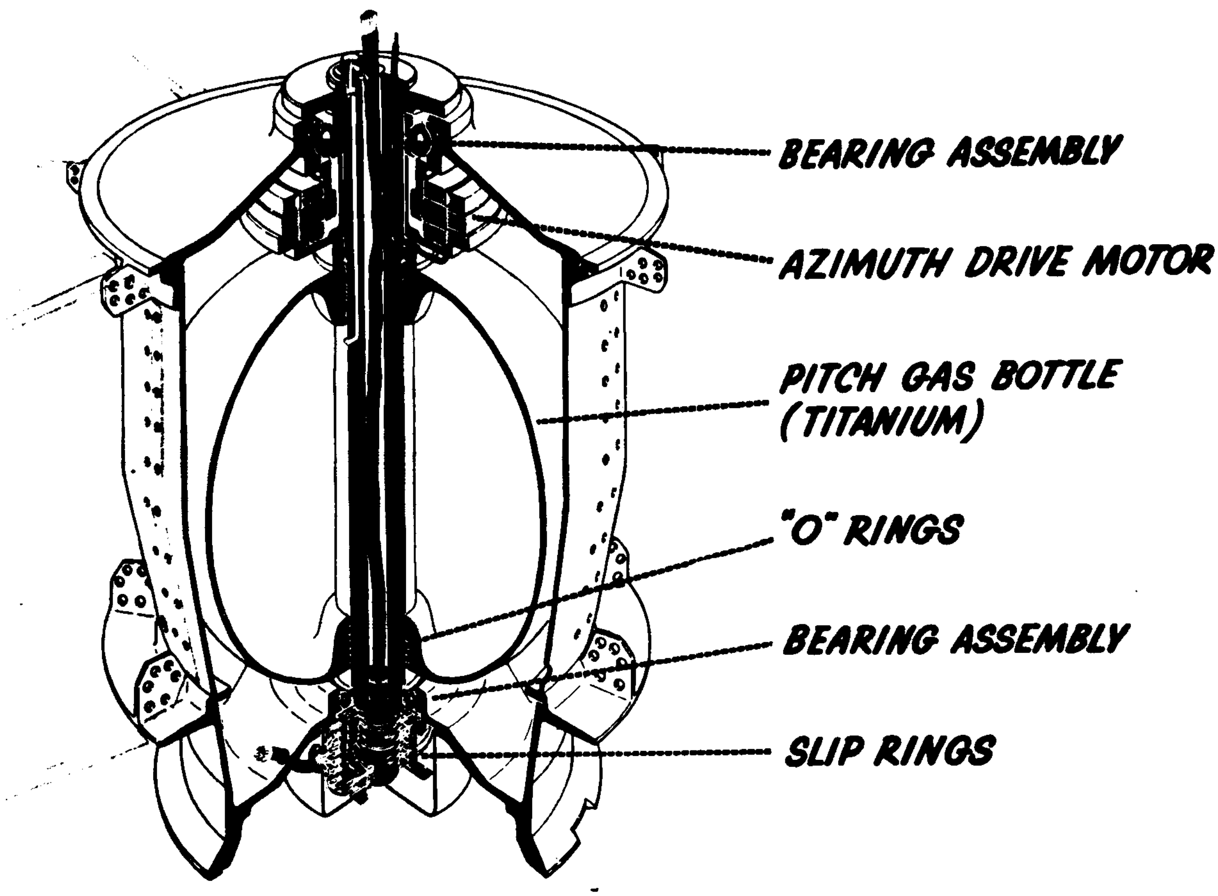


Figure 6-4—Azimuth Shaft Assembly

6.10.1 Slip Rings

The electrical connection through the slip ring is made by utilizing brushes making contact with the proper ring track. Brush force is 17 to 25 grams at the contact point. With the slip ring not rotating, the resistance between each ring lead and the associated brush lead at the connector does not exceed 0.1 ohm. The telemetry slip ring allocations for the OSO-D spacecraft are listed in Table 6-1.

Table 6-1
OSO-D Slip Ring Allocation

Slip Ring Circuit No.	Function
1	400 CPS Clock
2	NRL DSM Gate No. 1, DSM No. 21
3	Signal Ground
4	19 Volt Orbit Pwr.
5	NRL DSM Gate No. 2, DSM No. 22
6	NRL R.O. Gate No. 2 MF #2
7	NRL R.O. Gate No. 1 MF #13 & 23
8	ASE R.O. Gate No. 1 MF #6, 14, 22, & 13
9	Nutation Damper Release
10	Elevation Lock Release
11	ASC No. 2 Trigger
12	ASC No. 2 Data Out
13	Decoder Input
14	Digital Data R.O. (Harv.)
15	Harv. R.O. Gate No. 1 MF #3,4,11,12,19,20,27, & 28
16	Digital Data R.O. (ASE - NRL)
17	19 Volt Day Pwr.
18	19 Volt Day Pwr.
19	19 Volt Solar Cell
20	19 Volt Solar Cell
21	Power Ground
22	Power Ground

Section 7

ANTENNA SYSTEM

7.1 INTRODUCTION

The antenna system (Figure 7-1, block diagram) consists of the antenna array, two match boxes, a power divider, a diplexer, a hybrid circulator and a coaxial relay. This system is used for tracking, telemetry transmission, and command reception. The coaxial relay accepts either transmitter output signal and applies it to the diplexer. The output of the diplexer is then applied to the antenna array through the power divider and match boxes. When receiving a signal, the path is through the antenna array, the match boxes, the power divider, the diplexer, the hybrid circulator and then to the receivers.

7.2 ANTENNA ARRAY

The antenna array is located at the base of the wheel. It consists of 3 "V" shaped monopoles spaced 120 degrees apart. Each antenna element (Figure 7-2) consists of a support bracket and a stub. The support brackets also support the extendable arms of the spacecraft. Each stub is electrically connected to its respective support bracket to form a three-element array. The stub provides proper impedance matching and eliminates standing waves on the transmission line. The three elements are completely insulated from the spacecraft by the use of nylon and fiberglass-epoxy material. Two elements are excited and the third is parasitic. The element excitation is applied at the point where the support bracket connects to the spacecraft arm. The electrical length of each element is approximately one-half wavelength. The antenna system serves two purposes: functions as a receiving antenna for the command system; and a transmitting antenna for the tracking and telemetry system. This array is continually spinning, along with the wheel, at 30 rpm.

7.2.1 Match Boxes

Two match boxes are connected to the base of the two active antennas. These boxes are located under the arms next to the wheel. An rf cable assembly connects the boxes to the antenna.

These capacitive networks provide the proper impedance match between the antenna and the transmission line. The antennas will then be in proper balance for maximum power transfer.

7.2.2 Power Divider

The power divider is a coaxial tee connector located at the center of the coaxial transmission line that connects the two active antenna elements. The common input connects to the output of the diplexer. Transmitted power is then divided equally for each of the two active antennas. Proper impedance matching makes the equal power separation possible. This is accomplished with the antenna stub that is electrically connected to the antenna.

7.2.3 Diplexer

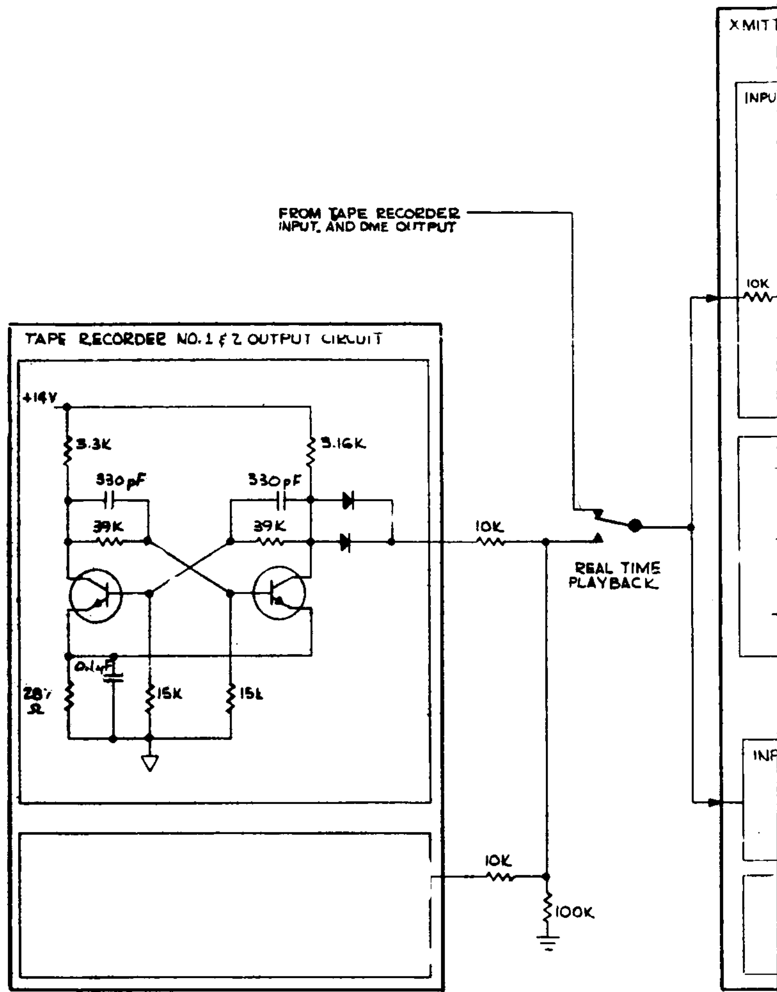
The diplexer is located in compartment number 8 of the wheel. It consists of an inductance-capacitance network that allows the transmitting and receiving systems to be connected to a common antenna array. This lump constant network essentially provides common input-output connection to the power divider. The diplexer also provides low loss paths to the receiver system and from the transmitter system. In addition, it provides a large amount of isolation between the receive and transmit connections. These functions must be isolated to prevent damage to the receiver system when transmitting.

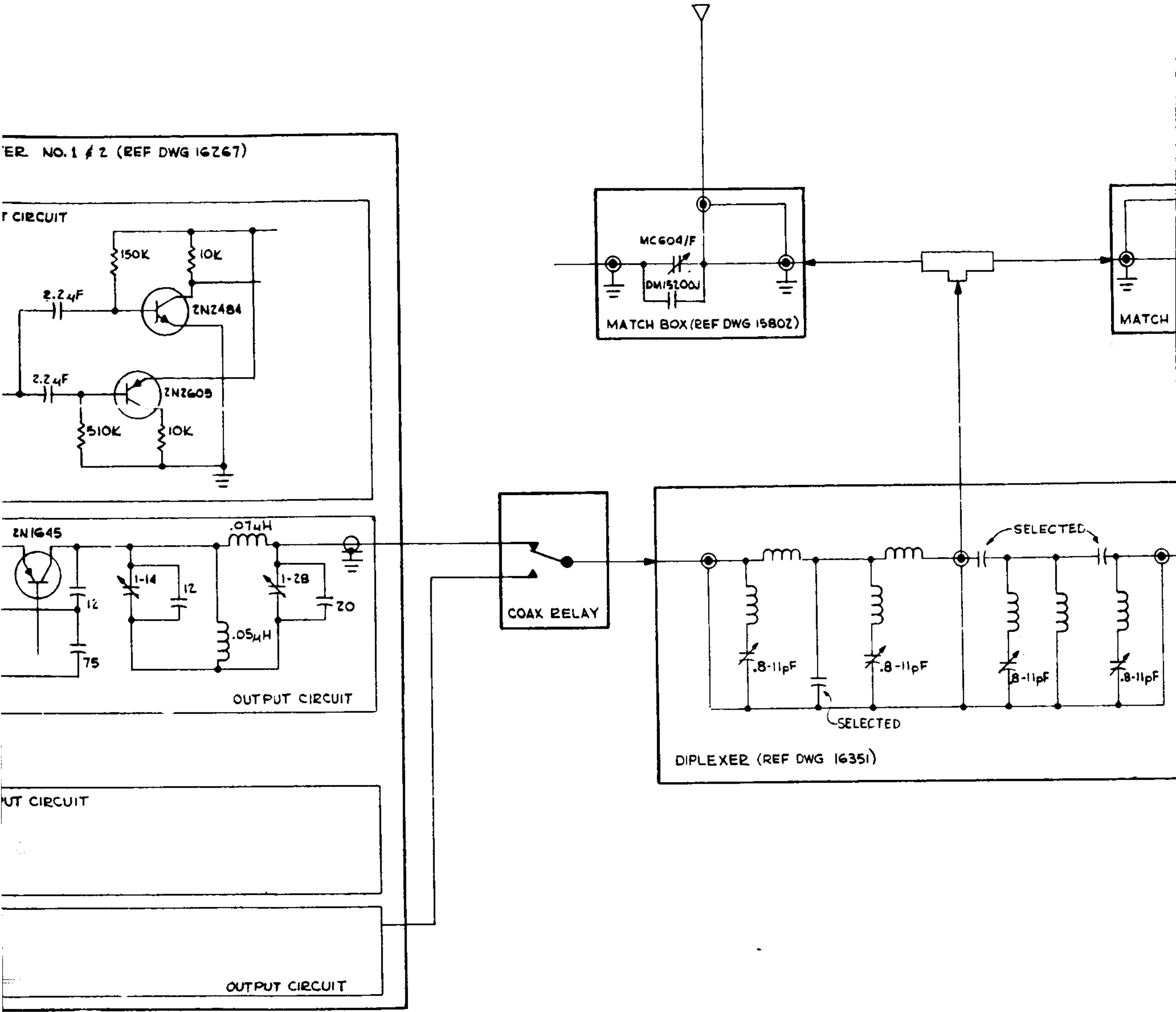
7.2.4 Coaxial Relay

The coaxial relay, located in compartment 8 of the wheel, is an rf switching device. It is a magnetic latching type relay that selects one of two transmitter outputs to be applied to the antenna system. This relay is energized by the continuous power bus which is applied through the contacts of either the transmitter number 1 relay or the transmitter number 2 relay, depending upon which transmitter is selected. The transmitter relays are controlled from the decoder command system.

7.2.5 Hybrid Circulator

The hybrid circulator is located in compartment number 7 of the wheel. This unit permits the simultaneous operation of two receivers at the same frequency from a single antenna system. It satisfies the condition of low path loss between the diplexer and either receiver and provides high isolation between the receivers. Thus, the receivers operate independently of each other.


FROM TAPE RECORDER
INPUT, AND DME OUTPUT
TAPE RECORDER NO. 1 & 2 OUTPUT CIRCUIT
+14V
3.3K
3.16K
330pF
330pF
39K
39K
10K
REAL TIME
PLAYBACK
287
Ω
15K
15K
10K
100K
10K



ER NO. 1 & 2 (REF DWG 16267)
T CIRCUIT
150K
10K
2.2μF
2N2484
2.2μF
2N2605
510K
10K
2N1645
.07μH
1-14
12
1-28
20
12
75
.05μH
OUTPUT CIRCUIT
UT CIRCUIT
OUTPUT CIRCUIT
MC604/F
DM15200J
MATCH BOX (REF DWG 15802)
MATCH
COAX RELAY
SELECTED
.8-11pF
.8-11pF
.8-11pF
.8-11pF
SELECTED
DIPLEXER (REF DWG 16351)

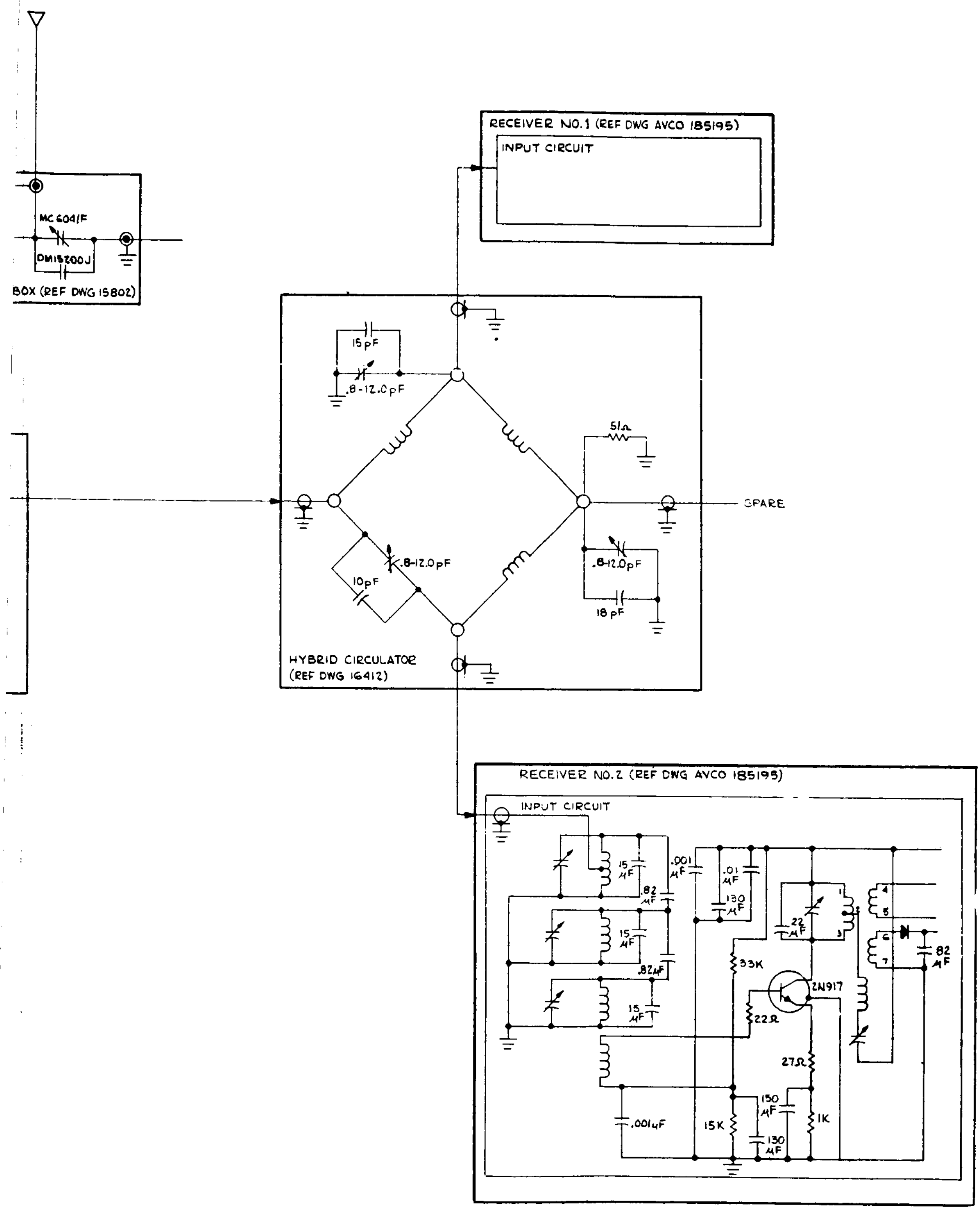


Figure 7-1—Antenna Block Diagram

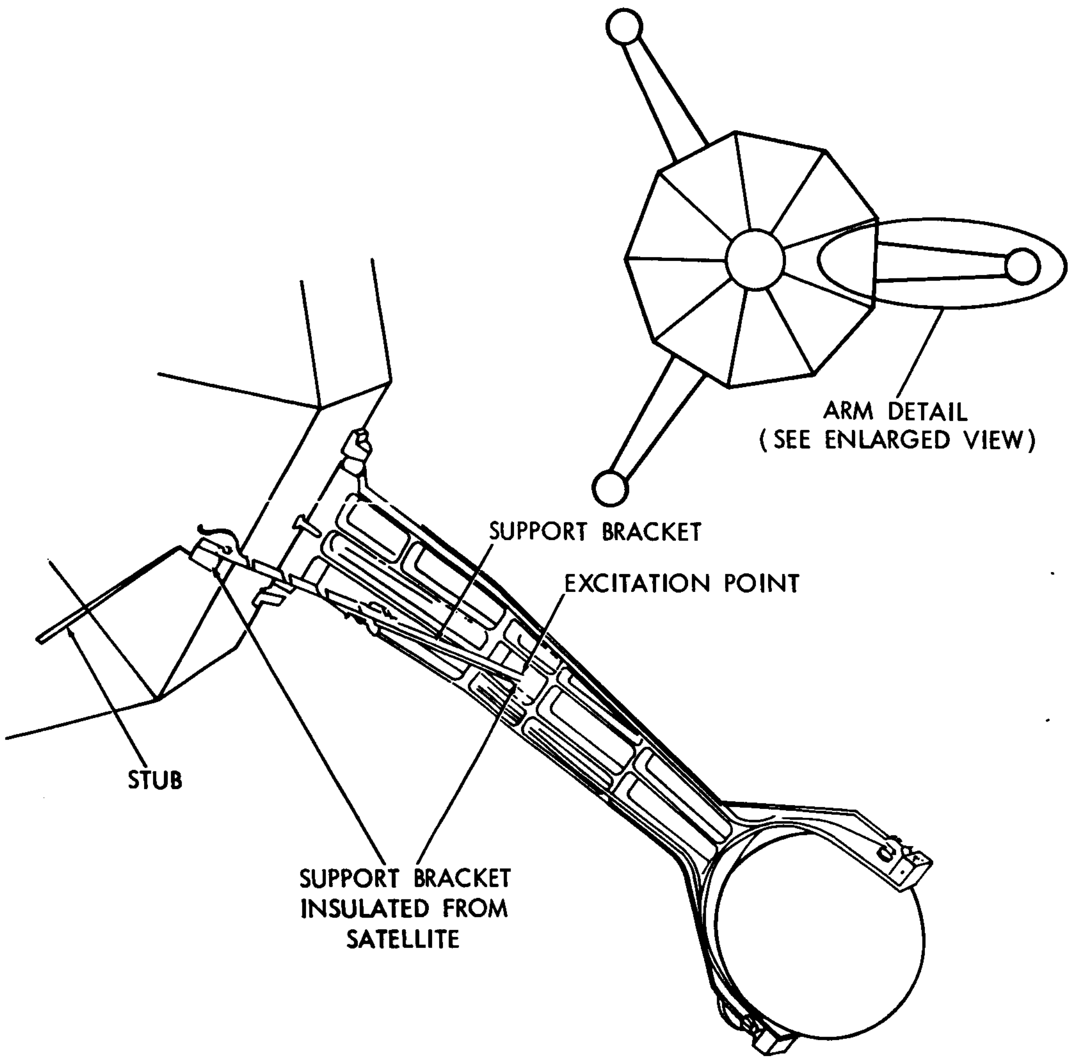


Figure 7-2–Antenna Elements

This unit consists of a lumped constant bridge circuit, each branch of which is housed in an individual compartment to prevent cross coupling. One rf input and two rf outputs are provided.

Section 8

EXPERIMENT COMPLEMENT

8.1 INTRODUCTION

The spacecrafts carry into orbit between 7 and 9 experiments. The sail section experiments are pointed and solar-oriented. Tables 8-1 through 8-4 list the institutions and experiments for a specific spacecraft.

Table 8-1
OSO-E1 Experiments

Institution	Experiment
Pointed	
Air Force Cambridge Research Laboratories	Ultraviolet monochromator: 250-1300Å
GSFC	Solar spectrometer: 1-400Å
Wheel	
Ames Research Center	Measurement of thermal radiation characteristics of surfaces to determine emissivity stability of spacecraft temperature-control coatings
Ames Research Center	Experiment to measure albedo of the earth: 3200-7800Å Also a directional radiometer to measure reflected sunlight and earth temperature on the dark side of the earth in the range of 1 to 30 microns to supplement the Ames albedo experiment. Mounted on the albedo experiment.
Wheel	
University of California	Solar X-ray and gamma-ray bursts: 7-190 kev.
(San Diego)	Measure anticoincidence events at 100 kev and at 2.5 Mev
Massachusetts Institute of Technology	Celestial gamma-ray detector: 100 Mev and greater
University of Michigan	Solar X-ray experiment: 8-20Å
University of Rochester	Cosmic-ray charge spectrum detector: measure intensity of the nuclear component of primary cosmic radiation and of high-energy gamma radiation > 100 Mev from the sun and the galaxy
University of California (Lawrence Radiation Laboratory, Livermore)	Proton-electron detector: electron energies > 60 kev and proton energies > 2 Mev. This experiment is similar to the experiment on OSO-A and OSO-D (Backup experiment only. To be flown if another wheel experiment is not available.)

Table 8-2
OSO-D Experiments

Institution	Experiment
Pointed	
American Science and Engineering, Inc.	Solar X-ray telescope; Spectrum analysis 8-20Å, above 20Å, and possibly below 8Å and map the sun in X-rays
Naval Research Laboratory	Bragg crystal X-ray spectrometer: 1-8Å
Harvard College Observatory	Improved normal-incidence 300-1300Å scanning spectrometer-spectroheliograph
Wheel	
American Science and Engineering, Inc.	Measurement of extrasolar X-radiation: 0.1-10Å, possibly to 50Å
University College, London, and University of Leicester	Distribution of total solar X-ray emission over a wide band: 1.2-3.6Å, 3-9Å, 6-18Å, 44-55Å, 44-70Å
University College, London	Study of the solar He II resonance emission: 304Å
University of California-Lawrence	Proton-electron detector: electron energies >60
Radiation Laboratory Livermore	Kev and proton energies >2 Mev
Naval Research Laboratory	X-ray ion chamber monitoring: four chambers 0.1-1.6Å, 0.5-3Å, 2-8Å, and 8-16Å
Naval Research Laboratory	Lyman-alpha night-sky glow: monitor 1050-1350Å which includes the alpha line at 1216Å

Table 8-3
OSO-F Experiments

Institution	Experiment
Pointed	
University College, London, and University of Leicester	X-ray spectroheliograph: 3-9Å and 8-18Å
Naval Research Laboratory	Extreme ultraviolet solar spectroheliograph: an improved version of experiment on OSO 2.
GSFC	Continuation of the studies of the solar spectrum: 1-400Å. Continuation of the studies previously started on OSO 1 (an improved version of the instrument scheduled for OSO-E1).
Wheel	
Centre National de la Recherche Scientifique, France	Measurement of the self-reversal of the solar Lyman-alpha line
Naval Research Laboratory	Solar X-ray radiation ion-chamber photometer, monitoring experiments: 0.1-1.6Å, 0.5-3Å, 2-8Å, and 8-16Å. Duplication of the experiment to be flown on OSO-D.
GSFC	Observations of the sun in the low-energy gamma-ray region: 5 kev to 150 kev. These data will supplement measurements made on OSO 2.
University of Minnesota	Dim-light monitoring experiment measuring and polarization of the light from air-glow layer. Similar to OSO 2 experiment.
University of Colorado	Solar far-ultraviolet radiation monitoring in three EUV bands: 290-370Å, 465-630Å, and 760-1030Å for effect upon ionization rates in the earth's upper atmosphere (F and E layers).

Table 8-4
OSO-G Experiments

Institution	Experiment
Pointed	
Harvard College Observatory	Spectrometer-spectroheliometer 300Å-1300Å
Naval Research Laboratory	Spectral burst and masking measurement of solar X-rays
Wheel	
Rutgers University	Study of the zodiacal light
Los Alamos Scientific Laboratories	Solar X-ray monitoring in the 16-40Å region
University of Bologna	Solar X-ray monitoring and gamma ray astronomy in the 20-200 kev energy range
University College, London	Study of the He I and He II Reservance radiation
University of New Mexico	Measure direction and energies of primary cosmic gamma rays

Section 9

SPACECRAFT AND EXPERIMENT TEMPERATURE MONITORING

9.1 INTRODUCTION

Throughout the spacecraft are sensing devices that measure temperature. These devices produce an analog output that is measured and time shared with other inputs by electronic subcommutators. There is one subcommutator in each multiplexer-encoder located in the wheel and one subcommutator attached to the pointed experiment in the sail. These subcommutators apply the analog data to the main multiplexer-encoder where it is converted to digital form and encoded. Thereafter, it is processed the same as the experiment digital data. Refer to Tables 4-3 and 4-4 for the analog subcommutator channel allocations.

9.2 TEMPERATURE MONITORING

Sixteen analog subcommutator channels are located throughout the spacecraft for measuring temperature. The wheel temperature measurements include: bottom skin, top skin and rim structural measurements; batteries number 1 and number 2; and the temperature of transmitter number 1.

The equipment that is monitored on the sail includes: gas bottle; hub; solar cells; servo amplifier; azimuth casting; subcommutator number 2; power switch; and the crystals within the NRL experiment.

9.2.1 Temperature Probe

The temperature probe consists of a single stage transistor dc amplifier. Temperature characteristics of the transistor cause the output voltage to vary between 0 and 5 volts dc. These temperature characteristics are between minus 50 degrees and plus 70 degrees centigrade for the -70A model and between minus 40 degrees and plus 100 degrees centigrade for the -100A model. Input voltage is supplied from a 15-volt regulated supply and the output impedance is 9 kilohm. The weight of the complete unit is approximately 6 grams which makes it possible to mount the unit by cementing it in place.

Section 10

LAUNCH PROGRAM

10.1 INTRODUCTION

There is a sequencing timer and a series of actuating devices installed in the spacecraft to automatically perform a sequence of events that must occur the latter part of the launch phase and prior to injection into orbit. The sequencing timer is started by the acceleration switch during third stage spin up. (See Figure 10-1.)

The launch signal is applied from the launch bus, through the closed contacts of both angular acceleration switches, to the run coil of the timer run relay. Control power is then applied, through the closed contacts of both sequence timers, through the contacts of the timer run relay, and then to the timer motors.

During specific times of the launch sequence timing cycle, pulses will energize applicable relays or during ground checkout will apply signals to the console for testing purposes. These energized relays will perform the functions of applying squib battery power to ignite squibs, apply launch power to the orbit power bus, energize the arming relay and auto-man relay in the spin control box.

10.2 ANGULAR ACCELERATION SWITCH

The angular acceleration switches sense spacecraft and third stage acceleration at spin-up and energize the run coil of the timer run relay which in turn starts the launch sequence timers.

The angular acceleration switches are located in compartments number 1 and 7 of the wheel. These switches consist of two permanent magnets attached to a fixed frame and a magnet attached to a movable bronze rotor. The two magnets are opposite to one another so that there is a strong attraction between them. The rotor is dynamically balanced and is mounted so that its axis of rotation is parallel to the spin axis of the spacecraft. As the spacecraft is spun-up (accelerated), the inertia of the rotor tends to cause it to rotate about its axis opposite to the direction of angular acceleration of the spacecraft (or to remain fixed in inertial space). If the acceleration is low, the force of attraction between the magnets will hold the rotor fixed relative to the spacecraft. However, as the acceleration is increased, a point is reached where the inertia force of the rotor is sufficient to overcome the magnetic forces and the rotor begins to rotate relative to the spacecraft.

An angular acceleration of the payload of 5.0 ± 0.5 radians/sec^2 causes the rotor to rotate approximately 180 degrees and operates the switch. Two angular acceleration switches are employed in parallel to increase the reliability of the system.

10.3 SEQUENCE TIMERS

The two sequence timers (one of which is redundant) are loacted in compartment 7 of the wheel. Each drive motor operates on 16 to 23 volts dc supplied by the continuous power bus. The timers are sealed units which consist of seven single-pole, single throw switches. Each switch is capable of switching 250 milliamps at 20 volts dc (resistive).

A total run time of 1400 seconds for the timer is divided into two functional times; -100 to 0 for prelaunch, reset, and other test functions, and from 0 to 1300 for operational functions. Figure 10-2 shows the time span and the switch opening and closing times. As each switch opens (or closes) a circuit is completed to perform a function.

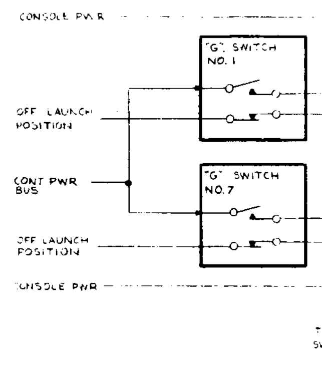
10.3.1 Timer Operation

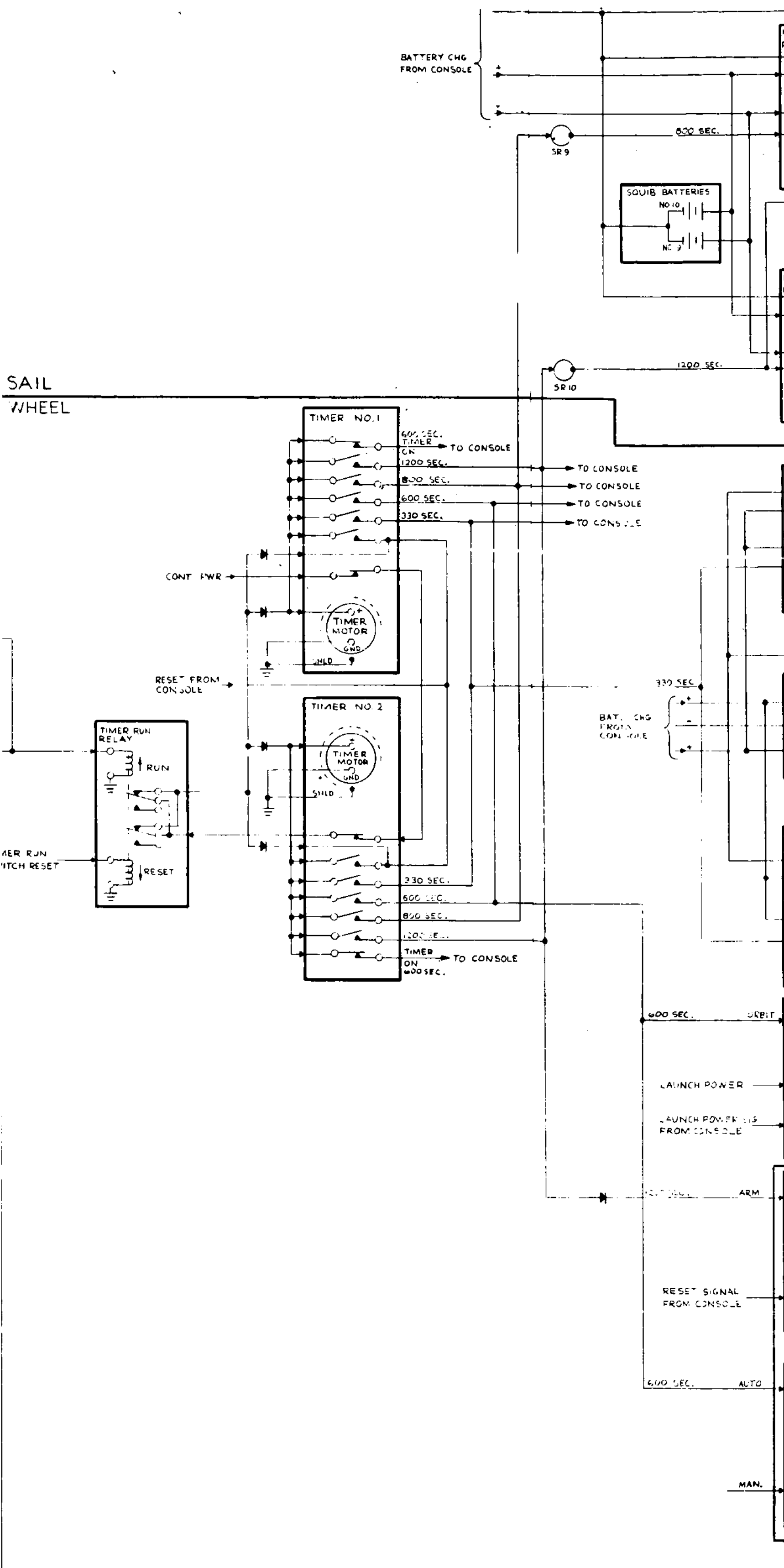
The third stage spin-up event actuates the acceleration switches and applies continuous bus power to the coil of the timer run relay. With this relay energized, power is then applied through the number 2 contacts of the timer to the timer motor.

Figure 10-3 shows the launch and orbit injection events. These events are for a typical mission and may vary slightly from mission to mission. The time events mentioned in the following circuit explanations may also vary, depending upon the mission.

10.3.2 Time Events

An automatic reset function is performed through the number 1 contact of the timer. The timer reset break is defined as zero time. All other time functions use this time as their reference point.


CONSOLE PWR
"G" SWITCH
NO. 1
OFF LAUNCH
POSITION
CONT PWR
BUS
"G" SWITCH
NO. 7
OFF LAUNCH
POSITION



BATTERY CHG FROM CONSOLE
800 SEC.
SR 9
SQUIB BATTERIES
NO 10
NO 9
1200 SEC.
SR 10
SAIL
WHEEL
TIMER NO. 1
TO CONSOLE
1200 SEC.
800 SEC.
600 SEC.
330 SEC.
TO CONSOLE
CONT PWR
TIMER MOTOR
GND
SHLD
RESET FROM CONSOLE
330 SEC.
TIMER NO. 2
TIMER RUN RELAY
RUN
RESET
TIMER MOTOR
330 SEC.
TIMER
TO CONSOLE
600 SEC.
ORBIT
LAUNCH POWER
ARM
RESET SIGNAL FROM CONSOLE
600 SEC.
AUTO
MAN.

10-4 (1)

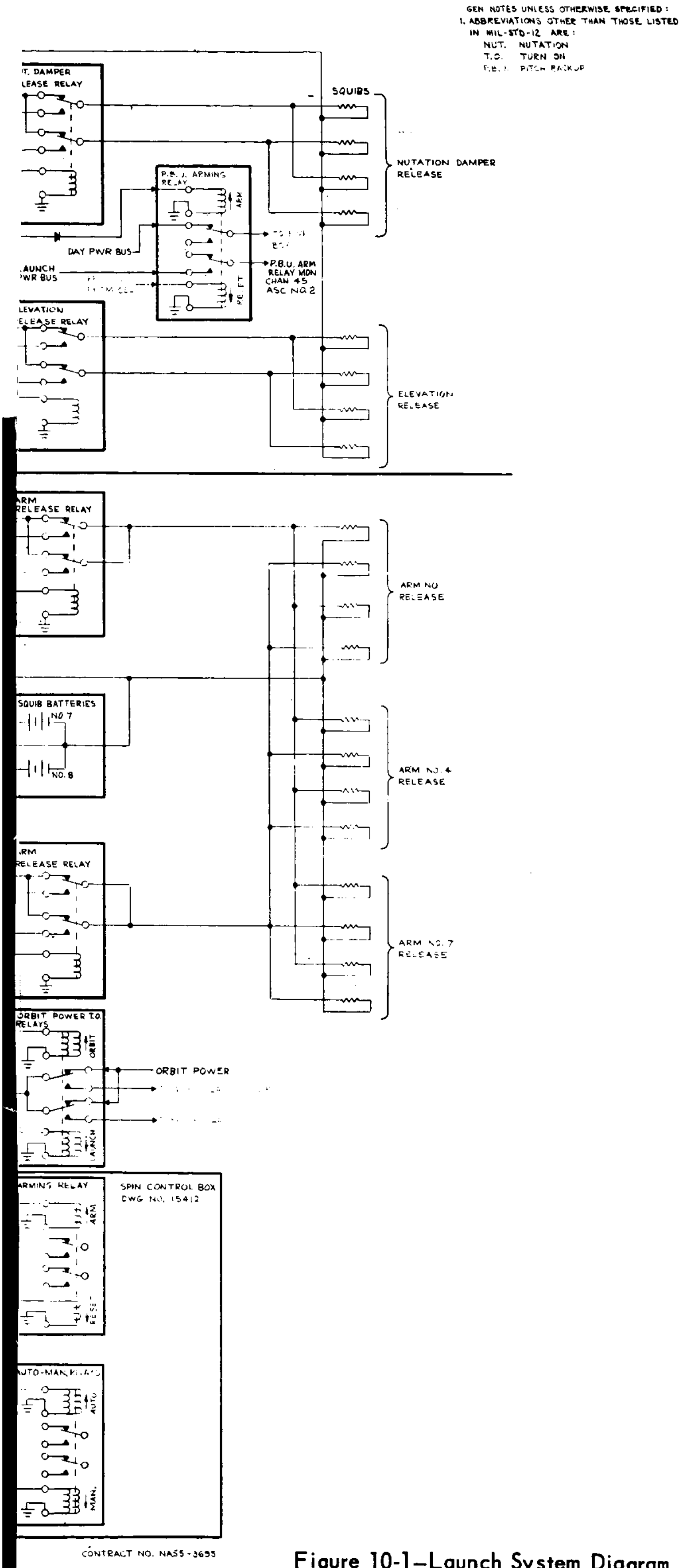
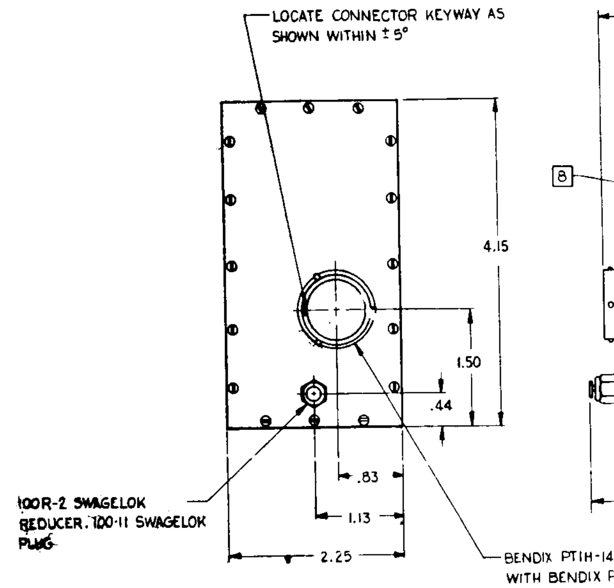
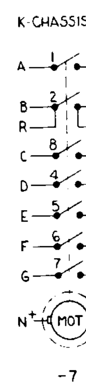


Figure 10-1—Launch System Diagram

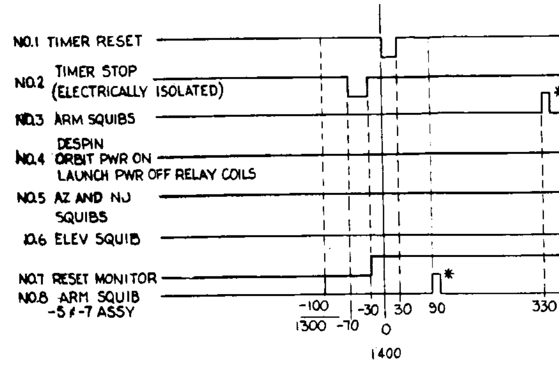




PROGRAM DIAGRAM
TIMER RESET BREAK IS DEFINED AS ZERO TIME. ALL OTHER TIMES EXCEPT THE BREAKS MARKED WITH ASTERISKS (*) ARE MEASURED FROM ZERO TIME WITH A TOLERANCE OF ± 15 SECONDS. THIS TOLERANCE IS IN ADDITION TO THE TIME SPEED TOLERANCE. BREAKS MARKED WITH ASTERISKS (*) FOLLOW THEIR MAKES BY 15 ± 5 SECONDS

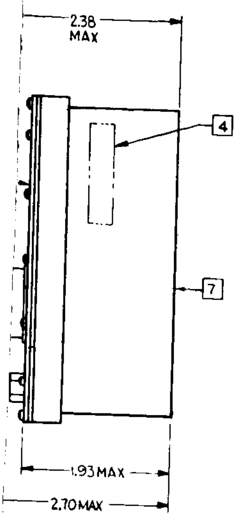
ACCURACY
RANGE CONDITION 1
TIMER SPEED HAS ± 5% TOLERANCE WITH SUPPLY VOLTAGE FROM 17VDC TO 20VDC AND TEMPERATURE RANGE FROM +10° C TO + 40°C

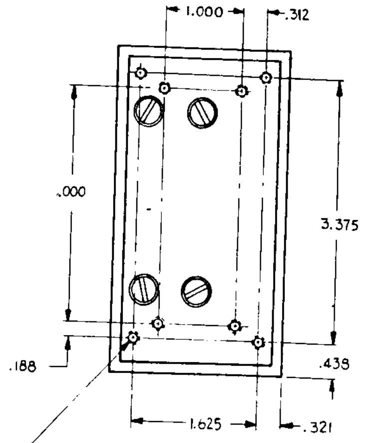
RANGE CONDITION 2
TIMER SPEED HAS +20% -10% TOLERANCE WITH SUPPLY VOLTAGE FROM 16 VDC TO 22 VDC AND TEMPERATURE RANGE FROM -10°C TO +45°C



SWITCHING LOAD IN MILLIAMPERES 100 100 300

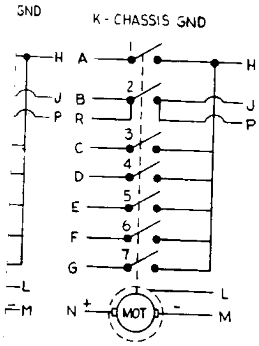
10-5



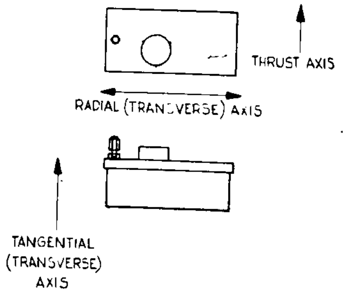


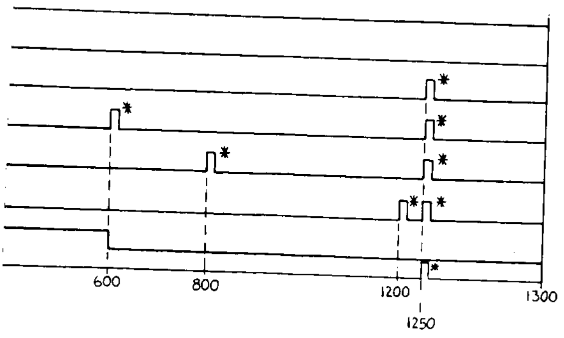
'SP RECEPTACLE (MATES
06P-14-15 S(005) PLUG

8-32 THD .250 DEEP
HELI-COIL INSERT
NO. 3585 - 2CN
8 REQD



SCHEMATIC DIAGRAM
-1, -3, -5





600 150 150

10-5 (2)

GEN. NOTES UNLESS OTHERWISE SPECIFIED:

1. PREFERRED VENDOR:
   LIND INSTRUMENTS INC MT VIEW CALIF

[2] SPECIFICATIONS:

TEMPERATURE:
HOLD ACCURACY TO RANGE CONDITION 1 FROM +10°C TO +40°C.
HOLD ACCURACY TO RANGE CONDITION 2 FROM -20°C TO +45°C.

VOLTAGE
HOLD ACCURACY TO RANGE CONDITION 1 FROM 17VDC TO 20VDC.
HOLD ACCURACY TO RANGE CONDITION 2 FROM 16VDC TO 22VDC.

VIBRATION
TIMER MUST OPERATE AND HOLD ACCURACY TO RANGE CONDITION 1 DURING ONE 15 MINUTE SWEEP ALONG THE THRUST AXIS AT THE FOLLOWING LEVELS:

5-18 CPS	0.4 DA
18-50 CPS	6.4 G PEAK
50-75 CPS	14.8 G PEAK
75-175 CPS	25.0 G PEAK
175-1000 CPS	14.8 G PEAK
1000-2000 CPS	21.1 G PEAK

TIMER MUST OPERATE AND HOLD ACCURACY TO RANGE CONDITION 1 DURING ONE 15 MINUTE SWEEP ALONG THE TANGENTIAL AXIS AND ONE 15 MINUTE SWEEP ALONG THE RADIAL AXIS AT THE FOLLOWING LEVELS

5-14 CPS	0.4 DISPLACEMENT PEAK TO PEAK
14-50 CPS	4.0 G PEAK
50-2000 CPS	6.0 G PEAK

ACCELERATION
TIMER MUST HOLD ACCURACY WITHIN RANGE CONDITION 1 DURING 18 G'S ACCELERATION FOR A PERIOD OF 5 MINUTES ALONG THRUST AXIS.

TIMER MUST HOLD ACCURACY WITHIN RANGE CONDITION 1 DURING 14 G'S ACCELERATION FOR A PERIOD OF 10 MINUTES ALONG RADIAL AXIS.

CYCLE TIME
BETWEEN 1400 & 1600 SECONDS ACCORDING TO AVAILABILITY OF GEAR TRAINS

CONTACTS
EACH BRUSH MUST BE CAPABLE OF SWITCHING 600 MA AT 20 VDC RESISTIVE AND CAPABLE OF CARRYING 2 AMPS. AT LEAST 4 BRUSHES IN PARALLEL WILL BE USED FOR EACH CIRCUIT, BUT THE LOAD ON THE CIRCUIT WILL NOT EXCEED THE RATING FOR A SINGLE BRUSH. CONTACT RESISTANCE AT EACH BRUSH MUST BE LESS THAN ONE OHM. AT LEAST TWO BRUSHES ARE TO BE ELIMINATED BETWEEN ADJACENT SWITCH POSITIONS. TRIM RESISTOR FOR SPEED CONTROL TO HAVE A MAXIMUM RESISTANCE OF 5 OHMS.

LIFE
1000 CYCLES MINIMUM

FINISH
NO CADMIUM MAY BE USED ON OUTSIDE OF UNIT.

LEAK RATE
AFTER SOAKING THE TIMER IN HELIUM AT 2 ATMOSPHERES OF PRESSURE FOR 48 HOURS. THE LEAK MUST BE LESS THAN 5×10^{-6} STD CC OF HELIUM PER SEC WHILE IN A VACUUM OF 30 MM HG OR LOWER.

MOTOR CURRENT
MAX MOTOR CURRENT: 50 MA FOR D18551-1 & 65 MA FOR D18551-3, -5 & -7 AT 19V AND OPERATING TEMPERATURE FROM +10° TO + 40°C

WEIGHT - MAX WEIGHT 1 POUND 6 OUNCES.

3. BBRC TO TEST TIMER IN ACCORDANCE WITH LATEST REV OF A18449 FOR D18551-1, & A16387 FOR D18551-3, -5 & -7.

[4.] MARK "18551" & APPLICABLE DASH NO. PER BPS 19.00-1-24 NO DECALCOMANIA OR NAME PLATES PERMITTED.

5. ALL FASTENERS TO BE MECHANICALLY RETAINED PER MIL-N-25027 OR MIL-F-18240

6. RESISTANCE BETWEEN PINS WHEN SWITCH CONTACTS ARE OPEN SHALL BE >10 MEGOHMS WITH 50 VOLTS DC INPUT.

[7] CASE MATL, AL 2024-T4

[8] TOP COVER, ½ HARD SHEET BRASS, -5 & -7 ASSY

Figure 10-2—Sequence Timer Functions

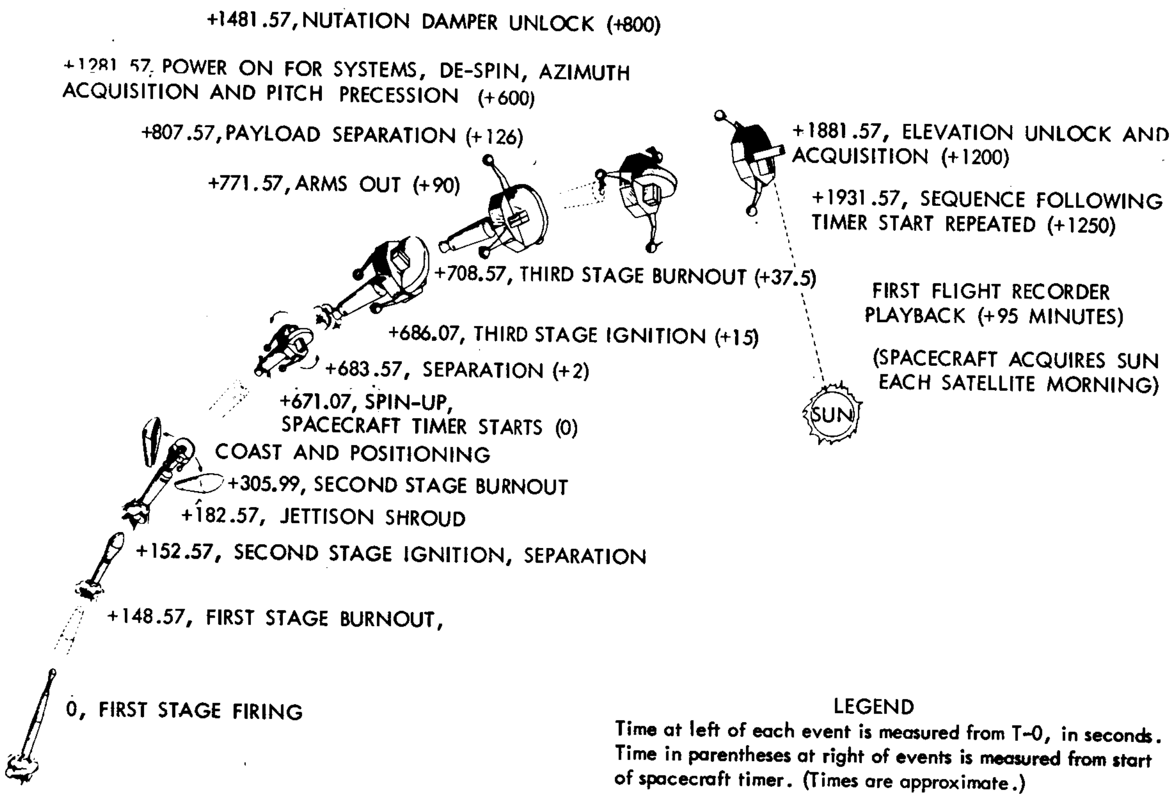


Figure 10-3—Typical Launch Sequence Events

10.3.2.1 Arm Release

At 330 seconds of the timing cycle, number 3 contact of the timer closes. A pulse with a time duration between 10 and 20 seconds is then applied to the coils of the two (redundant) arm release relays. Squib batteries number 7 and number 8 supply power through the contacts of the energized relays to the three sets of arm release squibs. With the release squibs now ignited, the three arms are extended from the stowed position.

10.3.2.2 Orbit Power and De-spin

When 600 seconds has elapsed, timer contact number 4 closes for 15 to 20 seconds. A pulse is then applied to the coils of the orbit power and auto-man relays. These relays have a redundant relay in parallel and will latch-in once energized. By energizing the orbit power and auto-man relays, orbit power comes on the spacecraft is de-spun to the nominal 0.5 rps.

10.3.2.3 Nutation Damper Release

The nutation damper release relays are energized with a pulse between 15 and 20 seconds time duration when number 5 contact of the timer closes for this period. This function occurs at 800 seconds after spin-up. With the nutation damper release relays energized, squib batteries number 9 and number 10 supply power through the closed contacts of the relays, exploding the nutation damper release squibs. The nutation damper is now free to restrain any wobbling of the spacecraft.

10.3.2.4 Elevation Release and Backup Arming

At 1200 seconds, timer contact number 6 closes applying a 10 to 20 second time duration pulse to the elevation release and backup arming relays. Separate squib batteries (number 9 and 10) supply power through the closed contacts of the elevation release relay to fire the elevation release squibs. The elevation drive mechanism is then unlatched. The latching type backup arming relay in the spin control subsystem is also energized which supplies day power to the system.

At 1250 seconds, all the timer sequence operations are repeated simultaneously, to provide redundant actuation of all events.

10.3.3 Squib Batteries

In order to isolate the squib firing circuit from the main spacecraft power supply, firing energy for the squibs is taken from separate batteries. The squib batteries are located in compartment number 4 of the wheel and in the sail structure. These are nickel-cadmium cells that are capable of taking a 80 to 96-hour change of 69 to 71 milliamperes. The cell is capable of providing 108 to 132 milliamperes at 1 volt or more for 4.5 hours after completing the following schedule:

a. Charge – at 59 to 71 milliamperes for 18 to 96 hours

b. Discharge – at 108 to 132 milliamperes for 4.5 hours

c. Charge – at 59 to 71 milliamperes for 18 hours

d. Repeat b and c until four discharge-charge cycles are completed

The cell after being charged is capable of providing a voltage greater than 0.650 volts for at least 2 seconds while being discharged across a 0.037 ohm load.

10.4 HYDRAULIC SYSTEM

During launch the three nitrogen-gas containers on the extended arms are folded down around the third stage motor until completion of third stage burning. They are then released by a squib actuated device and are caused to pivot to the erect position by centrifugal force. The third stage and payload are rotating at approximately 120 rpm. If the arms were not restrained, they would be violently thrown open and could possibly damage the spacecraft. In addition, if the arms do not erect at the same rate or if one arm does not fully erect, the dynamic balance of the spacecraft will be upset. A hydraulic system is employed to accomplish both of these tasks, slowing the erection and insuring the simultaneous erection of all three arms.

Each extendable arm is restrained by a piston moving in a fluid filled cylinder attached to the wheel structure (Figure 10-4). The three cylinders are interconnected so that the fluid, which is discharged from one cylinder, flows to the intake of the adjacent cylinder. All three arms will extend simultaneously because the system is completely filled with fluid. The rate of erection is controlled by an orifice in the discharge port of each cylinder. The hydraulic fluid is ethyl alcohol. Each cylinder is interconnected by copper lines running along the outer periphery of the wheel structure.

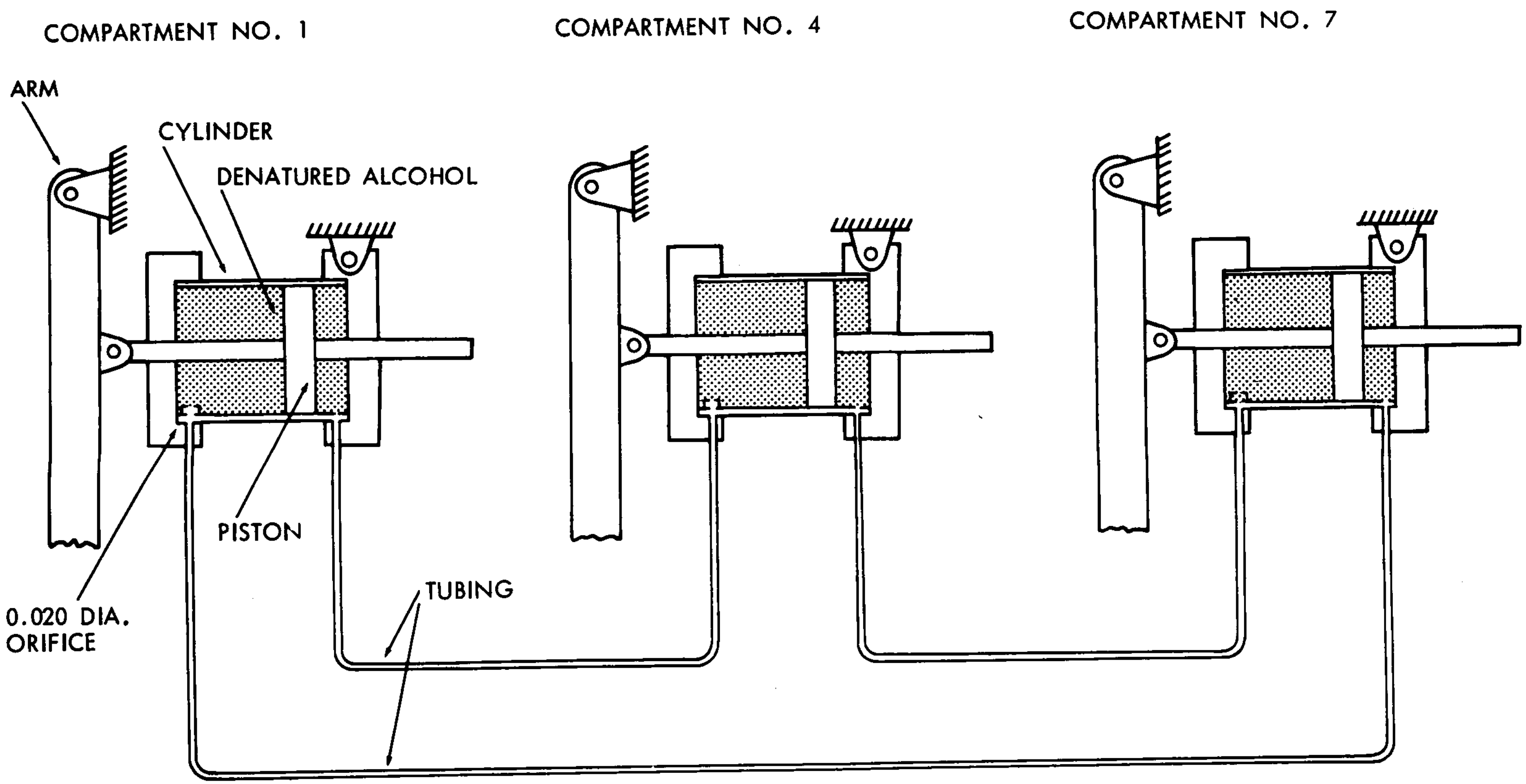


Figure 10-4–Hydraulic System