NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Report 32-1258

Mariner Venus 67 Guidance and Control System

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Abstract

This report functionally describes the power, attitude control and central computer and sequencer subsystems which make up the *Mariner* Venus 67 guidance and control system.

Mariner Venus 67 Guidance and Control System

I. Introduction

This report provides functional descriptions and block diagrams of the guidance and control (G&C) system used on the *Mariner* Venus 67 spacecraft. It is intended that the functional descriptions and block diagrams be complementary. The functional descriptions provide the details of the system which are not easily presented on the block diagrams. The subassembly and relay numbers referred to in the text correspond with those on the block diagrams. The report is divided into five parts: Sections II–VI.

The G&C system, Section II, consists of the power, the attitude control (AC), and the central computer and sequencer (CC&S) subsystems and their interconnections. The function of each subsystem and its components is described separately. Interfaces with other spacecraft subsystems including the G&C telemetry measurements are also described.

Section III presents a time sequence of G&C subsystem events from prelaunch to postencounter. The interactions of the G&C subsystems with each other and with other spacecraft subsystems are described. For each event in the sequence, the G&C telemetry measurements which are affected are also listed. The operational use of the radio direct commands (DC-Vs) are also discussed in this time sequence.

Various backups and redundancies which have been designed into the spacecraft are discussed in Section IV. Backups to G&C functions and redundancies within the G&C subsystems are explained. A more detailed analysis of the effect on the G&C subsystems when DC-Vs are used as backup and emergency commands is included.

A list of nominal performance parameters for the three G&C subsystems is compiled in Section V for reference purposes.

Block diagrams of the three G&C subsystems are provided in Section VI to give a more detailed picture of how each subsystem operates functionally. Interactions with each other and with other spacecraft subsystems are shown.

II. Functional Description of the Guidance and Control Subsystems

A. Power Subsystem

The function of the *Mariner* Venus 67 power subsystem is to generate, store, and convert all electrical power necessary for operation of the spacecraft. In order to perform this function, suitable switching, control, energy-conversion, and power-conditioning functions are provided.

The function of each of the major subassemblies of the *Mariner* Venus 67 power subsystem is described in the following subsections. The last subsection contains a listing of the power subsystem telemetry channels.

1. Solar panels 4A1, 4A3, 4A5, and 4A7. Primary spacecraft power is provided by the four photovoltaic solar panels. These panels convert solar energy to electrical energy when their sensitive surfaces are facing the sun. Each panel is divided into three separate sections, each wired to deliver the rated solar-panel voltage. The total panel area is 43.6 ft². Figure 1 shows the nominal solar-panel power curves as a function of time.

The output of each panel section is connected to the main power bus through an isolating diode; see Section II-A-3. These diodes prevent reverse current-flow into the sections. If there were no diodes, a short in a panel section would cause a reverse current power-drain on the system.

The maximum solar-panel voltage is limited to +50 Vdc by zener diodes which shunt the output of each solar-panel section. This upper limit is functionally related to

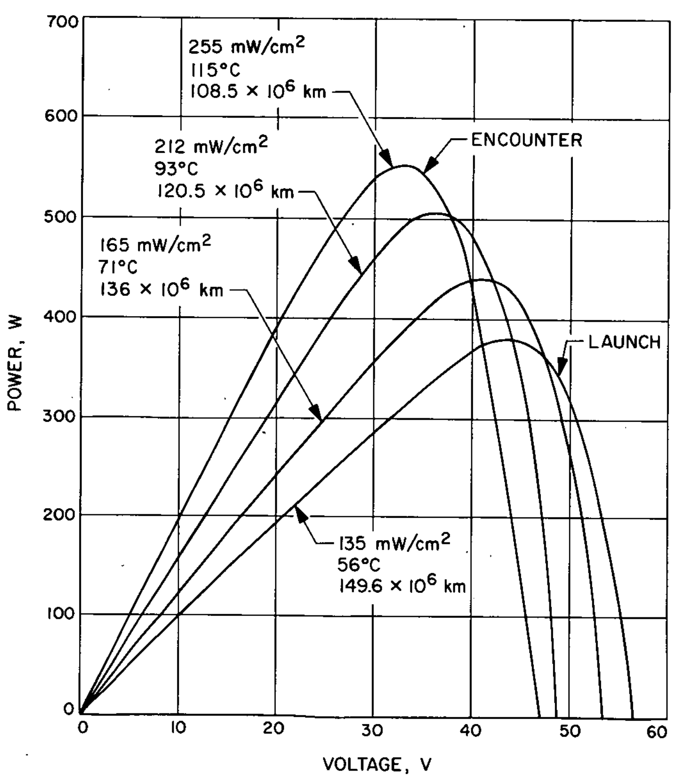


Fig. 1. *Mariner* Venus 67 solar-panel nominal power curves

the voltage regulating action of the booster regulators (B/Rs) in the power regulator subassembly.

Realization of the full design capabilities of the solar panels requires that the AC maintain spacecraft orientation so that the sensitive surfaces of the panels are normal to the incident solar radiation within ±2 deg.

2. Battery 4A14. Secondary spacecraft power is provided by a rechargeable battery which supplies electrical energy during periods of non-sun orientation: launch-to-sun acquisition and midcourse maneuver.

The battery is capable of providing a minimum energy of 1200 W-h through the first midcourse maneuver and, after midcourse, a minimum of 900 W-h through encounter. When not being used, the battery is kept on-line and fully charged and thus is always ready to supply a backup source of power.

The battery is connected to the main power bus through a motor-driven switch; see Section II-A-3. The battery is also connected through relays in the power regulator to a battery charger; see Section II-A-4. The battery voltage is nominally between 25.8 (full load) and 33.3 V (no load).

3. Power regulator 4A8. The raw-power lines from the spacecraft solar panels and battery are tied to the main power bus in the power switch and logic (PS&L) subassembly. Appropriate switching for prelaunch ground operation is provided. The two B/Rs which regulate the dc voltage and their associated switching are also located in this subassembly.

a. Motor-driven switch. The motor-driven switch provides the switching from ground power during the prelaunch mode to spacecraft battery power just prior to launch. During ground operations the switch provides +35 Vdc operational support equipment (OSE) power to the spacecraft. The switch is actuated 7 min before launch so that the battery supplies the spacecraft power. The switching action is such that connection is made between one power source and the bus before it is broken between the bus and the other source. This ensures that the supply of power to the spacecraft is not interrupted during the switching process.

The switch may be operated in either direction. When the spacecraft is operating on external power, the *internal power on* order from OSE will connect the battery to the main bus and disconnect the external power source. The *external power on* order from OSE drives the switch in the opposite direction. The switch is designed so that successive commands for switching in the same direction, which might jam the mechanism, cannot be received. Complete switching action in either direction is obtained through the inertia of the switching mechanism. Since OSE power and switch command inputs are removed at umbilical separation, the switch must be in the internal power position at that time.

b. Main power bus. The output lines of the solar-panel sections and the battery, through the motor-driven switch, are connected to the main power bus. Each section of the panels is diode-isolated from the bus (Section II-A-1), as is the battery.

Raw power from the bus is routed to the communications subsystem converter and to the heater in the science magnetometer, the only subsystems using unregulated power. Raw power is used to avoid the difficulties of switching and routing high voltages required by the communications subsystem. The line to the magnetometer heater is fused to protect against a heater short-circuit grounding the bus.

The main power bus is connected to the input switches of the B/Rs and to the battery charger. There are two relays located in the power regulator subassembly associated with the battery charger. Since they are functionally related to the battery charger, they are described in Section II-A-4.

c. Booster regulators. There are two B/Rs on the *Mariner* Venus 67 spacecraft. These boost the bus voltage to a regulated 52 Vdc $\pm$ 1%. The main booster handles the cruise power demands, and the maneuver booster handles the additional power demands during a maneuver. Error-detecting circuitry will replace the main booster by the maneuver booster if the main booster fails (described below).

A B/R consists of four major parts: (1) an input filter, (2) an error amplifier, (3) a transistor-controlled autotransformer, and (4) an output filter. Since the booster draws current in pulses, the input filter smooths high frequency voltage variations which would occur in the raw-power input. The error amplifier compares the output voltage with an internal zener voltage reference and generates an error signal. This signal acts through transistors to control an autotransformer so that the autotransformer duty cycle increases with the error. An increased duty cycle results in a higher average regulated voltage. The output filter smooths the varying voltage at the autotransformer output so that the regulated voltage is a nearly constant 52 V.

The two B/Rs are identical in operation. The main booster receives the raw-power input through Relay 4A8 K4. This relay is controlled by the booster control circuitry, an error-detecting device which monitors the booster output. If this output is less than 48 $\pm$ 1 V or greater than 58 $\pm$ 1 V for 3.5 $\pm$ 1 s, the booster control will permanently set the relay. Setting the relay removes the raw-power input from the main booster and applies it to the maneuver booster. The output of the maneuver booster is then routed over the same output line used by the main booster. This failure-mode switching is not reversible in flight.

In addition to the above failure-mode relay, another relay, 4A8 K3, is used to switch raw power into the maneuver booster and to switch its output to the maneuver loads. This relay is controlled by a relay closure (7A1 K10) in the AC subsystem. This switching takes place whenever the gyro switch control in the AC subsystem is on. Although the output of the maneuver booster supplies some of the cruise loads during failure-mode operation, the gyro switch control must still be on to supply power to the maneuver loads.

Since the maneuver booster cannot handle all the spacecraft cruise loads and the maneuver loads together, a circuit is included to disconnect power to the science loads by setting Relay 4A8 K5 when the main booster has failed and the gyros are on. When the gyros go off, 4A8 K5 resets and turns on power to science. This overload-inhibit circuit can be overridden by ground command; see Section II-A-9.

4. Battery charger 4A13. The battery charger has two modes of operation: in the first, it charges the battery during periods of sun orientation; in the second, it boosts the system voltage to remove the battery from the sharing mode of operation.

The relay controlling the battery charger, 4A8 K1, is located in the power regulator subassembly. The battery charger is turned on by setting this relay by command DC-V28 through the power distribution subassembly. The charger is turned off by similar commands DC-V25, DC-V26, or MT-7, from the power distribution subassembly which resets the relay. Successive DC-V28s will, if certain conditions are satisfied, alternately turn the charger on and off. See Sections II-A-9 and IV-B for more details on these commands.

When the battery charging relay is turned on, power from the main power bus is provided to the charger. The charger then supplies a small charging current[1] to the battery via the same relay. The battery will not be damaged by the presence of this trickle charge over long periods of time.

The share-mode detector monitors the unregulated bus voltage. When this voltage drops to 33 ± 1 Vdc, the share-mode detector will set Relays 4A13 K1 and K2 which switch the battery charger from charge to boost. The setting of 4A13 K1 sets another relay, 4A8 K2 located in the power regulator. This relay switches the battery in as input to the charger. The charger then boosts the battery voltage and applies it to the main power bus. The share-mode detector will then reset the relays when the main bus voltage rises to 38 ± 1.5 Vdc. After completing this cycle, the battery charger will not enter this mode again until approximately 1 s later.

The share-mode detector is inhibited during maneuvers by a signal from the maneuver load output of the maneuver B/R. In addition, the battery charger relay must be reset, to OFF, for the charger to operate in the boost mode. If the charger is on and a sharing condition is detected, all inputs and outputs to the charger are disconnected by these relays.

5. ***Power synchronizer 4A12.*** The power synchronizer supplies the frequency synchronization signals to the power inverters. Its frequency reference is the 38.4-kHz signal from the central clock of the CC&S subsystem. Power is provided by the 52 Vdc of the main booster regulator and the 2.4 kHz 50 V of the main inverter.

The 38.4-kHz input frequency is divided down by flip-flops to provide the output sync signals. A 2.4-kHz signal is supplied to the main inverter. Another 2.4-kHz signal is supplied to the maneuver inverter. Three-ϕ 400-Hz signals are sent to the 3-ϕ 400-Hz inverter.

If the 38.4-kHz signal from the CC&S should fail or double in frequency, Relay 4A12 K1 in the power synchronizer will be reset. When this occurs, power is switched to a 38.4-kHz free-running oscillator which then drives the remaining stages of the power synchronizer. This switching provides an automatic backup for the sync signal to the power synchronizer.

6. ***Main 2.4-kHz inverter 4A15.*** The main inverter supplies 50-Vrms 2.4-kHz power to the radio, command, CC&S, data encoder, attitude control, and pyrotechnic subsystems and to the power synchronizer. In addition, power is supplied to the power distribution subassembly where it may be switched to science.

Input power comes from the 52-Vdc output of the main B/R. The 2.4-kHz sync signal is provided by the power synchronizer. In the absence of this sync signal the inverter will free-run at 2.4 kHz.

7. ***Maneuver 2.4-kHz inverter 4A16.*** The maneuver inverter is identical in operation with the main inverter. It supplies 50-Vrms 2.4-kHz power to the AC gyro electronics, autopilot, and CC&S relay-hold transformer rectifier.

Input power is the 52-Vdc switched-output of the maneuver B/R. The 2.4-kHz sync signal is provided by the power synchronizer. In the absence of this sync signal the inverter will free-run at 2.4 kHz.

8. ***Three-ϕ 400-Hz inverter 4A18.*** This inverter supplies 27-Vrms 3-ϕ 400-Hz power to the AC gyro spin motors. One of the phases is also used to supply power to the tape recorder motor during launch. Tension must be kept on the tape at this time to prevent the reels from coming unwound due to vibrations. This power to the tape recorder is not used after launch.

Input power to the inverter is the 52-Vdc switched-output of the maneuver B/R. The 3-ϕ 400-Hz sync signals are provided by the power synchronizer. This inverter will not free-run in the absence of the sync signal.

9. ***Power distribution 4A11.*** This subassembly distributes switched power to the various scientific experiments on the spacecraft.

The 2.4-kHz main inverter power is supplied to science through Relay 4A11 K2 in this subassembly and then through Relay 4A8 K5 in the power regulator subassembly. This power is supplied (4A11 K2 is set) by the science-on command at separation (described below) or by DC-V2. Power may be turned off (4A11 K2 is reset) by DC-V26.

[1]Depending on the battery charge state: 0.005 to 0.5 A.

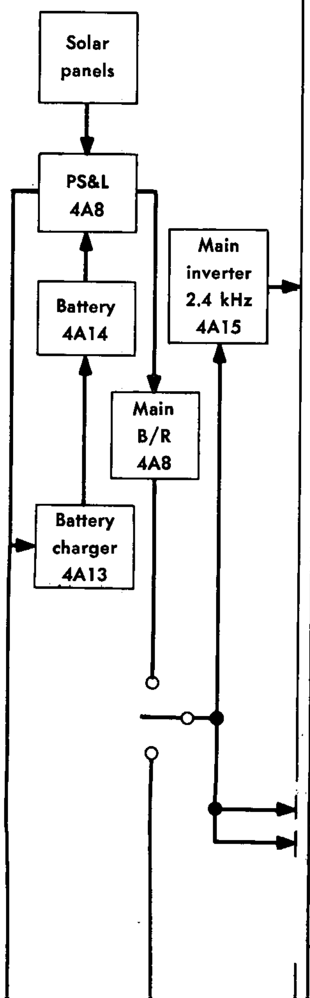
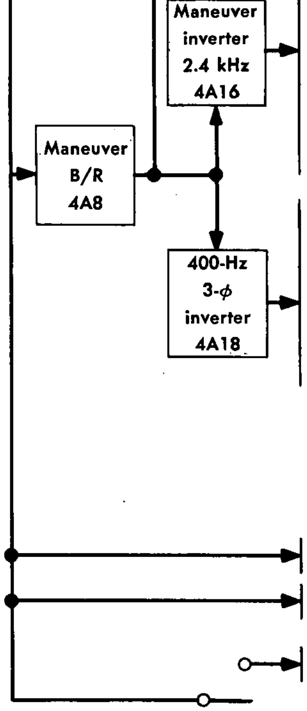


Table 1. ***Mariner*** **Venus 67 average power loads**

System/subsystem	Reference No.	Normal flight sequence phases, W						Abnormal flight sequence phases (gyros on), W		
		Launch	Pre-sun acquisition	Cruise	Maneuver	Encounter	Playback	Cruise	Encounter	Playback
Data automation subsystem	20A1	—	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Dual frequency receiver	35	—	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Trapped radiation detector	25A1	—	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Plasma probe	32A4	—	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
UV photometer	34	—	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Magnetometer	33A2	—	7.21	7.21	7.21	7.21	7.21	7.21	7.21	7.21
Total science, 2.4 kHz		—	27.74	27.74	27.74	27.74	27.74	27.74	27.74	27.74
Data encoder	6A13	8.33	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84
Tape electronics	16A4	—	—	—	—	7.1	6.4	—	7.1	6.4
Command	3A7	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
CC&S transformer rectifier	5A8	4.84	4.84	4.84	4.84	4.84	4.84	4.84	4.84	4.84
Control system electronics	7A1	13.6	13.6	5.5	17.8[a]	5.5	5.5	14.0	14.0	14.0
Pyrotechnic control subsystem	8A1	—	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Pyrotechnic control subsystem	8A2	—	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Power sync	4A12	3.79	3.79	3.79	3.79	3.79	3.79	3.79	3.79	3.79
Receiver	2TR1	7.8[b]	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Control unit	2CC1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Exciter	2TR2	11.2[c]	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Power distribution	4A11	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
Total engineering, 2.4 kHz		54.5	54.97	46.87	59.17	53.97	53.27	55.37	62.47	61.77
Total from main inverter	4A15	54.5	82.71	74.61	86.91	81.71	81.01	83.11	90.21	89.51
Total into main inverter	4A15	66.5	96.2	87.8	101.1	95.6	94.7	96.6	104.7	103.8
Telemetry oscillator	4A8	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Power sync	4A12	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Total from main B/R	4A8	70.8	100.5	92.1	105.4	99.9	99.0	100.9	109.0	108.1
Total into main B/R	4A8	87.4	121.1	114.6	126.4	123.8	122.7	124.7	130.5	133.5
Relay hold	5A9	7.50	—	—	—	—	—	—	—	—



Gyro control electronics	7A2	8.5	8.5	—	8.5	—	—	9.5	9.5	9.5
Total from maneuver inverter	4A16	16.0	8.5	—	15.5	—	—	9.5	9.5	9.5
Total into maneuver inverter	4A16	23.5	14.8	—	23.0	—	—	16.1	16.1	16.1
Gyro motors	7A2	9.6	9.6	—	9.6	—	—	9.6	9.6	9.6
Tape recorder	16A5	3.41	3.41[d]	—	0.2	—	—	0.2	0.2	0.2
Total from 400-Hz, 3-ϕ inverter	4A18	13.01	13.01	—	9.8	—	—	9.8	9.8	9.8
Total into 400-Hz, 3-ϕ inverter	4A18	16.06	15.87	—	12.55	—	—	12.55	12.55	12.55
Total from maneuver booster	4A8	39.56	30.67	—	35.55	—	—	28.65	28.65	28.65
Total into maneuver booster	4A8	53.46	42.95	—	48.70	—	—	44.77	44.77	44.77
Battery charger	4A13	4.4	4.4	13.1[e]	4.4[f]	0.0	0.0	13.1[e]	0.0	0.0
Heater power magnetometer	33A2	0.6	0.6	2.7[g]	2.7	1.7	1.7	2.7[g]	1.7	1.7
Cavity amplifier power supply	2PS2	10.2	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6
TWT[h] power supply	2PS3	0.0	61.2	61.2	61.2	61.2	61.2	61.2	61.2	61.2
Total from PS&L (cavity)		156.1	201.7	163.0	211.8	158.1	157.0	217.87	209.6	212.6
Total from PS&L (TWT)		145.9	230.3	191.6	240.4	186.6	185.6	246.5	238.2	216.9
Total demand on solar panels or battery (cavity)		160.9	208.1	166.3	216.1	161.3	160.2	222.3	213.9	241.2
Total demand on solar panels or battery (TWT)		150.4	237.4	195.5	245.3	190.5	189.4	251.5	243.1	246.1

Event	Spacecraft voltages	
	Expected voltage range, V	Voltage used in calculations, V
Launch	33–28	28
Preacquisition	28–48	28
Cruise	48–41	41
Maneuver	48–28	28
Encounter	41	41
Playback	41–39	41

[a]22.8 W with gas jets on.
[b]Add 0.7 W for ranging on.
[c]Exciter A 11.2 W, exciter B 10.4 W.
[d]Turned off 1 min after separation.
[e]Charger on 13.1 W, with 46.9-V input and battery at 29.1 V, charger off 0 W.
[f]13.1 W if power source is solar panels, 4.4 W if on battery.
[g]3.3 W at 48 V near earth.
[h]Traveling-wave tube.

Another relay in this subassembly, 4A11 K3, backs up the switching of power to science again via Relay 4A8 K5 in the power regulator subassembly. Thus, either Relay 4A11 K2 or K3 will supply the power to 4A8 K5 for science. Power is supplied (4A11 K3 is set) by CC&S Event MT-7 which occurs 12⅓ h before encounter or by DC-V2 or DC-V25. This relay is reset by DC-V26.

A third relay, 4A11 K4, will supply 2.4-kHz power directly to science by by-passing Overload Inhibit Relay 4A8 K5 in the power regulator subassembly. This override function may be turned on (4A11 K4 is set) by DC-V25 and is turned off (4A11 K4 is reset) by DC-V26.

A fourth relay, 4A11 K5, switches 2.4-kHz main inverter power to the tape recorder. Power is turned on (4A11 K5 is set) by MT-7 or DC-V25 and is turned off (4A11 K5 is reset) by DC-V28.

A fifth relay, 4A11 K1, is energized at launch and is de-energized at spacecraft–*Agena* separation. This relay provides the science-on command at this time. It also provides the RF power-up command to the radio subsystem. Since power to this relay is provided by the maneuver B/R, the relay will be de-energized, if it has not been de-energized by the spacecraft–*Agena* separation, when the gyros go off.

In addition to the relay outputs, this subassembly has logic outputs for turning the battery charger on and off. Command DC-V28 is gated with a signal from the battery charger to provide the charger-on command to Battery Charger Relay 4A8 K1 in the power regulator subassembly. The logic is such that DC-V28 will turn the charger on if it is off (boost enable mode) and not boosting. Commands MT-7, DC-V25, DC-V26 and DC-V28 are gated together with the signal from the battery charger to provide the charger-off command to the battery charger relay. The logic is such that any one of these four commands will turn the charger off if it is on (charging) and a sharing mode is not being detected.

Power for the various logic gates and all the relays in this subassembly except Relay 4A11 K1 is provided by a dc regulator in the subassembly. The regulator obtains its power from the 2.4-kHz main inverter.

10. Power loads. Table 1 shows the average power loads for *Mariner* Venus 67.

11. Power telemetry. Table 2 lists the power subsystem telemetry measurements.

Table 2. Power subsystem telemetry

Channel	Measurement
109	Raw-power bus voltage (solar panels and battery)
203	Total B/R input current
204	Current from raw-power bus to the communications converter and magnetometer heater
205	Main B/R output current
206	Battery V
207	Main 2.4-kHz inverter output voltage
216	Battery charging current from battery charger
221	Maneuver B/R output current
222	+X solar-panel current
223	−X solar-panel current
224	+Y solar-panel current
225	−Y solar-panel current
226	Battery output current
227	Main 2.4-kHz inverter output current
401	Bay 1 temperature
403	−X panel standard-cell temperature
407	Power regulator subassembly temperature
409	+X solar-panel front temperature
415	Standard solar-cell current
416	Radiation-resistant solar-cell current
417	Standard solar-cell voltage
427	−X solar-panel spar zener temperature
428	Battery temperature
429	−X solar-panel front temperature

B. Attitude Control Subsystem

The functions of the AC subsystem are related to the several modes of operation of this subsystem. During the acquisition and cruise mode of operation, the function of the AC subsystem is to establish and maintain 3-axis stable orientation of the spacecraft. This orientation is such that the sensitive surface of the solar panels faces the sun, and the Canopus sensor views the star Canopus. With this orientation established, the communications high-gain antenna will point toward the earth during the latter portion of the flight.

During the midcourse maneuver mode, the AC subsystem must orient the spacecraft such that the thrust vector of an on-board rocket motor is aligned to some predetermined direction in space. It must maintain this orientation during the motor burn period and then reestablish the cruise orientation.

The *standard* operation of the AC subsystem during these modes is described. The AC subsystem contains many interconnected DC-Vs. These are not normally used in a standard flight, and their use is described in Section IV.

The spacecraft body axis system is shown in Fig. 2. Positive (clockwise) pitch, yaw, and roll turns are defined. Figure 3 shows the relationship between clock and cone angle and the spacecraft body axes in the cruise orientation. The cone angle of a celestial object is defined as the angle, β (where $0 \leq \beta \leq 180$ deg), from the spacecraft–sun line to the spacecraft–object line. The clock angle of a celestial body is defined as the angle, α (where $0 \leq \alpha < 360$ deg), between a plane containing the sun, spacecraft and Canopus and a plane containing the sun, spacecraft and object. It is measured from the sun–spacecraft–Canopus plane and defined as positive, in the clockwise direction, when looking toward the sun from the spacecraft.

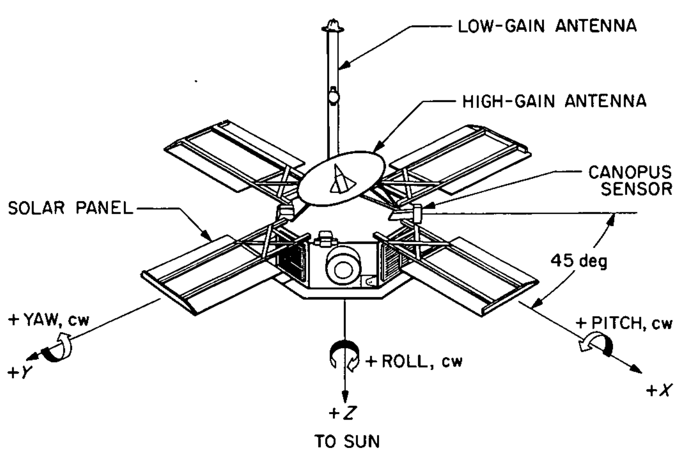


Fig. 2. Spacecraft coordinate system

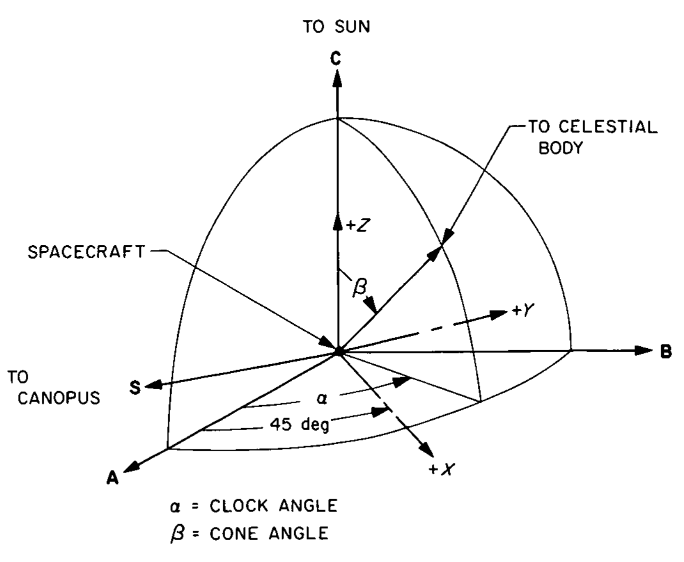


Fig. 3. Clock and cone angles

1. Acquisition and cruise functions. After the spacecraft has been injected into its heliocentric trajectory, it must establish the 3-axis cruise orientation. This process begins when AC dc power is switched on by the pyro arming switch at separation or by CC&S Command L2. Angular-position errors about the pitch and yaw axes are sensed by sun sensors. Rotation rates about all three axes are sensed by three single-degree-of-freedom gyroscopes. Both rate and position are used as inputs to switching amplifiers which switch power to gas jet actuators when the sum of the inputs exceeds a certain dead-band value. These actuators operate gas jets which release N_2 gas to cause spacecraft torques so that the pitch- and yaw-rate and position errors are reduced to limit cycle values. The roll rate is fixed at a constant *spin* level which is used to calibrate the science magnetometer at this time.

Roll acquisition begins with CC&S Command L3 at launch + 997 min. The roll rate is reduced to a *search* level and power is applied to the Canopus sensor. Roll angular position error is sensed when a body with a brightness greater than ½ that of Canopus enters the field of view of the Canopus sensor. Once this illumination has been sensed, the roll rate and roll position error are reduced to limit cycle values and the 3-axis cruise orientation is established. The gyros are turned off at this time and rate damping is provided by the derived-rate signal fed back around the switching amplifier.

a. Attitude control cruise power. The cruise power for AC is the transformer-isolated 50-Vrms output of the main 2.4-kHz inverter. This signal is rectified to provide the ±26-Vdc signals used in the AC. Some components use this power directly, while others use power routed via relays. The Canopus sensor and the switching amplifiers use ac power. A +26-Vdc line is routed to the CC&S for AC command switching. The Canopus sensor supplies a +25-Vdc signal to the CC&S for Canopus sensor cone-angle updates.

b. Sun sensors. The cruise and acquisition sun sensors are the position sensing elements in the pitch and yaw cruise attitude control loops. Power to the cruise sensors is the ±26-Vdc signals routed through two relays and a regulator which reduces the signals to ±12 Vdc. The first relay, 7A1 K7, supplies sensor power upon receipt of the AC power-on command. The second relay, 7A1 K3, turns the sensor power off during a midcourse maneuver. The cruise sun sensors are oriented so that their null axes point in the direction of the spacecraft positive roll axis.

Power is provided to the acquisition sensors by the ±26-Vdc signal routed through the above two relays and a third relay, 7A1 K5, which is controlled by the sun gate which keeps the power to the acquisition sensors on during sun acquisition. The acquisition sensors are positioned so that the sun will always be visible to at least one set of sensors during acquisition. This gives the sensors a 4π steradian (complete sphere) field-of-view. Power to the acquisition sensors is switched off when the sun gate sensor is looking at the sun.

A sun sensor consists of a photoresistor mounted beneath a shadow mask. The sensors are connected in pairs so that the output is a dc signal proportional to the angular deviation of the sensor axis from the line of sight to the sun; see Fig. 4. The sensor polarity is such that a

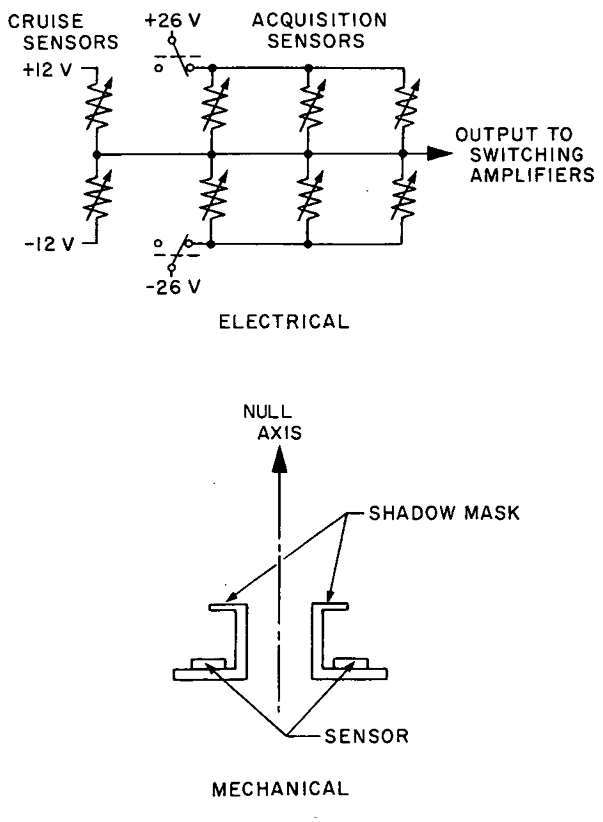


Fig. 4. Sun sensors

positive (cw) pitch (or yaw) rotation of the spacecraft, from its null position, gives a negative voltage.

c. Sun gate. The sun gate is used to determine when the spacecraft has acquired the sun. The sun gate sensor is a set of photoresistors masked so that they are sensitive to spacecraft cone angle but insensitive to clock angle. The sensor will turn off the gate signal when the positive roll axis is within approximately 5 deg cone angle of the sun.

The sun gate signal holds the power on to the acquisition sun sensors and holds the Canopus sensor power off. When the signal disappears, power is switched from the acquisition sun sensors to roll search logic. The gate signal holding the Canopus sensor power off is also removed.

d. Canopus sensor. The Canopus sensor is the position sensing element in the roll attitude control loop. Power is provided by the 50-Vrms signal from the main 2.4-kHz inverter. This power is switched to either the sensor or the sun shutter electronics. When the sensor is off, the shutter electronics are on and vice versa. The sun shutter protects the sensor from the damaging effects of very bright objects. The shutter is actuated when the sensor electronics are off and a bright object is detected by the sun detector. The sensor electronics are held off by the sun gate signal, CC&S Command M2, DC-V18, DC-V20, or by CC&S Command L3 before it has occurred.

The position of Canopus is described by its cone angle from the sun and its clock angle about the spacecraft–sun line (which is defined as zero with the clock angle of all other objects measured from Canopus). The sensor has a field-of-view of approximately 11 deg in cone and 4 deg in clock. The 11-deg field-of-view in cone is gimbaled electronically to follow Canopus through its total cone-angle excursion. Figure 5 shows the cone-angle excursion vs time for *Mariner* Venus 67. These cone-angle changes are commanded by the end counter of the CC&S and are backed up by DC-V17. Each CC&S or DC-V17 command will change the cone angle 1 increment of 5⅛ deg cyclically. Table 3 gives the values of the cone angle and the time of change.

The Canopus sensor consists of an image-dissector tube with a photocathode surface and the associated electronics. Light input to the surface of the tube is converted to an output roll-error signal and a light-intensity signal. If the light intensity is greater than ½ times that of Canopus, then an *acquire* signal is sent to the Canopus gate. This *acquire* signal will be turned off when the

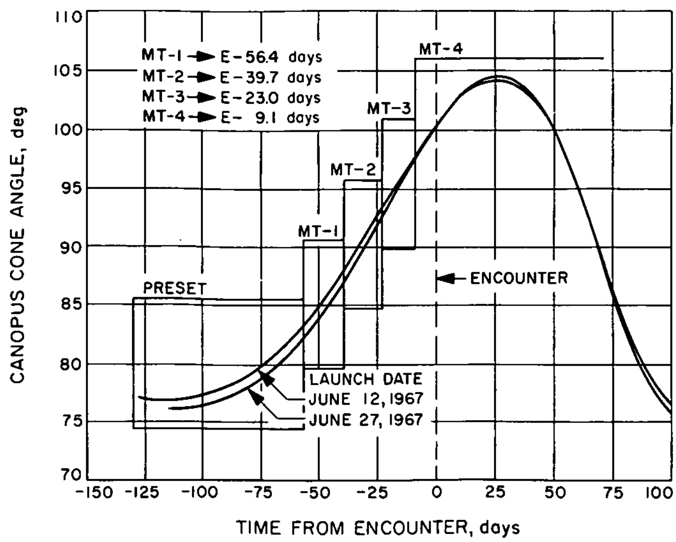


Fig. 5. Canopus cone angle vs time

brightness subsequently falls to ¼ times that of Canopus. The light-intensity signal is telemetered back and used to determine what object is in the field-of-view of the sensor. The roll-error signal and the acquire signal are used in the roll-acquisition logic; see Section II-B-1-f. When an object has been acquired, the roll-error signal is switched into the roll-switching amplifier as the position error signal. The characteristics of the roll-error signal are shown in Fig. 6.

e. Roll-search logic. The roll-search logic provides the *spin* and *search* signals used in the roll-attitude control loop. The ±26-Vdc power is provided when this power is switched from the acquisition sun sensors.

When the Canopus sensor is off, the *spin* signal is made available to the roll-axis control system. When this negative signal is switched into the roll-switching amplifier, the spacecraft establishes a negative roll rate of approximately 3.5 mrad/s. This is used for calibrating the science magnetometer. When Event L3 occurs

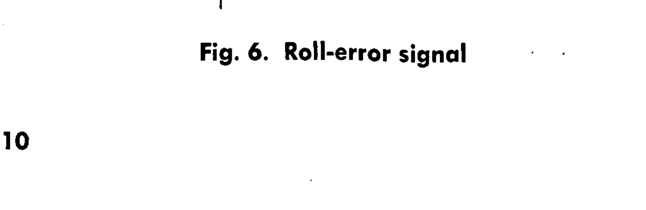


Fig. 6. Roll-error signal

Table 3. Cone angle vs time

Cone angle, deg	Condition
80.0	Preset at launch
85.1	MT-1 at E − 56.4 days
90.3	MT-2 at E − 39.7 days
95.4	MT-3 at E − 23.0 days
100.5	MT-4 at E − 9.1 days
105.7	Optional positions
100.5	
105.7	

(launch plus 997 min), the *spin* signal is permanently disabled.

When the Canopus sensor is on, the *search* signal is made available to the roll-switching amplifier. This negative signal establishes a spacecraft roll rate of approximately 2.0 mrad/s. When an object has been acquired, the *search* signal still exists but is no longer input to the switching amplifier.

A signal from the roll negative torque gas jets is fed back to the roll-search logic. If the negative roll jets stay on for more than approximately 30 s, both the *spin* and the *search* signals will be inhibited. Thus, if the roll gyro malfunctions and fails to null out the *spin* or *search* signal being fed into the switching amplifier, the signal will be switched off after 30 s to prevent the spacecraft from spinning up to damaging rates. This inhibit may be reset by the use of DC-V21.

f. Canopus gate. The Canopus gate is used to switch the roll axis control system from the search to the acquire mode. The ±26-Vdc power used comes on when the AC power goes on at separation. Both the *acquire* signal and the roll-error signal from the Canopus sensor are input to this gate. When the *acquire* signal is received, and if the roll-error signal is negative, the Canopus gate will switch Relay 7A1 K13 causing the roll-error signal to be input to the roll-switching amplifier in place of the *search* signal. The signal which holds the gyros on is removed by this relay at this time also. A polarity check of the roll-error signal prevents the acquisition of reflections of very bright objects which are within the acceptable intensity range but with inverted roll-error signals. Acquiring a very bright object with an inverted error signal would cause the spacecraft to go into a high-velocity limit cycle with rapid gas consumption. If the *acquire* signal goes off, the gate will reset the relay, switching the *search* signal into the roll-switching amplifier and providing a turnon signal for the gyros.

g. Gyros: rate. Three single-degree-of-freedom gyros provide the rate-error signal to the pitch, yaw and roll attitude control loops. Power for the gyro motors is supplied by the 3-ϕ 400-Hz inverter. Power to the amplifiers in the gyro loops is provided from the maneuver 2.4-kHz inverter. All gyro power is held on by the gyro switch control which may be triggered by any of several signals. During launch the switch is held on by AC power through CC&S Command L2 and the pyro arming switch. When either of these opens, this power is removed. When the relay controlled by the Canopus gate is in the search mode, a signal is routed to the gyro switch control. In addition, CC&S Command M1, or M2, or DC-V18 will hold the gyros on. The switch control has a 200-s delay in turning off, allowing part of the roll rate to be damped out when the Canopus sensor acquires a body and switches off the signal to the gyros.

When used during acquisition, each gyro has an output to its switching amplifier which is proportional to the spacecraft angular rate about its sensitive axis. For a positive rotation rate, the output to the switching amplifier is a negative dc signal. The gyros are turned off after Canopus has been acquired and are not normally used during cruise. They are next used during the midcourse maneuver; see Section II-B-2.

h. Switching amplifiers, derived rate, and gas system. The switching amplifiers use the position and rate-error signals during acquisition to control gas valve actuators. Both ac and dc power is provided by the main 2.4-kHz inverter. The switching amplifiers begin operation when the AC dc power is switched on at separation. The input–output characteristics of the switching amplifier power switch are shown in Fig. 7.

The dead band is provided so that the gas jets will not be on continuously. The amplifiers have a minimum-on-time characteristic (20 ms) which controls the size of the nominal limit cycle. The gas valve actuators open the valves to the gas jets which release N_2 gas. The gas system consists of two independent gas supplies and sets of jets. Thus, if one jet should stick open and exhaust the N_2 supply in one bottle, there still would be available in the other bottle about ⅓ of the total N_2 supply left before the failure. This would be sufficient to perform the remaining necessary attitude control functions.

The configuration of the switching amplifiers and gas jets is such that a positive signal into the switching amplifier, above the dead-band level, will cause the gas jets which apply a positive restoring torque to the spacecraft to open. Thus, closing the loop, if the spacecraft makes a negative rotation from its null position or if a negative-rotation rate exists, a positive signal is input to the switching amplifier causing a positive restoring torque.

Since the gyros are switched off after Canopus acquisition, their rate-error signal is not available to the switching amplifiers during cruise mode. Rate control is provided by the derived-rate feedback signal around the switching amplifier. The behavior in the phase plane is shown in Fig. 8.

The switching line without derived rate, in Fig. 8, is vertical. When the switching amplifier power switch activates the gas jets, the derived-rate compensation essentially integrates this signal and feeds it back to the input. Due to the sign inversion in the switching amplifier, the feedback signal is opposite in polarity to the position error input. Therefore, the switching amplifier

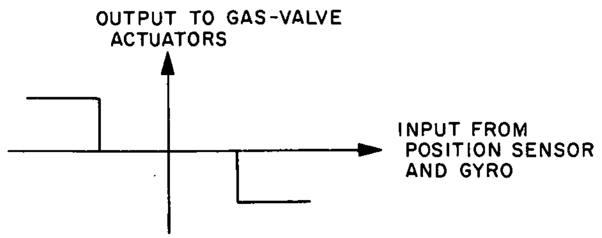


Fig. 7. Switching-amplifier characteristics

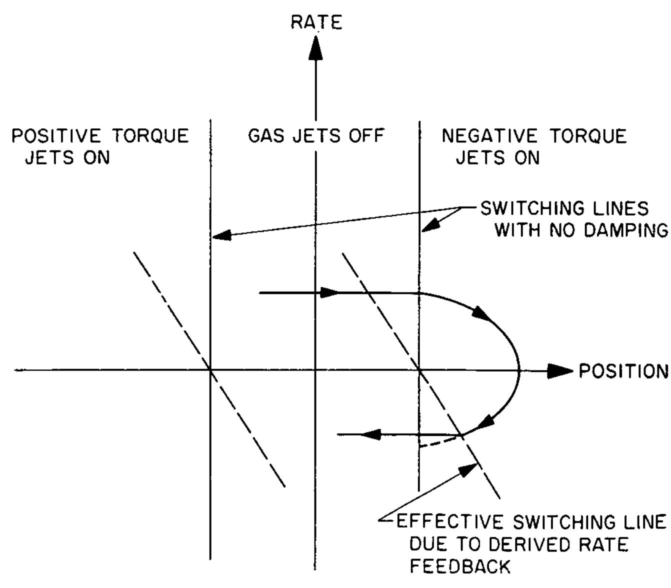


Fig. 8. Derived-rate damping in the phase plane

will turn off sooner with the feedback than it would without it and, thus, introduce damping into the control loops as shown in the figure.

i. Planet sensor. The planet sensor is utilized for on-board initiation of the encounter sequence. It consists of a cadmium sulfide detector with appropriate optics and electronics. The sensor is activated by CC&S Event MT-8.

The sensor draws its excitation power from and supplies its output data signal to the data automation subsystem (DAS). As the lighted limb of Venus passes into the sensor field-of-view, the output signal goes from *low* to *high* allowing the DAS to initiate the data recording sequence. Figure 9 shows the approximate planet–spacecraft geometry at the time the sensor views the limb. The sensor orientation is chosen so that this occurs nominally 60 min before encounter. The field-of-view is designed to minimize the time dispersions of the planet-in-view signal for the various trajectories. The sensor provides no AC functions.

j. Terminator sensor. The terminator sensor is utilized for on-board initiation of the high-gain antenna pointing angle change. It consists of a cadmium sulfide detector with appropriate optics and electronics. The sensor is activated by CC&S Event MT-7 or DC-V25. It draws its excitation power from and supplies its output signal to

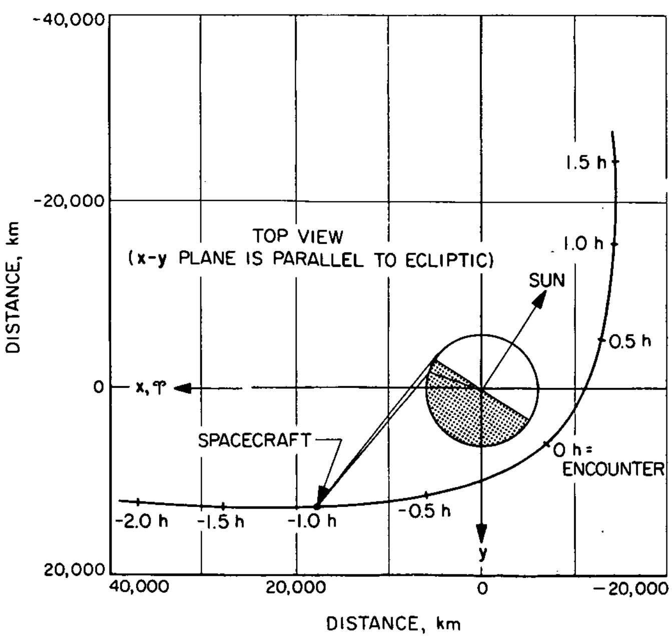


Fig. 9. Planet sensor, approximate encounter geometry

the pyro subsystem. As the terminator[2] passes into the sensor field-of-view, the output signal goes from *low* to *high*, allowing the pyro subsystem to fire squibs to change the antenna pointing angle. Figure 10 shows where the spacecraft is when the terminator sensor sees the terminator near encounter. The sensor orientation is chosen so that this occurs at the mid-occultation point on the trajectory. The sensor provides no AC functions.

2. Maneuver functions. Errors during injection guidance may cause the actual trajectory of the spacecraft to differ from the nominal trajectory. If this difference is large enough, a midcourse maneuver is required to correct the miss distance at Venus. *Mariner* Venus 67 is capable of two midcourse maneuvers.

The function of the AC subsystem during the midcourse maneuver mode is to orient the thrust vector of a body-fixed rocket motor to some predetermined direction in space. To do this, the spacecraft performs a pitch and roll turn in sequence as controlled by the CC&S. This orientation is maintained during motor burn by controlling the thrust vector to pass through the spacecraft center of gravity with an autopilot. After the maneuver the spacecraft returns to the cruise orientation.

a. Attitude control maneuver power. The same power sources used in the acquisition mode are used during the midcourse maneuver. The gyro power is switched on by CC&S Command M1. The 3-ϕ 400-Hz inverter supplies power for the gyro spin motors. Power for the gyro amplifiers, command current regulator, roll one shots and midcourse autopilot is provided by the maneuver 2.4-kHz inverter.

Attitude control +26 Vdc power is provided to the CC&S so that it may be switched back to the AC by CC&S commands. The maneuver may be stopped by switching off this power to the CC&S by using DC-V13; see Section IV.

b. Gyros: rate and position. The gyros warm up for 60 min after the midcourse sequence is initiated by CC&S Command M1. CC&S Command M2 then switches power off to all the sun sensors and switches capacitors into the feedback loop of all three gyros. These capacitors will then integrate the sensed rate to give a position-error signal. Thus, the gyros provide rate

[2]The line separating the sun-lighted and darkened portions of the planet surface.

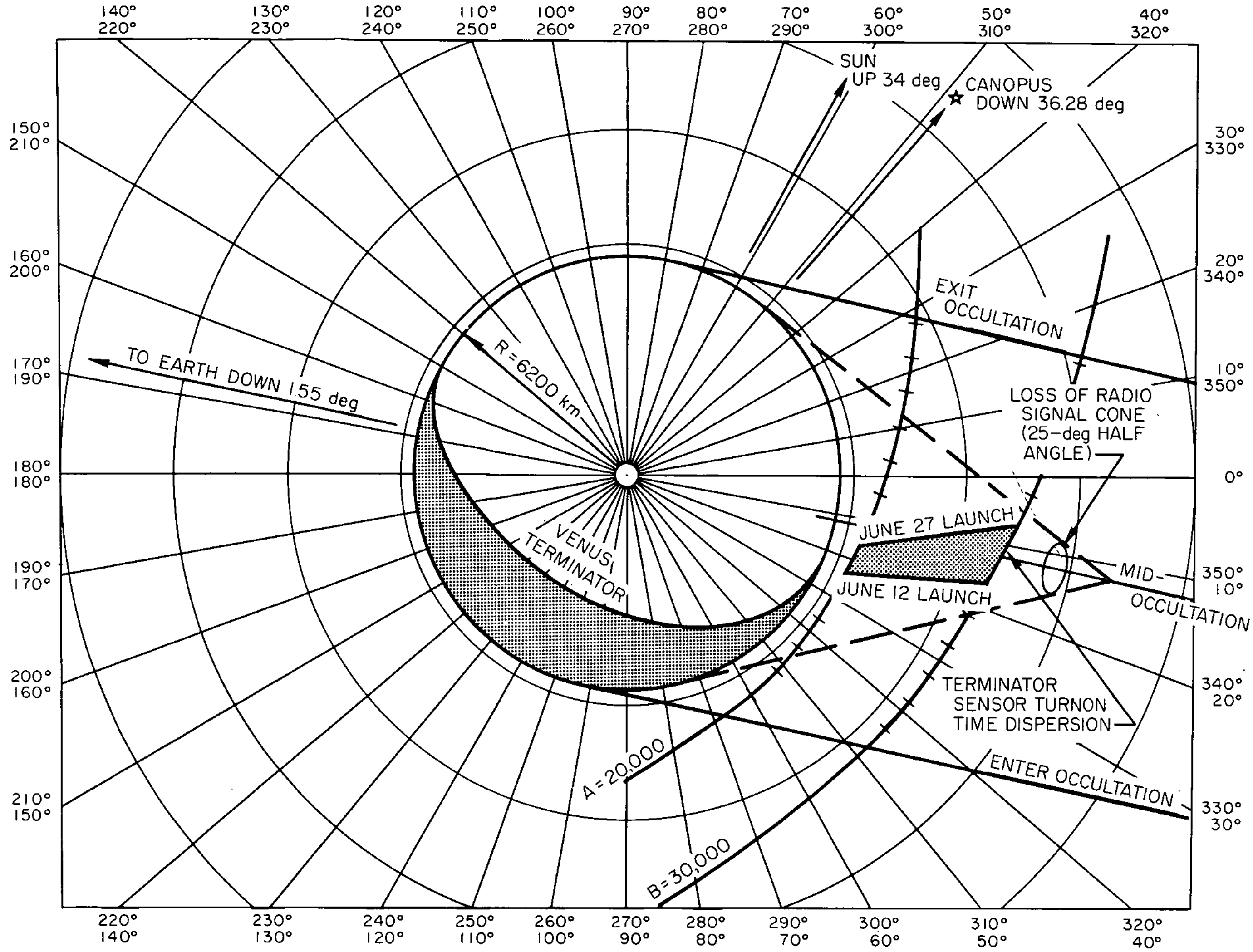


Fig. 10. Terminator sensor, approximate encounter geometry

plus position-error signals to the switching amplifiers for the remainder of the maneuver.

The pitch turn begins with the M4 event which occurs simultaneously with M2. The turn is accomplished by switching a constant current from the command current regulator into the gyro torquer. The CC&S Polarity Relay M3 selects the proper polarity current. A positive current causes a negative spacecraft turn, and a negative current causes a positive spacecraft turn. When the current is first applied to the torquer, the gyro senses the error signal and applies it to the switching amplifier. The gas jets fire until the resulting spacecraft rate nulls the torquer signal. The spacecraft then continues to turn at this constant rate as long as the current is applied. After a period of time specified by the stored pitch command, the CC&S switches off this current. Since the torquer signal, due to the command current, is no longer present to null the sensed rate, the gas jets operate to reduce the pitch rate and position errors to small limit cycle excursions about the new pitch position.

The roll turn is initiated by CC&S Event M5 and is performed in a similar manner to the pitch turn. Command current, whose polarity is controlled by the CC&S Polarity Relay M3, is input to the roll torquer. The new pitch and roll positions are maintained for the remainder of the maneuver.

During the motor burn, which begins with CC&S Event M6, the gyro signals act through the autopilot amplifiers to continuously adjust the jet vane angles. This angle adjustment controls the torques generated by the motor thrust so that spacecraft attitude is maintained during burn; see Section II-B-2-f. Although the gyro signals are input to the autopilot during the turns, the autopilot has no effect on the spacecraft attitude until the midcourse motor ignites.

The maneuver sequence is terminated when the CC&S M1 and M2 relays are reset. The gyros will remain on, however, since the Canopus sensor is off. When M2 is reset, sun sensor power is applied again and normal sun acquisition begins. When sun acquisition is complete, Canopus acquisition begins. The gyros turn off 200 s after the Canopus sensor acquires a body.

c. Capacitor cycling. Before the capacitors are connected into the gyro loop, they are in an unenergized portion of the gyro circuitry for an extended period of time. In this configuration, they tend to lose dielectric strength which degrades their performance when connected into the gyro loop. In order to correct this difficulty, the capacitors are temporarily connected in series between +35 Vdc and −35 Vdc and then reconnected in the parallel configuration. This cycling process results in a *reforming* of the capacitors and occurs immediately after gyro turnon for approximately 12 s. If DC-V18 were used to turn on the gyros, the cycling would not occur. The cycling circuitry is switched out of the loop by CC&S M2 so that a failure in its circuitry will not affect the maneuver.

d. Roll one shots. The roll one shots are emergency circuits controlled by Commands DC-V18 and DC-V21. If the Canopus sensor fails, the roll position may be controlled by switching the capacitor into the roll gyro feedback loop by using DC-V18. Vernier control may be obtained by using the roll one shots. The +2¼-deg one shots, triggered by DC-V18, will switch a negative command current into the roll gyro torquer for a time equivalent to a +2¼-deg roll turn. The −2¼-deg one shot, triggered by DC-V21, will switch a positive command current into the roll gyro torquer for a time equivalent to a −2¼-deg roll turn. The spacecraft will not perform the −2¼-deg roll turn unless the capacitor had previously been switched into the gyro loop by DC-V18; see Section IV.

e. Earth sensor. Since a Canopus sensor failure prior to a midcourse maneuver would probably preclude the maneuver, an earth sensor is used to provide a roll-reference backup. If the Canopus sensor fails, the spacecraft could be put into a roll inertial mode using DC-V18. Successive DC-V18s or DC-V21s, as described in the previous subsection, could then be used to step the spacecraft around until the earth appears in the sensor field-of-view. This would be indicated by the earth sensor light intensity output to telemetry. Since roll orientation is now known, a midcourse maneuver could then be performed. Any maneuver performed in this manner will have degraded accuracy.

The earth sensor consists of a cadmium sulfide photoconductor with appropriate optics and electronics. Excitation power is provided the +26-Vdc unswitched AC power. The +26 V is applied across the photocell and a fixed resistor. The voltage across the fixed resistor changes in relation to the light received by the photocell. This voltage, indicating light flux, is telemetered continuously.

Although primarily intended as a backup to the Canopus sensor for midcourse maneuvers, the earth sensor may be used to aid in Canopus identification. Since the sensor is on during roll, spin, and search, it will indicate to telemetry when the earth is in its field-of-view. Knowing the geometrical relationship between the earth and the stars and the time the earth appeared in the sensor field-of-view, the star the Canopus sensor acquires can be identified. When Canopus is acquired, the earth does not appear in the sensor field-of-view.

f. Autopilot. The midcourse autopilot is used to control the attitude of the spacecraft during midcourse motor burn. This control is accomplished by continuous adjustment of the angular positions of four jet vanes mounted at the downstream end of the midcourse motor nozzle. Since the motor is not mounted along any of the spacecraft body axes, the motion of each jet vane is controlled by a mixture of the signals of the three gyros. Figure 11 shows the orientation of the spacecraft motor and the jet vanes.

Each jet vane has its own separate control system, consisting of an autopilot amplifier, a jet-vane actuator and a feedback loop. Power to the autopilot is provided by the maneuver 2.4-kHz inverter and is switched on by the CC&S M2 event. The three gyro signals and the feedback signal are summed in different ratios at the input to each amplifier. The jet vanes are then adjusted so that the motor thrust vector passes through the spacecraft center of gravity and thus nulls the gyro-error signals.

*3. **Attitude control telemetry.*** Table 4 lists the AC subsystem telemetry measurements.

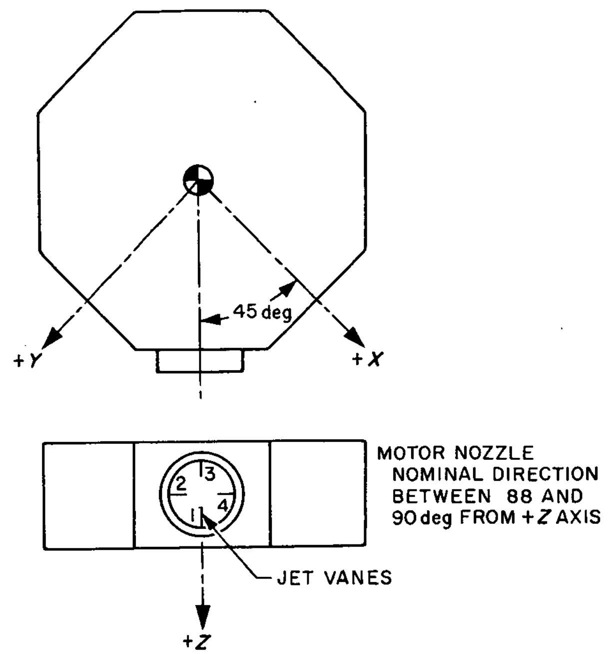


Fig. 11. Midcourse motor and jet vanes

C. Central Computer and Sequencer Subsystem

The CC&S subsystem:

(1) Provides frequency references for use in various spacecraft subsystems.

(2) Issues commands to other spacecraft subsystems during the launch, midcourse, cruise, and encounter modes.

(3) Receives commands, in flight, from the command subsystem and stores them for use during the midcourse maneuver.

(4) Controls the execution of the stored commands during the maneuver.

The outputs from the CC&S to accomplish these functions are either relay-contact closures or transformer-isolated transistor switches.

How the CC&S accomplishes the above functions may best be described by describing the functions of the various CC&S subassemblies.

1. Central clock 5A1. The central clock provides the frequency references used in the spacecraft. Basically, it consists of a 307.2-kHz crystal oscillator followed by a series of flip-flops which divide the frequency down to frequencies used in the CC&S and in other subsystems.

Table 4. AC subsystem telemetry

Channel	Measurement
103	Pitch gyro output to switching amplifier when gyros are on; pitch cruise sun sensor output to switching amplifier when gyros are off
104	Yaw gyro output to switching amplifier when gyros are on; yaw cruise sun sensor output to switching amplifier when gyros are off
107	Roll gyro output to switching amplifier
108	Canopus sensor light intensity
112	Pitch position: cruise and acquisition sun sensor output to switching amplifier
113	Yaw position: cruise and acquisition sun sensor output to switching amplifier
114	Roll position: Canopus sensor roll-error signal or roll-search signal to the switching amplifier
115	Event Counter 1: gyros on event
116	Event Counter 4: sun acquire event
118	Earth sensor light intensity
208	$+X/-Y$ N_2 gas bottle pressure
209	$-X/+Y$ N_2 gas bottle pressure
218	$+X/-Y$ N_2 gas bottle temperature
219	$-X/+Y$ N_2 gas bottle temperature
303	Canopus sensor cone angle
306	Terminator sensor excitation voltage
406	+X roll and yaw gas jet assembly temperature
410	Canopus sensor temperature
425	−Y pitch gas jet assembly temperature
426	Bay 7 temperature
430	Primary sun sensor temperature
433	−X roll and yaw gas jet assembly temperature

A 38.4-kHz square wave is sent by an isolated transistor switch to the power synchronizer as a frequency reference for the power subsystem. *Sense* and *prime* signals, 25 pulses/s, are supplied to the launch and maneuver magnetic counters and are used to read information out of the counters into the associated diode matrices. Another 25-pulses/s signal is sent to the end counter and is used to synchronize update pulses into the master timer.

The 25-pulses/s *count* signals are further divided down in the central clock by magnetic counters. A 20-pulses/s signal is sent to the maneuver duration subassembly and is used as the timing signal for the velocity shift register. This signal is not a true 20-pulses/s pulse train since it is formed by dropping every fifth pulse of a 25-pulses/s signal; see Section II-C-9. A 1-pulse/s signal is also sent to the maneuver duration subassembly as a timing signal for the pitch and roll shift registers. Finally, the 1-pulse/s *count* signals are sent to the launch counter subassembly and are used as the basis for the counting of the remainder of the CC&S.

Following the division down to 400 pulses/s, there is a gate which can be used to prevent this frequency from entering the remaining stages of the central clock. This gate is closed by sending an override signal from OSE. The override is interlocked with a 10-kHz square wave which is used to drive the remaining stages of the CC&S at a rate 25 times the normal rate. The override option is used for speeding the CC&S up during ground testing and cannot be applied during flight.

2. *Launch counter 5A2.* The launch counter subassembly commands various events to occur during the launch phase of the flight. The 1-pulse/s signals from the central clock are divided down to 1-pulse/min signals and are used by the launch and maneuver counters. The counting signals can be inhibited at the 1-pulse/s point by an inhibit signal from the OSE. A clear signal which, when sent from the OSE, resets all the magnetic counters to their initial state also enters at this point and passes through the launch, maneuver and end counters.

When the clear signal is sent, an output relay in the launch counter turns on a light in the blockhouse. At 3 min before launch, the inhibit signal is removed and the counter begins to count. If the launch counter was cleared and is counting correctly, a signal from the counter through the launch diode matrix will reset the clear relay causing the blockhouse light to go off at 1 min before launch. The launch would be held if the light fails to go off, indicating the counter is not counting or if it goes off too early, indicating the counter was not clear.

The launch diode matrix has two additional outputs:

(1) At release-inhibit + 56 min (53 min from launch) a pulse from the matrix triggers a relay driver causing the L1 event relay to set. This relay setting permits the squibs releasing the solar panels to fire.

(2) At release-inhibit + 60 min (57 min from launch) a pulse from the matrix triggers a relay driver causing the L2 event relay to set. This relay setting will cause the AC dc power to come on.

Overflow of the launch counter at release-inhibit + 1000 min (997 min from launch) will trigger the relay driver causing the L3 event relay to set. This starts Canopus acquisition by turning on the Canopus sensor and switching the search signal into the roll-switching amplifier. It also inhibits the roll-spin signal (see AC). This relay also clamps the L1 and L2 relay drivers. The clamp prevents the relay driver from triggering since additional signals will appear at the outputs of the diode matrix periodically. Although triggering these relay drivers has no effect after the relays are set, the drivers are clamped to reduce power consumption.

Another relay present in this subassembly verifies the receipt of encounter update or master timer speedup pulses. The relay driver is triggered by a signal from the first stage driver in the end counter subassembly. The output of the relay sends an indication to the CC&S OSE via the umbilical to verify that each update or speedup pulse has been received.

All relay drivers in this subassembly except those of the *clear* and *verify* relays are clamped by the launch clamp; see Section II-C-5.

In addition to the above outputs, the launch counter also sends a pulse to the end counter every 3⅓ h. This pulse is used as the count signal for the master timer.

3. *End counter 5A3.* The end counter subassembly causes various events to occur during the cruise and encounter phases of the flight. It receives a pulse from the launch counter at 3⅓-h intervals and uses it to drive the master timer magnetic counter. The outputs of this counter are gated together in a diode matrix and trigger various relay drivers.

Since the time of flight between the earth and planetary encounter varies with launch date, the time for the start of the encounter experiments and the other master timer events relative to launch must be variable. Before launch an estimate of the flight time from release of the CC&S inhibit to encounter is made. The master timer, whose capacity is greater than the longest flight-time expected, must then be preset so that the events which it controls occur at the proper time during the flight. The initial conditions are such that, at 1 count every 3⅓ h, the 1005th count will occur 2⅔ h before encounter, so that all events controlled by the master timer may be referenced to encounter.

Encounter update pulses sent from the CC&S OSE to the pulse synchronizer at 10 pulses/s supply the initial conditions. Each of these pulses is verified by a signal from the first-stage driver to the *verify* relay in the launch clock. The update pulses must be sent after the clear signal has been sent since the clear signal resets all the magnetic counters to their initial state. This input line is also used during tests to speed up the master timer. A 1-pulse/s master timer speedup signal is sent from the OSE during this mode.

There are eight outputs from the master timer diode matrix to relay drivers and associated relays.

Events MT-1, -2, -3 and -4, the Canopus cone-angle updates, occur at E (Encounter) − 56.4 days (1352⅔ h), E − 39.7 days (952⅔ h), E − 23 days (552⅔ h), and E − 9.1 days (219⅓ h) respectively. The relay drivers and relays for these events are located in the transformer rectifier subassembly.

Event MT-5 occurs at E − 18 days (432⅔ h). The relay driver sets a relay causing the radio transmitter to switch to the high-gain antenna and the receiver to the low-gain antenna.

Event MT-6 occurs at E − 86.9 days (2086 h). The relay driver sets a relay causing the data encoder (DE) to switch the data rate to 8.3 bits/s.

Event MT-7 occurs at E − 12⅔ h. The relay driver sets two relays: one provides the return path for power to the pyro subsystem to turn on excitation power to the terminator sensor; the other provides the signal to the power subsystem to turn on science (if it is off), tape recorder electronics, and to turn off the battery charger.

Event MT-8 occurs at E − 6 h. The relay driver sets a relay giving a signal to the DAS which uses it to turn on the planet sensor and to switch to Data Mode 3.

Event MT-9 occurs at E + 14 h. The relay driver sets a relay causing the DE to switch to Mode 4 and begin tape playback.

In addition to the above, the master timer generates a pulse at 66⅔-h intervals. This pulse triggers a relay driver which pulses a relay. This signal is used in the radio subsystem for failure mode switching of power supplies and exciters.

All the relay drivers in this subassembly are clamped off during launch by the launch clamp.

In addition to the relay outputs, there is also an electronic switch which sends a signal to the DE Event Counter 2 whenever a relay changes state or whenever the parity check signal from the input decoder subassembly appears; see Section II-C-8.

4. Transformer rectifier 5A8. The transformer rectifier subassembly conditions and provides all the CC&S operating power. It receives the 2.4-kHz power from the main power inverter and converts it to dc voltages for use in the remainder of the CC&S.

A +16 Vdc output is used in the CC&S flip-flop, logic gate, one shot, electronic switch and power switch circuits.

A +28 Vdc output is used in the magnetic counter, relay driver, relay, pulse former and other logic gate circuits.

A +65 Vdc output is used as power for the magnetic shift registers in the maneuver duration subassembly.

In addition to supplying CC&S power, this subassembly contains the output relay drivers and relays for the MT-1, -2, -3 and -4 events. These signals are sent from the master timer diode matrix and are used to change the Canopus sensor cone angle in the AC subsystem; see Section II-C-3. These relay drivers are clamped by the launch clamp.

A relay to isolate the relay hold is also in this subassembly. This relay is held in the set position by a hold current from the relay hold transformer rectifier subassembly through the *Agena* separation connector. While in the set position, current passes through the contacts of this relay to bias to reset the set coils of all the other CC&S relays except the *clear* and *verify* relays. This current prevents the relays from changing state due to accidental driver firings, vibrations, or shock during the launch-to-separation phase of flight. The current ceases when the separation connector opens.

5. Relay hold transformer rectifier 5A9. This subassembly supplies the current to hold all relays reset (see above) and provides the launch clamp to clamp off the relay drivers during launch-to-*Agena* separation.

The power for the relay hold current is obtained from the 2.4-kHz maneuver inverter or the CC&S OSE to position relays prior to spacecraft turnon. The current is routed through the *Agena* separation connector to the hold relay in the transformer rectifier subassembly; see Section II-C-4.

Also in this subassembly is a relay to clamp all relay drivers reset (the launch-clamp function) during launch to separation. This relay is held in the set position by the relay hold current. In this position the clamp is on and the relay drivers cannot be triggered. When the relay hold is removed, the launch clamp is released after approximately a ¼-s delay.

6. Maneuver clock 5A4. The maneuver clock subassembly commands various events to occur during the midcourse maneuver phase of the flight. The magnetic counter is activated when DC-V27 is received. This command sets the midcourse relay so that power is applied to the counter, the midcourse clamp is removed, and the MC + 0 command is sent to the address register and maneuver duration subassembly.

The counter is driven by the 1-pulse/min signal from the launch clock. Counter outputs are gated together in a diode matrix to provide signals at various times in the midcourse sequence. There is a 1-min resolution on the times of these outputs depending on when DC-V27 was received. These outputs trigger pulse filters and formers which send out a single pulse. The devices act like flip-flops in that they put out just one pulse when first triggered and must be reset before another pulse may be put out. Thus, they may have only one output during each maneuver sequence.

The outputs of these devices occur at midcourse plus 60, 82, 104 and 110 min. These signals along with MC + 0 are sent to the address register and maneuver duration output subassembly; see Section II-C-7-a.

Outputs MC + 60, 82, and 104 min are all gated together so that each will trigger the relay driver which sets the maneuver timing relay. These signals correspond to start midcourse pitch, roll, and motor burn, respectively. The relay is reset by a relay driver which is triggered at MC + 110 min or the roll, pitch, or velocity (RPV) overflow. The RPV overflow signal occurs when either the pitch, roll, or velocity shift registers in the maneuver duration subassembly overflow. This event represents the end of the turn or motor burn. Thus, the maneuver timing relay is set at the start of a midcourse event (turn or motor burn) and is reset at the end of the event. The output of the relay is used by the DE for the timing of midcourse events on telemetry (TM) channel 220.

When the counter overflows at MC + 199 min, the midcourse relay is reset, thus removing the power to the counter and stopping it in its reset state. The midcourse clamp is also reapplied at this time.

7. Address register and maneuver duration output 5A6. This subassembly contains the relays which control the midcourse maneuver. It also contains the logic flip-flops and gates which control the address of the maneuver command information when it is being read into the shift registers. The polarity information for the pitch and roll turns is stored in this subassembly.

a. Maneuver duration output. The MC + 0 signal from the maneuver clock triggers a relay driver which sets the M1 event relay. This relay turns on the gyros and provides a signal to switch the DE to Data Mode 1 from the AC subsystem.

The MC + 60 signal from the maneuver clock triggers a relay driver which sets the M2 event relay. This relay turns off the Canopus sensor, turns off the sun sensors, turns on the autopilot power, and puts all spacecraft axes under inertial control by switching the capacitors into all the gyro loops. The relay driver also sets the M4 event relay which switches the command current into the pitch gyro torquer and clamps off the motor burn relay driver.

The MC + 60 relay driver also sends a signal to the maneuver duration subassembly to turn on the pitch shift register. The turnon of the register signals the pitch polarity flip-flop. If this is in the proper state, it will set the Polarity Relay M3; see Section II-C-7-b.

When the pitch shift register overflows, a signal from the maneuver duration subassembly triggers a relay driver which resets the M3 and M4 relays, thus stopping the pitch turn.

The MC + 82 signal from the maneuver clock triggers a relay driver which sets the M5 event relay which switches the command current into the roll gyro torquer. The relay also clamps off the motor burn relay driver.

This relay driver also sends a signal to the roll shift register. This acts in the same way as the pitch signal above. The M3 relay will be set if the roll polarity flip-flop is in the correct state; see Section II-C-7-b.

Relays M4 and M5 are interlocked so that the command current may only enter one gyro torquer at a time. In addition, when M5 sets, it clamps the relay driver of the M4 relay.

When the roll shift register overflows, a signal from the maneuver duration subassembly triggers the relay driver which resets the M3 and M5 relays, thus stopping the roll turn.

The MC + 104 signal from the maneuver clock triggers a relay driver which pulses the M6 relay causing the motor to ignite. The relay driver also sends a signal to the maneuver duration subassembly which enables a gate allowing the 20-pulses/s counting pulses to enter the velocity shift register.

When the velocity shift register overflows, a signal from the maneuver duration subassembly triggers a relay driver which pulses the M7 relay causing the motor to shut off.

The MC + 110 signal from the maneuver clock triggers the relay driver which resets Relays M3, M4 and M5 if they have not been previously reset by the maneuver duration overflows. This signal also triggers the relay driver which resets Relays M1 and M2. Sun reacquisition begins when this event occurs.

b. Address register. The address portion of this subassembly consists of two flip-flops set up in a shift register configuration. These flip-flops are triggered on the first five bits of the command information by trigger pulses from the input decoder. Since there are only two flip-flops, only Bits 4 and 5 are stored and the first three bits are not used. The outputs of the flip-flops are gated to provide signals to turn on the maneuver duration pitch, roll, and velocity shift registers when information is being read in. These gates are inhibited until the sixth bit and are inhibited again after the seventeenth bit.

The pitch and roll polarity flip-flops are enabled on the eighteenth command bit. A "1" in Bit 18 will set the flip-flop. The information is stored until a turn starts. At that time the turning on of the maneuver duration pitch or roll shift register will reset the corresponding polarity flip-flop if it had been set previously. This will send a pulse to trigger the polarity relay (M3) relay driver. If the polarity bit (Bit 18) is a 0, the flip-flop will not have changed state and the polarity relay will stay reset. This relay when set corresponds to a positive spacecraft turn; when reset, to a negative turn.

*8. **Input decoder 5A7.*** The input decoder receives maneuver commands from the command subsystem and routes them to the shift registers in the maneuver duration subassembly. It addresses the proper register and sets the polarity by sending information and trigger pulses to the address register and maneuver duration output subassembly.

There are three inputs from the command subsystem to the input decoder. The command *alert* is sent to reset the eight input decoder flip-flops to their initial state before a command is read in. The command *sync* appears at each bit of the 18-bit command *info*.

The first five flip-flops act as a bit counter and provide signals to various logic gates to read the address into the address flip-flops, to read the information into the shift registers, or to read the polarity bit into the polarity flip-flops. The first three flip-flops have six stable configurations which are cycled through three times for the 18-bit command word. The other two have three stable configurations which are cycled each time the first three flip-flops reach their fifth state. Thus, there are 18 total stable configurations for this counter.

The counter controls two gate flip-flops which gate various output signals which are routed to other subassemblies. An output is gated with the trailing edge of the *sync* pulse to provide ϕ *B* trigger pulses to the address flip-flops on the first through fifth *info* bits. Other outputs are gated to provide the *sync MC* signal to read information into the maneuver duration shift registers on the 6 through 17 *info* bits. The information signal is gated to provide the *info MC* signal to the shift registers on Bits 6 through 17. The *polarity set* signal is an output which is used as a trigger pulse on Bit 18 for the polarity flip-flops. This signal is also used to inhibit the output gates of the address flip-flops on Bits 1 through 5 and on Bit 18.

The eighth flip-flop in the input decoder is used for the parity check. Bit 6 of the information is adjusted before the command is sent to the spacecraft so that there are an odd number of "1" bits. This flip-flop changes state every time a "1" is read in. Thus, it will change state an odd number of times and be in the set state at the end of the word if an odd number of "1" bits were in the command. The *polarity set* signal is gated with the output of this flip-flop. This gate is enabled after Bit 18 and, if the flip-flop is set, a signal will be sent to the electronic switch in the end counter which sends a signal to the DE Counter 2. Thus, the parity of each stored command is checked as it is read in. If the DE signal does not occur, then a "1" bit has been dropped or added somewhere and that command must be read in again.

Table 5 gives the function of each of the 18 bits in the quantitative command. Note that although the address is five bits long, only Bits 4 and 5 are used by the CC&S.

Table 5. Bit functions

Bits	Function
1–5	Address: PITCH — 01110 ROLL — 00001 VELOCITY — 01011
6	Parity: Adjusted prior to sending command so that there are an odd number of "1" bits in the command word
7–17	Command information stored in shift registers
18	Polarity: "1" positive turn "0" negative turn

9. ***Maneuver duration 5A5.*** This subassembly stores the commands used during the maneuver phases of the flight. It uses these commands to control the duration of the maneuver turns and the magnitude of the velocity increment.

The primary elements in the maneuver duration subassembly are the three 11-bit magnetic shift registers. These store the pitch, roll, and velocity information for the midcourse maneuver and, at the proper time, issue commands to output relays.

Power to each register is turned on by separate power switches controlled by logic gates. The power switch for the pitch register may be turned on by either a pitch address signal from the address registers or by a flip-flop. The flip-flop will turn on the power switch on a signal from a relay driver in the maneuver duration output at MC + 60 and will turn the power switch off on the pitch-roll overflow signal. The flip-flop is clamped by the midcourse clamp.

The power switch for the roll register may be turned on by either a roll address signal from the address register or by a flip-flop. The flip-flop will turn on the power switch on a signal at MC + 82 from a maneuver duration output relay driver and will turn off the power switch when it is reset by the pitch-roll overflow signal. The flip-flop is clamped by the midcourse clamp.

The power switch for the velocity register may be turned on by either a velocity address from the address register or by a flip-flop. This flip-flop turns on the velocity register power switch when the roll flip-flop turns off the roll register power switch. The flip-flop will turn off the power switch when it is reset by the velocity overflow signal. The flip-flop is clamped by the midcourse clamp.

There are two modes of operation for the registers. The first is the reading-in of information into one of the registers from the input decoder. In this case the power switch for the particular register is controlled by the signal from the address register. Sync pulses to shift the information into the register are also provided from the input decoder. The sync pulses, *sync MC*, are gated so that the midcourse clamp and any one of the power switches must be on in order for the sync pulses to shift the information in. Thus, meaningful information cannot be inserted after the midcourse sequence has begun.

Each register consists of 11 stages with two cores per stage. The shift pulses are then split into two phases. The α phase takes the information from each main core of the register and shifts it over to a temporary core. It also takes new information being read in from the input decoder through the information driver and shifts it to a temporary core in front of the first main core. The β phase then shifts the information from each of the temporary cores over to each of the next main cores.

Info MC and *sync MC* pulses are synchronized in the input decoder and are received at a rate of 1 pulse/s. When more than 11 bits are entered into the register, the first bits are "pushed out" the other end and are not used. Thus, although Bits 6–17 are read into the registers, only Bits 7–17 are stored. The information in the cores consists of them being either demagnetized or magnetized. This corresponds to a two-level state, either "0" or "1" respectively.

The other mode of operation of the registers is that of maneuver control from the previously read-in information. The power switches for the registers are then controlled by the flip-flops. The *info MC* and *sync MC* pulses from the input decoder are not present. If they were present, the *sync MC* pulses would be gated out since the midcourse clamp is not present. The *info MC* pulses are not gated out, however, and could be read into the register at this time.

The shifting of the information in the registers during the maneuver is controlled by either the 1-pulse/s or 20-pulses/s pulses from the central clock. The 1-pulse/s signal is allowed to shift the register when either the pitch or roll flip-flop has turned on its associated power switch. The 20-pulses/s signal is allowed to shift the register when another flip-flop is set by the velocity start signal. This signal comes from a relay driver in the maneuver duration output when it is triggered by the MC + 104 signal; see Section II-C-7. This flip-flop is reset when the midcourse clamp signal goes back on.

When the shift registers are counting during the maneuver, a logic gate feeds back the *exclusive or* signals from Bits 9 and 11 to the first bit (core). That is, when either Bit 9 or 11, but not both, is in the "1" state, a "1" is fed back to Bit 1. This feedback bit is put into the register by the same information driver used when the maneuver information is being read in. This feedback loop is not in operation when information is being read in since a logic gate opens the loop if none of the flip-flops controlling the register power switches are on. With this feedback configuration the registers then have the maximum sequence of 2047 shifts.

It should be noted that the coded word read into the register is not a binary number representing time. It is a two-level code indicating one of a possible 2047 states of the register. The shifting of the register does not represent a binary count but just the changing of states of the register in a predetermined sequence. Thus, for the turns, the state that is the correct number of pulses (at 1 s/pulse) from the final state is read into the register. For the velocity, the state that is the correct number of pulses (at 1 s/20 pulses) from the final state is read into the velocity register.

The final state of the registers is that all bits are "1." When this occurs, a signal from an *and* gate sensing the state of all 11 bits of the register sends out an overflow signal. There are two of these gates, one for the two turns and one for the velocity increment. The roll and pitch overflow signal resets the flip-flops controlling the roll and pitch register power switches. The velocity overflow signal resets the flip-flop controlling the velocity register power switch.

The roll and pitch overflow signal is *or* gated with the velocity overflow signal to provide a signal when any register overflows. This signal, RPV overflow, is sent to the maneuver clock to reset the maneuver timing relay; see Section II-C-6. The two other overflow signals are sent to the maneuver duration output to stop the turn or to shut off the motor.

The phasing of the 20-pulses/s signals is shown in Fig. 12. Note that the 20 pulses/s is actually 25 pulses/s with every fifth pulse removed.

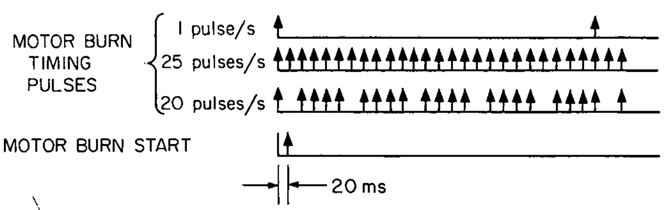


Fig. 12. Phasing of motor burn timing signal

10. CC&S telemetry. Table 6 lists CC&S telemetry measurements.

Table 6. CC&S telemetry

Channel	Measurement
115	Event Counter 2: CC&S output event or parity check
220	CC&S timing of maneuver events
309	CC&S 28-V monitor
426	Bay 7 temperature

III. Time Sequence of Guidance and Control Events

The sequential operation of the guidance and control subsystems is described in this section. The operation of other subsystems which interact with the guidance and control system is also included. These events are listed in Table 7. The first columns list the number and type of events that occur at a particular time. The next column lists the time of the events. Some of these events will vary with launch azimuth, date of launch, or direct commands, but a nominal time is listed. The fourth column lists the subsystems involved in the events. The fifth and sixth columns describe how various guidance and control telemetry channels are affected by the events. The final column discusses in more detail what is happening in the particular guidance and control subsystems.

Table 7. G&C time sequence

Event No.	Event	Time	Subsystems	Telemetry		Discussion
				Channel	Measurement	
1	Verify update pulses	T−15 min	CC&S-OSE to CC&S			Number of encounter update pulses to be input at T−7 min is verified at this time
2	Switch to internal power	T−7 min	Power-OSE to Power	109 206 226	Primary system voltage Battery voltage Battery current drain	Motor-driven switch switches spacecraft from OSE to battery power
3	Clear CC&S	T−7 min	CC&S-OSE to CC&S			Reset magnetic counters in CC&S; lights clear light in blockhouse
4	Insert encounter update pulses	T−7 min	CC&S-OSE to CC&S			Insert initial conditions into encounter magnetic counter based on estimated time of closest approach to Venus; each pulse is verified in blockhouse
5	Release OSE relay hold	T−5 min	CC&S-OSE to CC&S			Relay hold function of the OSE is released at this time
6	Release CC&S inhibit	T−3 min	CC&S-OSE to CC&S			CC&S launch counter and end counter begin counting
7	Clear relay release	T−1 min	CC&S	115	DE Counter 2	Clear light turned off in blockhouse; this event should occur 2 min after the release of the CC&S inhibit (Event 6)
8	Launch	T	OSE connections			Separation of umbilical
9	Injection	I (T+19.1 to 35.2 min)	*Agena*			
10	Spacecraft–*Agena* separation	S (I+2.6 min)	*Agena* and spacecraft			
a	RF power up and science on		Separation connector to Power	204 227	PS&L current to communications converter 2.4-kHz output current	Relay in power resets, causing RF power to be increased and science power to be turned on
b	Release CC&S relay hold current and launch clamp		Separation connector to CC&S			Current holding CC&S relays and clamp holding relay drivers off are removed
c	Arm pyrotechnic subsystem (Pyro)		Pyro arming switch to Pyro			

Table 7 (contd)

Event No.	Event	Time	Subsystems	Telemetry		Discussion
				Channel	Measurement	
10d	Turn on AC dc power		Pyro arming switch to AC	103 104 107 112 113 114	Pitch gyro Yaw gyro Roll gyro Pitch position Yaw position Roll position	Sun acquisition begins; sun sensors activated; switching amplifiers activated; gyro signals act to eliminate pitch and yaw rotation rates; roll rate controlled by *spin* signal to calibrate magnetometer; pitch and yaw position errors are not nulled out until solar panels open and all sun sensors are exposed
e	Separation initiated timer activated					
11	Arm Pyro	S+30±20 s	Separation-initiated timer to Pyro	116	DE Counter 3	This function wired in parallel with Pyro arming switch for redundancy
12	Deploy solar panels	S+190±80 s	Separation-initiated timer to Pyro	115 116	DE Counters 1 and 2 DE Counters 3 and 4	Sun acquisition continues when sun sensors are all exposed; pitch and yaw rate and position-error signals nulled
13	Deploy solar panels	T+53 min	CC&S-L1 to Pyro		See Event 12 in this table	Wired in series with separation-initiated timer for redundancy
14	Turn on AC dc power	T+57 min	CC&S-L2 to AC		See Event 10d in this table	Wired in series with Pyro arming switch for redundancy; backup: DC-V13
15	Sun acquisition complete	Event 12 or 14 + 0 to 20 min	AC	103 104 112 113 109 222 223 224 225 116	Pitch gyro Yaw gyro Pitch position Yaw position System voltage +X panel current −X panel current +Y panel current −Y panel current DE Counter 4	Acquisition sun sensors are turned off. Pitch and yaw rate and position error are nulled out; the solar panels begin to supply power to operate the spacecraft
16	Begin roll acquisition	T+997 min	CC&S-L3 to AC	107 108 114 118	Roll gyro Canopus sensor light intensity Roll position Earth sensor light intensity	*Search* signal replaces *spin* as position-error input to roll-switching amplifier; *spin* signal is also inhibited permanently; Canopus sensor is turned on and roll search begins; earth sensor is checked to see if earth goes through field-of-view during search; star map is made; backup: DC-V13
17	Canopus acquisition complete	Event 16 + 0 to 60 min	AC and Power	103 104 107 108 114 221	Pitch position Yaw position Roll gyro Canpus sensor light intensity Roll position Maneuver B/R output current	When body is acquired, *search* signal is replaced by the roll-error signal; gyros are switched off 200 s later; when gyros go off, TM Channels 103 and 104 change measurements and power is taken off the RF power-up and science-on relay so that it will reset at this time and issue these commands if it had not done so; the Canopus sensor light intensity is checked to see if an acceptable object has been acquired; if not, a DC-V21 roll override is transmitted and the roll search continues until another body is acquired; this process is completed when an acceptable body has been acquired, hopefully, Canopus

Table 7 (contd)

Event No.	Event	Time	Subsystems	Telemetry		Discussion
				Channel	Measurement	
18	CC&S cyclic	Event 6 + 3⅓ to 66⅔ h, then every 66⅔ h	CC&S to Radio	115	DE Counter 2	The CC&S issues cyclic pulses to radio every 66⅔ h; the pulses occur every 20th count of the end counter; thus, the time of the first pulse depends on the initial conditions of the end counter at the time the CC&S starts counting
19	Transmit midcourse maneuver commands: QC-V1-1 pitch turn duration and polarity QC-V1-2 roll turn duration and polarity QC-V1-3 motor burn duration	M−30 min (T+2 to 10 days)	From ground to Radio, Command, and CC&S	 115 115 115	 DE Counter 2 DE Counter 2 DE Counter 2	These commands are stored in the CC&S magnetic shift registers until the start midcourse (M) command is given; the CC&S Bit 6 (Command Bit 14) is adjusted before the command is transmitted so that the CC&S word has an odd number of "1"s; this parity check provides the signal for DE Counter 2; if this check does not occur, the command must be retransmitted
20	Arm first propulsion maneuver; DC-V29	M−10 min	From ground to Radio, Command, and Pyro			Sent to ensure that the first motor burn Pyro squibs will be used in the maneuver
21	Remove propulsion inhibit; DC-V14	M−5 min	From ground to Radio, Command, Pyro, and AC			Sent to ensure that the Pyro and AC subsystems are not in the maneuver inhibit mode
22	Initiate midcourse maneuver sequence; DC-V27	M	From ground to Radio, Command, and CC&S	103 104 107 115 221	Pitch gyro Yaw gyro Roll gyro DE Counter 2 Maneuver B/R output current —All engineering	CC&S Event M1 turns on the gyros and causes AC to command DE to Data Mode 1; AC capacitors are cycled at this time; maneuver B/R and 2.4-kHz inverter are turned on; TM channels 103 and 104 change measurements
23	Start pitch turn	M+59 to 60 min	CC&S M2 to AC CC&S M3 or $\overline{M3}$ to AC CC&S M4 to AC	103 109 115 222 223 224 225 226	Pitch gyro Primary system voltage DE Counter 2 +X panel current −X panel current +Y panel current −Y panel current Battery drain current	CC&S Event M2 turns off sun sensor power, turns on autopilot power, connects capacitors into gyro feedback loops and turns off the Canopus sensor; the polarity from the command current generator is determined by M3 or $\overline{M3}$ and the current is switched into the pitch gyro torquer by M4; the pitch magnetic shift register is turned on and 1-pulse/s pulses begin to count into the register; as the spacecraft turns from the sun the output of the solar panels decreases and power is drawn from the battery
24	Stop pitch turn	Event 23 + 1 to 1319 s	CC&S $\overline{M3}$ to AC CC&S $\overline{M4}$ to AC	103 115 220	Pitch gyro DE Counter 2 CC&S timing of events	The pitch register overflows, turns off, and resets M3 and M4; the pitch rate settles back to the limit cycle and the position is held within a limit cycle at the new value resulting from the maneuver

Table 7 (contd)

Event No.	Event	Time	Subsystems	Telemetry		Discussion
				Channel	Measurement	
25	Start roll turn	M+81 to 82 min	CC&S M3 or $\overline{M3}$ to AC CC&S M5 to AC	107 115	Roll gyro DE Counter 2	The polarity of the command current is again determined by M3 and the current is switched into the roll-gyro torquer by M5; the roll magnetic shift register is turned on and 1-pulse/s pulses begin to count into the register
26	Stop roll turn	Event 25 + 1 to 1319 s	CC&S $\overline{M3}$ to AC CC&S $\overline{M5}$ to AC	107 115 220	Roll gyro DE Counter 2 CC&S timing of events	The roll register overflows, turns off, and resets M3 and M5; the velocity register is turned on at this time; the roll rate settles to the limit cycle and the position is held within a limit cycle at the new value resulting from the maneuver
27	Ignite midcourse motor	M+103 to 104 min	CC&S M6 to Pyro	115	DE Counter 2	The midcourse motor is turned on by M6 and 20-pulses/s pulses begin to count into the velocity shift register
28	Shut off midcourse motor	Event 27 + 0.06 to 102.36 s	CC&S M7 to Pyro	115 220	DE Counter 2 CC&S timing of events	The velocity register overflows and turns off the midcourse motor by pulsing M7
29	Initiate sun reacquisition	M+109 to 110 min	CC&S $\overline{M1}$ to AC CC&S $\overline{M2}$ to AC	103 104 112 113 115	Pitch gyro Yaw gyro Pitch position Yaw position DE Counter 2	M1 and M2 are reset; M3, M4 and M5 are reset again for redundancy; sun sensor power is turned on, the autopilot is turned off, the capacitors are switched out of the gyro loops and the DE is switched back to Data Mode 2; sun reacquisition begins
30	Sun reacquisition complete; begin Canopus reacquisition	Event 29 + 0 to 20 min	AC	103 104 109 112 113 116 222 223 224 225	Pitch gyro Yaw gyro Primary system voltage Pitch position Yaw position DE Counter 4 +X panel current −X panel current +Y panel current −Y panel current	The sun is reacquired in pitch and yaw and Canopus reacquisition begins; the Canopus sensor is turned on and the *search* signal is switched into the roll-switching amplifier; the power system is again operating on solar power
31	Canopus reacquisition complete	Event 30 + 0 to 60 min	AC and Power		See Event 17	See discussion at Event 17 in this table
32	End of midcourse maneuver sequence	M+198 to 199 min	CC&S	115	DE Counter 2	Maneuver counter in CC&S overflows and turns off; the midcourse clamp is applied to the midcourse event relays again
33	Second midcourse maneuver	T+10 to 20 days	See Events 19–32		See Events 19–32	The sequence from Events 19–32 is repeated again with the exception that DC-V23 is sent to arm the Pyro second motor burn squibs at Event 20
34	Switch bit rate to 8⅓ bits/s	E−86.9 days	CC&S MT-6 to DE	115	DE Counter 2 Lower rate for all measurements	CC&S end counter Event MT-6; backup: DC-V5

Table 7 (contd)

Event No.	Event	Time	Subsystems	Telemetry		Discussion
				Channel	Measurement	
35	Canopus sensor cone-angle update No. 1	E−56.4 days	CC&S MT-1 to AC	115 303	DE Counter 2 Canopus sensor cone angle	CC&S end counter Event MT-1; cone angle to 85.1 deg; backup: DC-V17
36	Canopus sensor cone-angle update No. 2	E−39.7 days	CC&S MT-2 to AC	115 303	DE Counter 2 Canopus sensor cone angle	CC&S end counter Event MT-2; cone angle to 90.3 deg; backup: DC-V17
37	Canopus sensor cone-angle update No. 3	E−23 days	CC&S MT-3 to AC	115 303	DE Counter 2 Canopus sensor cone angle	CC&S end counter Event MT-3; cone angle to 95.4 deg; backup: DC-V17
38	Transmit-hi/re-ceive-lo	E−18 days	CC&S MT-5 to Radio	115	DE Counter 2	CC&S end counter Event MT-5; radio switched to transmit via high-gain antenna and receive via low-gain antenna; backup: DC-V10
39	Canopus sensor cone-angle update No. 4	E−9.1 days	CC&S MT-4 to AC	115 303	DE Counter 2 Canopus sensor cone angle	CC&S end counter Event MT-4; cone angle to 100.5 deg; backup: DC-V17
40	Begin encounter sequence	E−12⅔ h	CC&S MT-7 to Power and Pyro	115 227 306	DE Counter 2 2.4-kHz output current Terminator sensor excitation voltage	CC&S end counter Event MT-7; sent to Pyro which energizes terminator sensor; sent to power to turn on 2.4-kHz power to tape recorder electronics, turn off battery charger and turn on science (if off) by backup science-on relay; backup: DC-V25
41	Begin DAS encounter mode	E−6 h	CC&S MT-8 to DAS DAS to planet sensor DAS to DE		Changes to all science measurements (Data Mode 3)	CC&S end counter Event MT-8; sent to DAS which energizes planet sensor and switches DE to Data Mode 3; backup: DC-V24
42	Planet sensor acquisition	E−72 to 48 min	Planet sensor to DAS			Planet sensor acquires Venus and signals DAS
43	Encounter	E	Spacecraft			Closest approach to Venus
44	Antenna pointing-angle change	E+8 min	Terminator sensor to Pyro			Terminator sensor output to Pyro fires squibs to change high-gain antenna pointing angle; backup: DC-V22 and DAS Timer A
45	Begin tape playback	E+14 h	CC&S MT-9 to DE		Switches from Data Mode 2 to 4	CC&S end counter Event MT-9; switches DE to Mode 4 and begins tape recorder playback; backup: DC-V4
46	Return to cruise mode: DC-V2, DC-V28	E+3.25 days	From ground to Radio, Command, DE, and Power		Returns to Data Mode 2	After all recorded data has been played back the spacecraft may be returned to the cruise mode by sending DC-V2 to switch the DE to Data Mode 2 and DC-V28 to turn off the tape recorder

IV. Backups, Redundancies, and Direct Commands

The *Mariner* Venus 67 spacecraft has many areas of redundancy to improve reliability. These include redundancies to back up certain functions and redundant starts (or stops) of critical events. In addition, DC-Vs provide backups for the occurrence of events and provide a means of control from the earth of some of the operations of the spacecraft subsystems. The commands are used both for reliability and for accommodating nonstandard modes of operation.

The first part of this section describes the backups and redundancies in the three guidance and control subsystems. The second part discusses the direct commands which affect or back up the guidance and control subsystems.

A. Backups and Redundancies

The backup event commands and redundant functions are discussed. Space does not permit the discussion of the detailed redundancies which have been designed into the actual electronic circuits. Some of the backups and redundancies have already been described in the functional description of the subsystems, but they will be mentioned again here for completeness.

1. Power subsystem. There are twelve diode-isolated sections of solar cells. A shorting failure in any one section (or an open diode failure) will leave eleven operating sections which would provide sufficient power to operate the spacecraft.

The battery is connected to the main power bus through three separate contacts of the motor driven switch.

A battery charger provides a charge current to the battery to keep it at full capacity. When turned off, the battery charger is available to remove the power system from an unnecessary sharing mode by boosting the primary system voltage. It will do this when the primary voltage drops below 33 ± 1 V.

An error-detecting circuit monitors the output of the main B/R. If this output is less than 48 ± 1 V or greater than 58 ± 1 V for 3.5 ± 1 s, this circuit permanently turns off the main booster and switches on the maneuver booster to provide spacecraft power. Since the maneuver booster is not capable of providing power for both cruise and maneuver loads, an overload inhibit circuit turns off science when the main booster has failed and the gyros are on. If the maneuver booster fails, there is no means of providing power to the maneuver loads from the main booster regulator.

The power synchronizer has a 38.4-kHz free-running circuit which is energized and replaces the 38.4-kHz CC&S sync signal if it fails. All of the sync outputs can be provided by this backup.

All the power inverters except the 3-ϕ 400-Hz inverter have free-running backup modes of operation. The absence of the sync signal from the power synchronizer will cause these inverters to operate in their free-running mode. The 3-ϕ 400-Hz inverter will not operate in the absence of its sync signal.

Three relays (4A11 K2, K3, and K4) will provide power to the science experiments. Two of these relays (4A11 K2 and K3) each have two sets of contacts to supply power. The tape recorder electronics power relay (4A11 K5) has two sets of contacts to supply power. The numerous backup direct commands controlling these relays are discussed in the last portion of this section.

The science-on and RF power-up relay (4A11 K1) may be de-energized at separation by the separation connector or when the maneuver booster regulator turns off after Canopus acquisition. This relay has a redundant parallel wiring to the separation connector so that launch vibrations are less likely to cause an inadvertent early resetting.

2. Attitude control subsystem. The AC power-on relay (7A1 K7) may be de-energized by either the pyro arming switch or CC&S Command L2.

The N_2 gas supply has dual bottles, regulators, lines, and valves so that a leak or valve failing open in one system will not deplete all the gas. In addition, there is sufficient gas in one system to successfully support a full flight.

The AC turn-axis relays in the CC&S are interconnected so that a command current cannot be input to two axes at the same time.

The power for cycling the capacitors is disconnected when the gyros are switched to the rate-plus-position mode. This prevents a failure in the capacitor-cycling circuit from affecting the maneuver.

The roll, spin and search signals are inhibited if the negative roll gas jet stays on for more than 30 s.

The sun gate has two sun sensors wired in parallel so that an open failure in one sensor will not cause loss of the sun gate signal.

The DC backups in the roll AC are described in the last part of this section.

3. Central computer and sequencer subsystem. All the CC&S relays except the *clear* and *verify* relays are held in the reset position during launch by a relay-hold current which prevents them from changing state due to vibration. This current is removed at separation.

The relay drivers in the launch clock (except the *clear* and *verify* relay drivers), the end counter, and the transformer-rectifier subassemblies are held off by the launch clamp. This prevents an inadvertent pulse from triggering the driver. The launch clamp is removed at separation.

The relay drivers in the maneuver duration output and the flip-flops in the maneuver duration subassemblies are held off by the maneuver clamp. This clamp is removed when the midcourse maneuver sequence is initiated.

Either CC&S Command L1 or the separation-initiated timer will fire the squibs to open the solar panels.

Either CC&S Command L2 or the pyro-arming switch will turn on AC power.

In addition to the interconnections of the turn-axis relays, the relay driver for the start pitch command is clamped off when a roll turn is being performed.

The relay driver for midcourse motor ignition is clamped off when either a pitch or roll turn is being performed.

The parity of each midcourse maneuver quantitative command is checked by counting the number of "1" bits in the word. Bit 6 of the command word to the CC&S is adjusted before transmission from the ground so that there are an odd number of "1"s in the word. If an odd number is counted, a signal is sent to the DE which telemeters a verification of the parity correctness of the command. If an even number of "1"s is counted, no signal is telemetered, thus indicating that the command was not received correctly and must be sent again.

There are numerous clamps within the input decoder to prevent pulses from entering the wrong circuits. One function that is not clamped in this way is the receipt of a quantitative command through the command decoder during the execution of a midcourse maneuver. The *info MC* from the input decoder is not clamped out of the shift register's info driver when a maneuver is being performed. If this signal exists when the registers are counting out information, undesirable interactions may occur.

It is also possible to stop a turn or motor burn in progress by transmitting to the CC&S a quantitative command containing all "1"s. This will cause an overflow, after eleven "1" bits are present in the register, and therefore shut off the event. This is not a normal mode of operation, but has been demonstrated in tests.

B. Direct Commands

The direct commands which affect or back up the guidance and control subsystems are described in Table 8. The discussion for each command is outlined as follows:

Command: Number and definition of the direct command.

Criteria for use: Conditions which might necessitate use of this command are discussed.

Effect on spacecraft: The immediate effect on the spacecraft subsystems involved is discussed. Some commands may not go directly to a G&C subsystem but may still have an indirect effect on a G&C subsystem. These commands are also included.

Discussion: The discussion includes all items not mentioned above. Specifically, the effect a command has on the spacecraft may depend on the time it is sent and/or upon other commands which have been sent previously. In addition, the limitations as to when the command can be sent and the possible harmful effects of the commands are discussed.

Table 8. Direct commands

Command No.	Command definition	Criteria for use	Effect on spacecraft	Remarks
DC-V1	Command TM to Mode 1	1. Backup command for AC to switch DE to Data Mode 1 at the start of midcourse 2. Operational command to switch DE to Data Mode 1	Switches DE to Data Mode 1 (not a G&C function)	—
DC-V2	Turn on science; command TM to Mode 2	1. Backup command for initial science-on command 2. If power emergency causes science to be turned off, DC-V2 may be used as an operational command to turn on science when the emergency has passed 3. Operational command to switch to Data Mode 2 after postencounter tape playback 4. Backup command for AC to switch DE to Data Mode 2 after midcourse	1. Switches 2.4-kHz main inverter power in power subsystem to science experiments sets 4A11 K2 and K3) 2. Switches DE to Data Mode 2 (not a G&C function)	Should not be used during launch when power applied to science experiments might cause arcing
DC-V4	Command TM to Mode 4	1. Backup for CC&S MT-9 event 2. Operational command to repeat tape playback	Switches DE to Data Mode 4 and begins tape playback (not a G&C function)	—
DC-V5	Command switch data rate	1. Backup for CC&S MT-6 event 2. Operational command to select data rate	Switches telemetry data rate from 33⅓ bits/s to 8⅓ bits/s or vice versa (not a G&C function)	—
DC-V10	Transmit-hi/receive-lo	1. Backup for CC&S MT-5 event 2. Operational command to transmit via the high-gain antenna and receive via the low-gain antenna	Switches transmitter to high-gain antenna and receiver to low-gain antenna (not a G&C function)	—
DC-V13	Maneuver command inhibit	1. Backup command to turn on AC power 2. Emergency command to inhibit midcourse maneuver in the event of a malfunction	1. Disconnects +26 Vdc AC power and commanded current from CC&S (sets 7A1 K9) 2. Opens line between CC&S and motor ignition and shutoff squibs (in Pyro subsystem)	1. Backup command to turn on AC power a. If CC&S L2 and Pyro arming switch *both* fail to open or if AC power is desired before they are scheduled to occur, DC-V13 may be used to turn on AC power b. Power switched to sun sensors and switching amplifier preamps (resets 7A1 K7) c. Since all AC power to CC&S is cut off, there is no power through CC&S L3 to the roll search logic. Thus, there is no spin signal, and the spacecraft will start Canopus acquisition immediately after sun acquisition (i.e., after the sun gate signal goes off) d. No midcourse maneuver is possible in this mode of operation unless DC-V13 is reset by DC-V14

Table 8 (contd)

Command No.	Command definition	Criteria for use	Effect on spacecraft	Remarks
DC-V13 (contd)				2. Inhibit midcourse maneuver. When used to inhibit the maneuver, the capacitors are shorted out of the gyro loop (resets 7A2 K4 and K5) and sun sensor power is applied (resets 7A1 K3). Canopus acquisition begins when sun acquisition is completed. DC-V13 should not be sent so that it is received during motor burn since it will inhibit the shutoff squibs and turn off the autopilot power. Thus, the motor will burn uncontrolled until fuel depletion
DC-V14	Remove maneuver inhibit	Command to reset DC-V13	1. Connects +26 Vdc AC power and commanded current with CC&S (resets 7A1 K9) 2. Connects line between CC&S and motor ignition and shutoff squibs (in Pyro subsystem)	1. If DC-V13 has been used to turn on AC power and neither CC&S L2 nor the Pyro arming switch have opened, then DC-V14 will turn off the AC power (sets 7A1 K7) 2. If DC-V13 has been used to inhibit the maneuver, DC-V14 will remove the inhibit. In order that the whole maneuver be inhibited, DC-V14 should be sent later than MC+110 min (110 min after DC-V27) when normal postmaneuver sun acquisition begins. If the malfunction had been associated with the maneuver clock, DC-V14 should be sent after MC+199 min when the maneuver counter has stopped counting
DC-V15	Canopus gate override	1. Emergency command so that the spacecraft will acquire in roll any object of sufficient brightness to have a roll-error signal 2. Emergency command to turn off the gyros during acquisition mode	1. Switches roll-error signal output of Canopus sensor directly into roll-switching amplifier (sets 7A1 K14) 2. Opens line to gyro switch control (sets 7A1 K14). This line provides the signal to keep the gyros on during acquisition mode. The gyros will turn off 200 s after this on signal has been removed (7A1 K10 resets)	DC-V15 will have a different effect depending on when it is sent: 1. If DC-V15 is sent after normal Canopus acquisition, this command will have no immediate effect on the spacecraft. If it is left in the position and Canopus acquisition is lost, a low brightness gate violation occurs, or pitch and yaw acquisition is lost, then the gyros will not be turned on. The derived rate feedback provides the only rate control in this event 2. Sending DC-V15 during a maneuver has no immediate effect. However, the gyros would turn off 200 s after MC+110 min and would not be available for sun and Canopus acquisition 3. If DC-V15 is sent before the Canopus sensor is turned on (i.e., before sun acquisition is complete), the gyros will turn off in 200 s

Table 8 (contd)

Command No.	Command definition	Criteria for use	Effect on spacecraft	Remarks
DC-15 (contd)				4. If DC-V15 is sent while the Canopus sensor is on but not acquired or if DC-V15 had been sent and the sensor comes on, then the spacecraft would try to acquire in roll any object with sufficient brightness to have a roll-error signal
DC-V17	Cycle Canopus cone angle	1. Backup command for CC&S MT-1, -2, -3 and -4 2. Operational command to step Canopus sensor cone angle	Changes the cone-angle field-of-view of the Canopus sensor by one step. This command is cyclic (i.e., eight consecutive commands will cycle the sensor back to the starting cone angle). The cone angles are in order of occurrence: *Angle, deg* — *Command* 80.0 — Preset condition 85.1 — MT-1 90.3 — MT-2 95.4 — MT-3 100.5 — MT-4 105.7, 100.5, 105.7 — Optional positions	— —
DC-V18	Roll gyro on inertial control, positive roll increment	1. Emergency command if the Canopus sensor fails, then DC-V18 will place the roll gyro on rate and position control 2. Each DC-V18 after the first can be used to turn the spacecraft +2¼ deg in roll 3. If other than normal Canopus acquired roll position is desired, DC-V18 (along with DC-V21) can be used to control the roll position	1. Turns on all three gyros (sets 7A1 K16 which sets 7A1 K10) 2. Turns off Canopus sensor (sets 7A1 K6) 3. Switches capacitor into roll gyro loop (sets 7A2 K5) 4. Subsequent DC-V18s after the first apply commanded current to the roll gyro torquer so that the spacecraft makes a +2¼-deg roll turn (pulses 7A2eK1 and 7A2eK2)	1. The first DC-V18 turns on the gyros and applies power to the gyro amplifiers, pre-amplifiers and the roll one shots. Subsequent DC-V18s will step the spacecraft +2¼ deg in roll 2. The capacitors will not be cycled when this command is used to turn on the gyros. If the capacitors have not been used or cycled recently, the first one shot turn will be less than +2¼ deg. Subsequent one shot turns will have the correct magnitude 3. Nominally, when stepping positively in roll, a 5-min wait is required between each DC-V18 to ensure the correct one shot magnitude. These commands may be sent at one minute intervals resulting in a negligible decrease in the magnitude of each step. Commands spaced closer than one minute apart will decrease the magnitude of each step in proportion to the time interval between commands. If accuracy is required, this relationship between step size and command interval must be calibrated prior to use during flight

Table 8 (contd)

Command No.	Command definition	Criteria for use	Effect on spacecraft	Remarks
DC-V19	Return roll to automatic optical control	Resets DC-V15, -V18 and -V20 when they are no longer needed	Resets functions of DC-V15, -V18, and -V20. Returns roll control to automatic optical control (resets 7A1 K14, K15, and K16)	—
DC-V20	Remove roll control	Emergency command in the event of a Canopus sensor failure, DC-V20 may be used to leave the roll axis uncontrolled	1. Turns off Canopus sensor (sets 7A1 K15 which sets 7A1 K6) 2. Opens line to gyro switch control. This line provides the signal to keep the gyros on during acquisition mode. The gyros will turn off 200 s after DC-V20 is received (7A1 K10 resets)	1. If pitch or yaw acquisition is lost, the gyros will not turn on since DC-V20 has opened up this line 2. Extended use of DC-V20 may be harmful to the spacecraft since a windmill effect due to unbalanced solar forces may cause the spacecraft to spin up about the roll axis
DC-V21	Roll override, negative roll increment	1. Operational command to be used when the Canopus sensor has acquired an undesirable object. Causes spacecraft to continue searching 2. Used in conjunction with DC-V18 for vernier control of roll axis. Each DC-V21 can be used to turn the spacecraft −2¼ deg in roll	1. Provides turn-on signal for all gyros (resets 7A1 K13 which sets 7A1 K10) 2. Switches search signal into roll-switching amplifier (resets 7A1 K13) 3. If the roll search or spin signal has been inhibited because the negative roll gas jet was on for more than 30 s, DC-V21 will reset the inhibit and the signal will be on 4. Applies command current to roll gyro torquer equivalent to −2¼-deg roll turn (pulses 7A2eK1)	1. DC-V18 must have been sent previously to insert the capacitor into the gyro loop for DC-V21 to cause a −2¼-deg roll turn 2. DC-V21 will not turn on the gyros if DC-V15 or 20 has been sent previously 3. Nominally, when stepping negatively in roll, a 5-min wait is required between each DC-V21 to ensure the correct one shot magnitude. These commands may be sent at one-min intervals resulting in a negligible decrease in the magnitude of each step. Commands spaced closer than 1 min apart will decrease the magnitude of each step in proportion to the time interval between commands. If accuracy is required, this relationship between step size and command interval must be calibrated prior to use during flight
DC-V22	Antenna pointing angle change	Backup for terminator sensor command to change antenna pointing angle	Causes Pyro to change antenna pointing angle (not a G&C function	—
DC-V23	Arm Pyro for second midcourse maneuver	If a second midcourse maneuver is desired, this command must be sent before the maneuver is initiated by DC-V27	Connects Pyro second maneuver motor burn and shutoff squibs so that CC&S commands will control them. (Command sent to Pyro subsystem.)	—
DC-V24	Begin DAS encounter mode	1. Backup to CC&S MT-8 event 2. Operational command to switch to Data Mode 3	1. DAS switches DE to Data Mode 3 (not a G&C function) 2. DAS switches excitation power to planet sensor 3. DAS switches plasma probe to encounter format (not a G&C function)	—

Table 8 (contd)

Command No.	Command definition	Criteria for use	Effect on spacecraft	Remarks
DC-V25	Begin encounter sequence, science on, and overload inhibit override	1. Backup command for CC&S MT-7 event 2. Emergency command to override the function of the booster regulator overload inhibit circuitry	1. Switches 2.4-kHz main inverter power to science via science power-on backup relay (sets 4A11 K3) 2. Switches 2.4-kHz main inverter power to science (sets 4A11 K4) bypassing overload inhibit relay (4A8 K5) 3. Switches 2.4-KHz main inverter power to tape recorder (sets 4A11 K5) 4. Turns the battery charger off if it is on and no sharing mode is detected (resets 4A8 K1) 5. Turns on terminator sensor excitation power (command sent to Pyro subsystem)	1. This command will have no effect on science if science power is already on 2. If science has been turned off due to a main booster regulator failure with the gyros on (overload inhibit circuit), this command will turn science back on. Power for all loads will then be drawn off the maneuver booster regulator. Thus, before this command is sent with the overload inhibit in effect, the total possible load must not exceed the capacity of the maneuver booster regulator 3. DC-V25 will not turn off the battery charger if it is on and a sharing mode is being detected by the share mode detector. See remarks for DC-V28
DC-V26	Science off	If a malfunction in the power system indicates excessive drain on the battery, DC-V26 may be used as an emergency command to turn off science power to reduce this power drain	1. Switches off 2.4-kHz main inverter power to science (resets 4A11 K2, K3, and K4) 2. Turns off the battery charger if it is on and no sharing mode is detected (resets 4A8 K1)	1. Does not turn off tape recorder electronics if they have been turned on. (See DC-V28) 2. If spacecraft telemetry indicated a malfunction in the battery charger when it is on and DC-V28 was inoperational, DC-V26 can be used to turn off the battery charger, and then DC-V2 can be used to turn science back on 3. DC-V26 enables the overload inhibit circuit by resetting 4A11 K4 if it was set. Thus, it acts as a reset for the overload inhibit override function of DC-V25 4. DC-V26 will not turn off the battery charger if it is on and a sharing mode is being detected by the share mode detector. See discussion under DC-V28
DC-V27	Initiate midcourse maneuver	If spacecraft trajectory information indicates a midcourse maneuver is necessary, this command initiates the maneuver sequence. Two midcourse maneuvers are possible with *Mariner* Venus 67 (DC-V23 must be sent prior to the second DC-V27)	Sets CC&S midcourse relay (MC) thus starting maneuver sequence. This 199-min sequence controls gyro turn-on, switching to Data Mode 1 and the starting times of the pitch and roll turns and motor ignition. The shutoff times are controlled by the CC&S pitch, roll and velocity shift registers	—

Table 8 (contd)

Command No.	Command definition	Criteria for use	Effect on spacecraft	Remarks
DC-V28	Switch battery charger, tape recorder off	1. Operational command to be sent if battery telemetry indicates battery charger should be turned on to charge the battery or turned off if the battery has been fully charged 2. Emergency command to turn off the tape recorder	1. Turns off the battery charger if it is on and no sharing mode is detected (resets 4A8 K1) 2. Turns on the battery charger if it is off and not boosting (sets 4A8 K1) 3. Switches off the 2.4-kHz main inverter power to the tape recorder (resets 4A11 K5)	1. When the battery charger is off, it is in the boost-enable mode. This mode is controlled automatically by the share mode detector. If the share mode detector detects a sharing condition (i.e., the raw-power voltage falls below 33 ± 1 Vdc) and is not inhibited by the maneuver loads being on, then the battery charger will use the battery to boost the raw-power voltage. If the battery charger is off but not boosting, DC-V28 will turn the battery charger on. If the battery charger is off and is boosting, then DC-V28 will have no effect. Thus, when the charger is off and is boosting, DC-V28 cannot be used to stop the boosting action by turning on the charger 2. When the battery charger is on, it uses raw power to charge the battery. If the share mode detector is not inhibited by the maneuver loads being on, it can still detect a sharing condition. If it does detect a sharing condition, the resulting switching (sets 4A13 K1 and K2 which sets 4A8 K2) will disconnect all inputs and outputs to the battery charger. If the battery charger is on and no sharing condition is detected, DC-V28 will turn the charger off. If the battery charger is on and a sharing condition is detected, DC-V28 will have no effect. Thus, when the charger is on and a sharing mode is detected, DC-V28 cannot be used to override this mode by turning off the charger
DC-V29	Arm Pyro for first mid-course maneuver	Operational command sent before the first maneuver (DC-V27) to ensure that the first motor burn Pyro squibs will be used during maneuver	Connects Pyro first maneuver motor burn and shutoff squibs so that CC&S commands will control them. (Command sent to Pyro subsystem)	This command allows reset capability if the second maneuver squibs are used first

V. Nominal Performance Parameters

A list of nominal performance parameters for the three G&C subsystems is compiled in this section for reference purposes.

A. Power Subsystem

1. *Solar panels*

Type	P on N boron diffused silicon
Number of panels	4
Number of sections per panel	3
Active area, total	43.6 ft^2
Number of cells, total	17640
Maximum power capability	370 W (at earth) 550 W (at Venus)

2. *Battery*

Type	Zinc-silver oxide
Number of cells	18
Capacity	1200 W-h (midcourse) 900 W-h (encounter)
Voltage	25.8–33.3 V

3. *Booster regulators (main and maneuver)*

Output	52.0 Vdc ± 1%
Capacity	150 W
Efficiency	72% @ 120 W and 50 V input

4. *Main booster failure switching*

Switch to maneuver B/R if main booster regulator input is	>58 ± 1 V for 3.5 ± 1 s, or <48 ± 1 V for 3.5 ± 1 s

5. *Battery charger*

Charger mode	
Charge current	0.005 to 0.5 A
Capacity	15 W
Boost mode	
Capacity	40 W
Share mode detector	
Boost if primary system voltage	<33 ± 1 Vdc
Stops boosting when primary system voltage	>38.5 ± 1.5 Vdc
After boosting will not boost again for at least	1.0 s

6. *Power synchronizer*

Outputs	(1) 2400-Hz square wave 19 ± 2 V peak-to-peak (2) 400-Hz 3-ϕ square wave (120-deg separation) 50 ± 3 V peak-to-peak
Frequency accuracy	(1) 0.01% with CC&S 38.4-kHz signal (2) 2% when free running

7. *Main 2.4-kHz inverter*

Output	2.4-kHz square wave 50 Vrms + 3, −2%
Frequency accuracy	(1) 0.01% or 2% with power synchronizer input (2) 5% when free running
Capacity	100 W
Efficiency	>86% @ 100 W output

8. *Maneuver 2.4-kHz inverter*

Output	2.4-kHz square wave 50 Vrms +5, −0%
Frequency accuracy	(1) 0.01% or 2% with power synchronizer input (2) 5% when free running
Capacity	80 W
Efficiency	>86% @ 80 W output

9. *Three-φ 400-Hz inverter*

Output	400-Hz 3-φ square wave 27 Vrms ± 10%
Frequency accuracy	0.01% or 2% with power synchronizer input
Capacity	18 W
Efficiency	>78% @ 9 W output

B. Attitude Control Subsystem

1. *Dead-band size*

Pitch and yaw	±9 mrad (position) ±1.1 mrad/s (rate)
Roll	±4.5 mrad (position) ±0.33 mrad/s (rate)

2. *Turn rates*

Roll spin	−3.55 mrad/s
Roll search	−2.02 mrad/s
Commanded turns (pitch and roll)	±3.14 mrad/s

3. *Angular acceleration constant* 0.48 mrad/s^2 (pitch and yaw)
0.45 mrad/s^2 (roll)

4. *Gas system*

Initial gas weight	2.5 lb of N_2/bottle 2 bottles

5. *Canopus sensor*

Look direction	0 deg clock 80 deg (preset), 85.1 deg (MT-1), 90.3 deg (MT-2), 95.4 deg (MT-3), 100.5 deg (MT-4), 105.7 deg (optional) cone
Field-of-view	±2 deg clock ±5.5 deg cone
Low-brightness gate	0.5 × Canopus
Low-gate dropout	0.25 × Canopus
Sensitivity threshold	0.02 × Canopus

6. *Earth sensor*

Look direction	270 deg clock 132 deg cone
Field-of-view	±1.5 deg clock ±25 deg cone

7. *Planet sensor*

Look direction	0 deg clock 25° 54′ cone
Field-of-view	4° 33′ × 1° 30′ with major axis aligned at an angle of +41° 4′ in clock
Sensitivity threshold	0.01 ft-cd

8. *Terminator sensor*

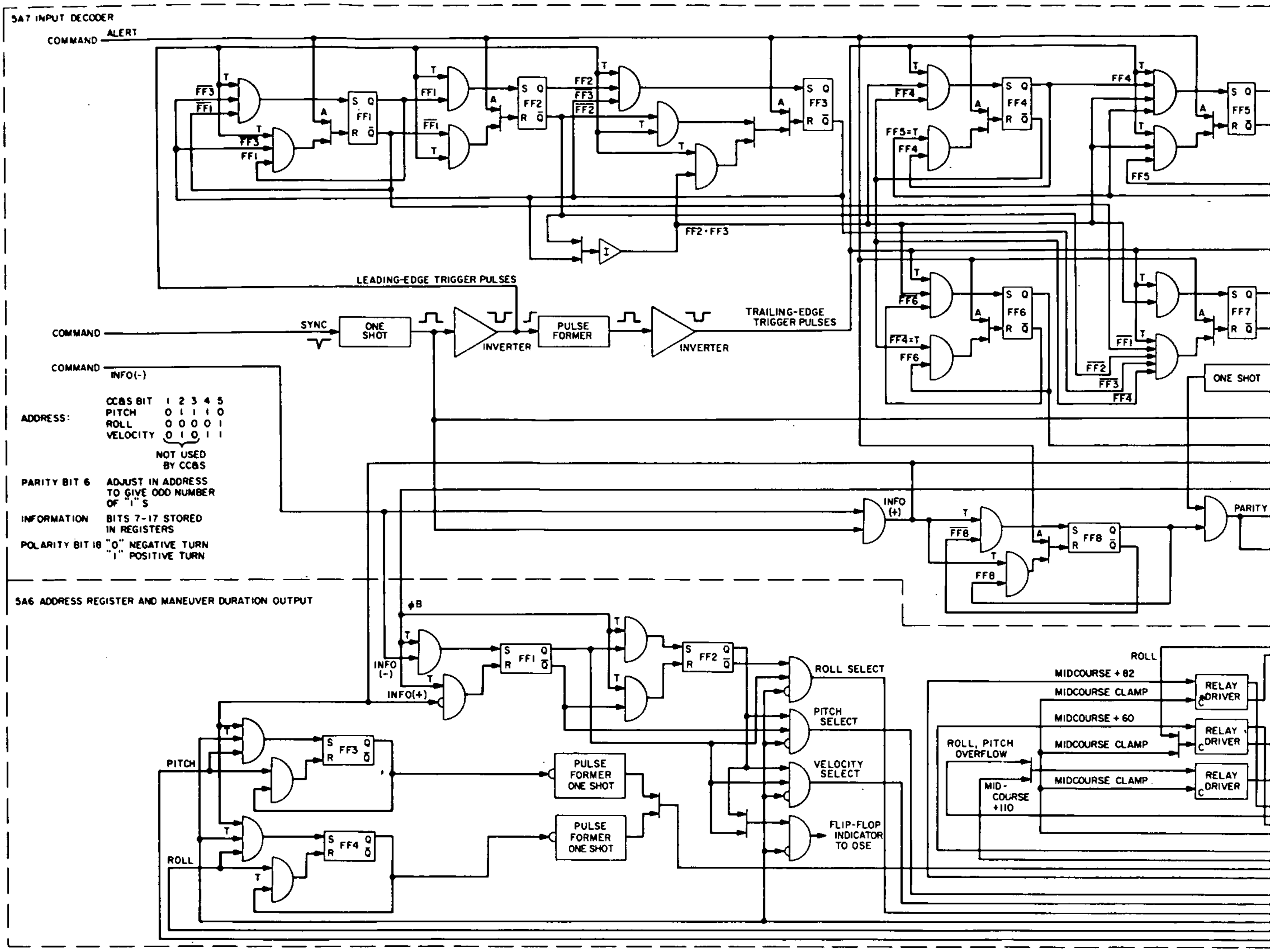
Look direction	110 deg clock 110 deg cone
Field-of-view	±0.75 deg clock ±1.25 deg cone
Sensitivity threshold	0.1 ft-cd

C. Central Computer and Sequencer Subsystem

1. *Oscillator frequency*	307.2 kHz
2. *Output frequencies*	
To power	38.4 kHz
To radio	1 pulse/66⅔ h
3. *Frequency accuracy*	±0.01%
4. *End counter event resolution*	±1⅔ h
5. *Midcourse event start resolution*	±½ min
6. *Midcourse event stop resolution*	
Turns	±0.5 s
Motor burn	±0.02 s or ±0.04 s

VI. Block Diagrams

Block diagrams of the three G&C subsystems are included in this section in Figs. 13–15. The interconnections between the CC&S, Pyro, and Command subsystems are shown in Fig. 13, for the CC&S subsystem. Figure 14 is the Power subsystem, and Fig. 15 the Attitude Control subsystem.


5A7 INPUT DECODER
COMMAND ALERT
LEADING-EDGE TRIGGER PULSES
COMMAND
SYNC
ONE SHOT
INVERTER
PULSE FORMER
INVERTER
TRAILING-EDGE TRIGGER PULSES
FF2 · FF3
COMMAND INFO(-)
ADDRESS:
CCBS BIT 1 2 3 4 5
PITCH 0 1 1 1 0
ROLL 0 0 0 0 1
VELOCITY 0 1 0 1 1
NOT USED BY CCBS
PARITY BIT 6 ADJUST IN ADDRESS TO GIVE ODD NUMBER OF "1"S
INFORMATION BITS 7-17 STORED IN REGISTERS
POLARITY BIT 18 "0" NEGATIVE TURN "1" POSITIVE TURN
INFO (+)
PARITY
ONE SHOT
5A6 ADDRESS REGISTER AND MANEUVER DURATION OUTPUT
ϕB
INFO (-)
INFO(+)
PITCH
ROLL
PULSE FORMER ONE SHOT
PULSE FORMER ONE SHOT
ROLL SELECT
PITCH SELECT
VELOCITY SELECT
FLIP-FLOP INDICATOR TO OSE
ROLL
MIDCOURSE + 82
MIDCOURSE CLAMP
MIDCOURSE + 60
MIDCOURSE CLAMP
ROLL, PITCH OVERFLOW
MIDCOURSE CLAMP
MID-COURSE +110
RELAY DRIVER
RELAY DRIVER
RELAY DRIVER

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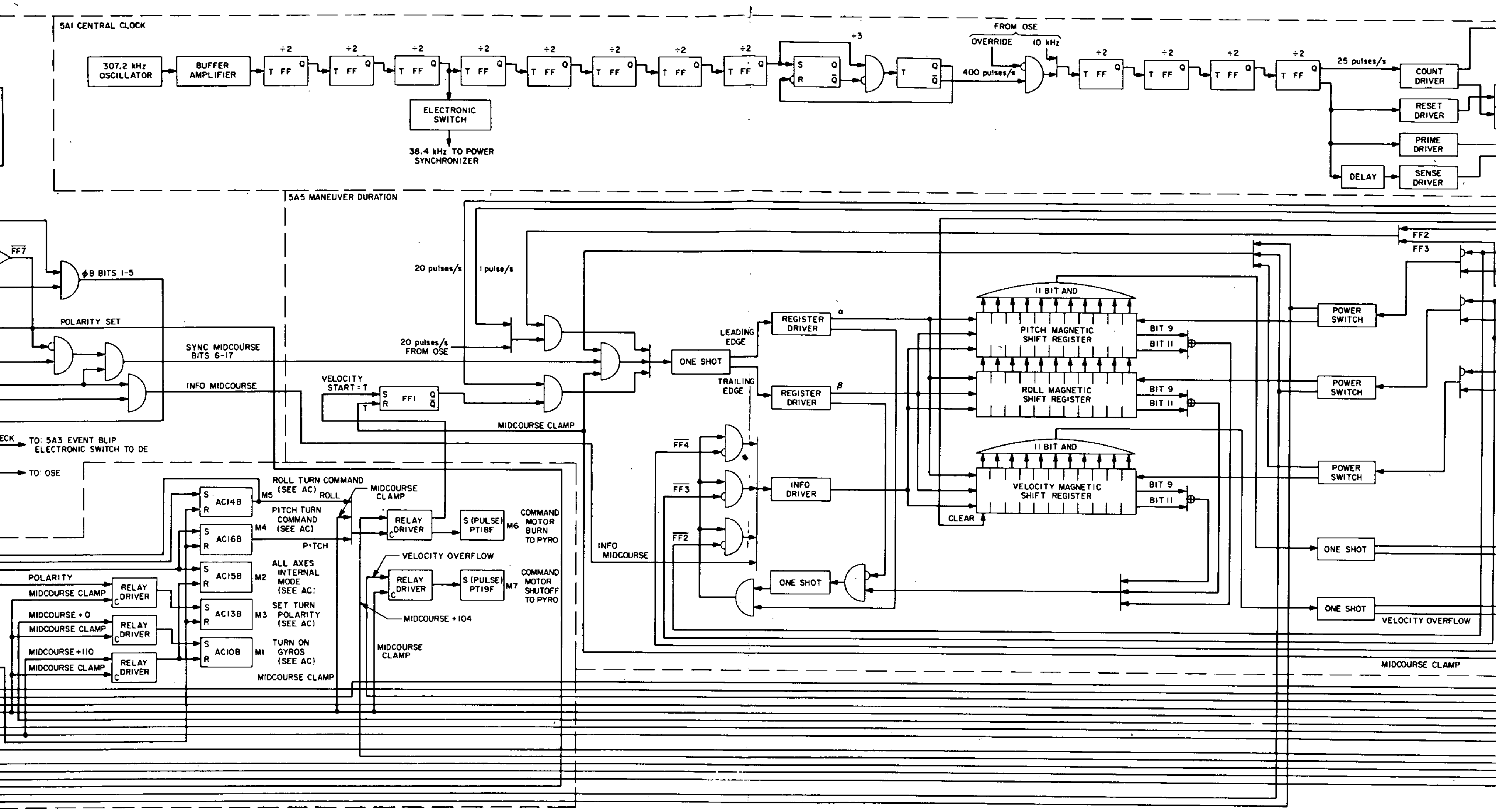

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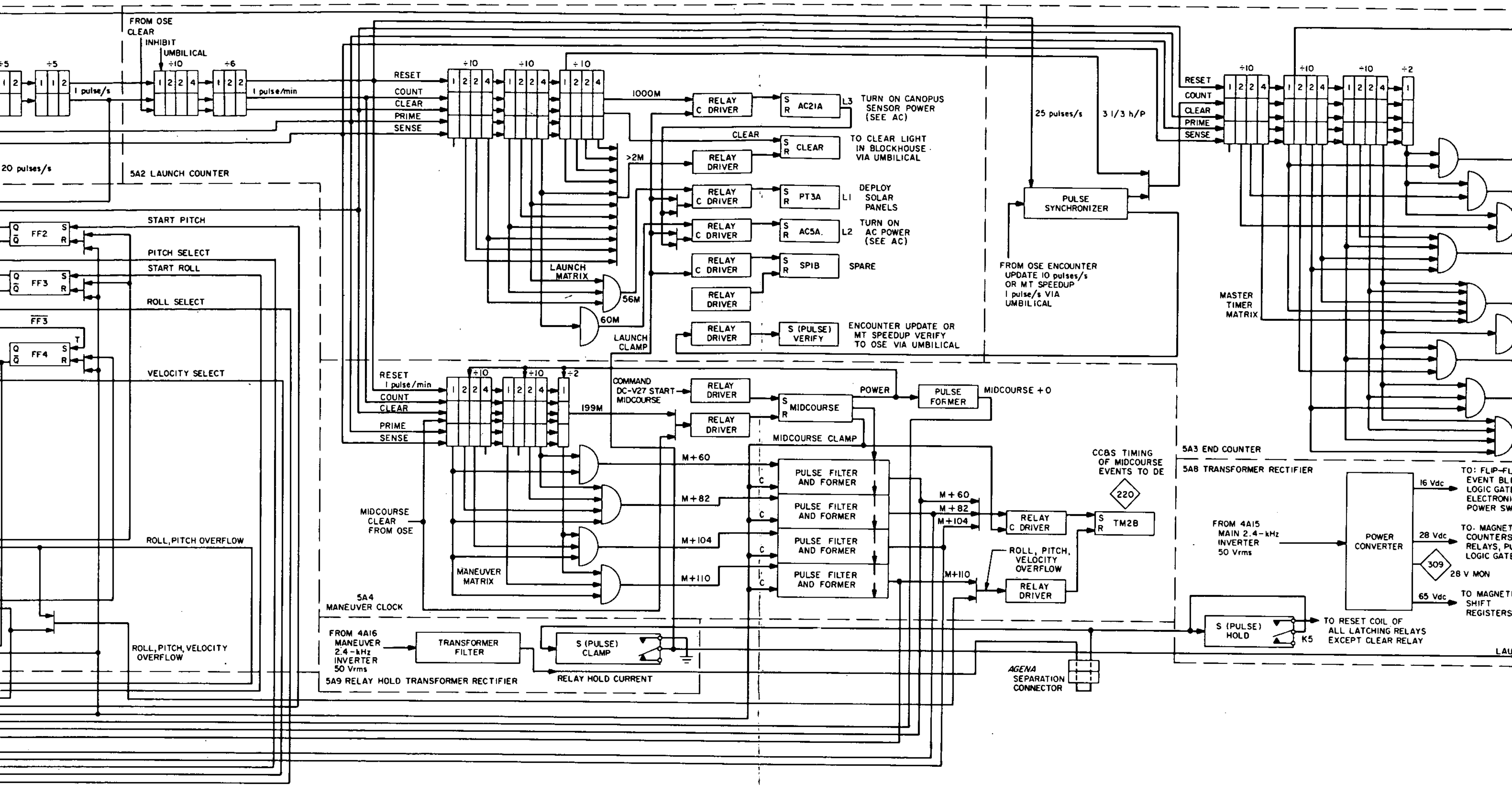

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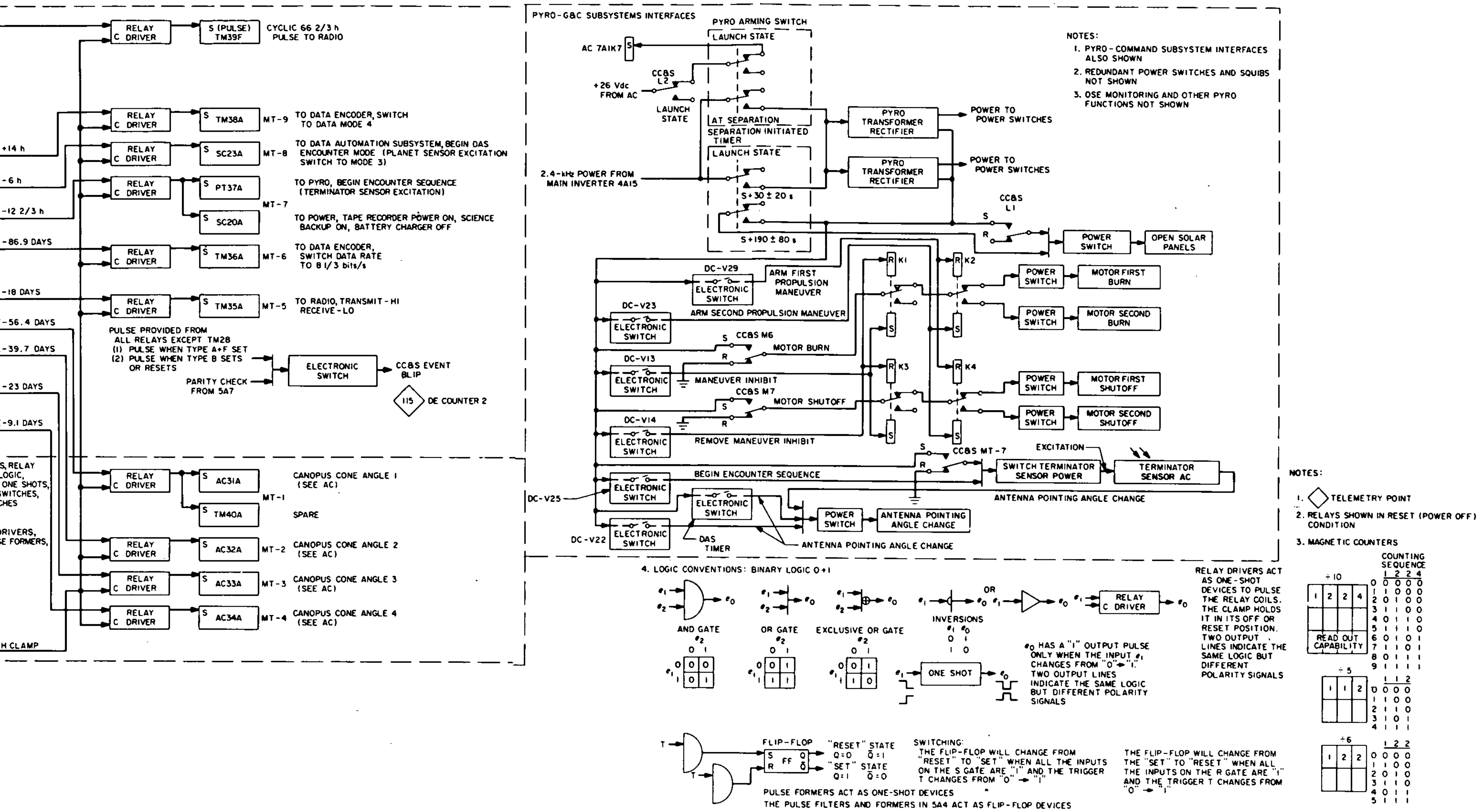

Fig. 13. G&C block diagram: CC&S subsystem

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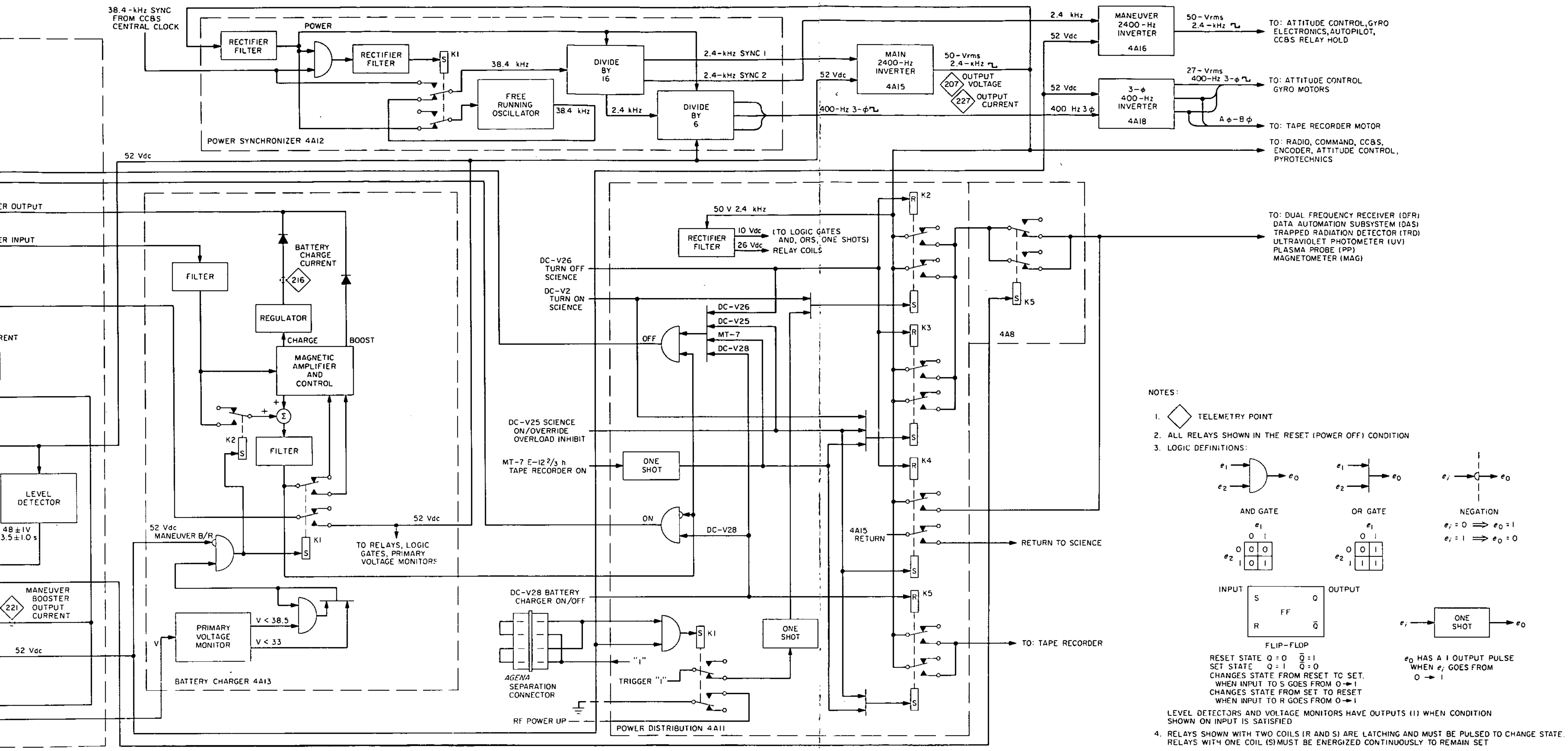

Fig. 14. G&C block diagram: power subsystem

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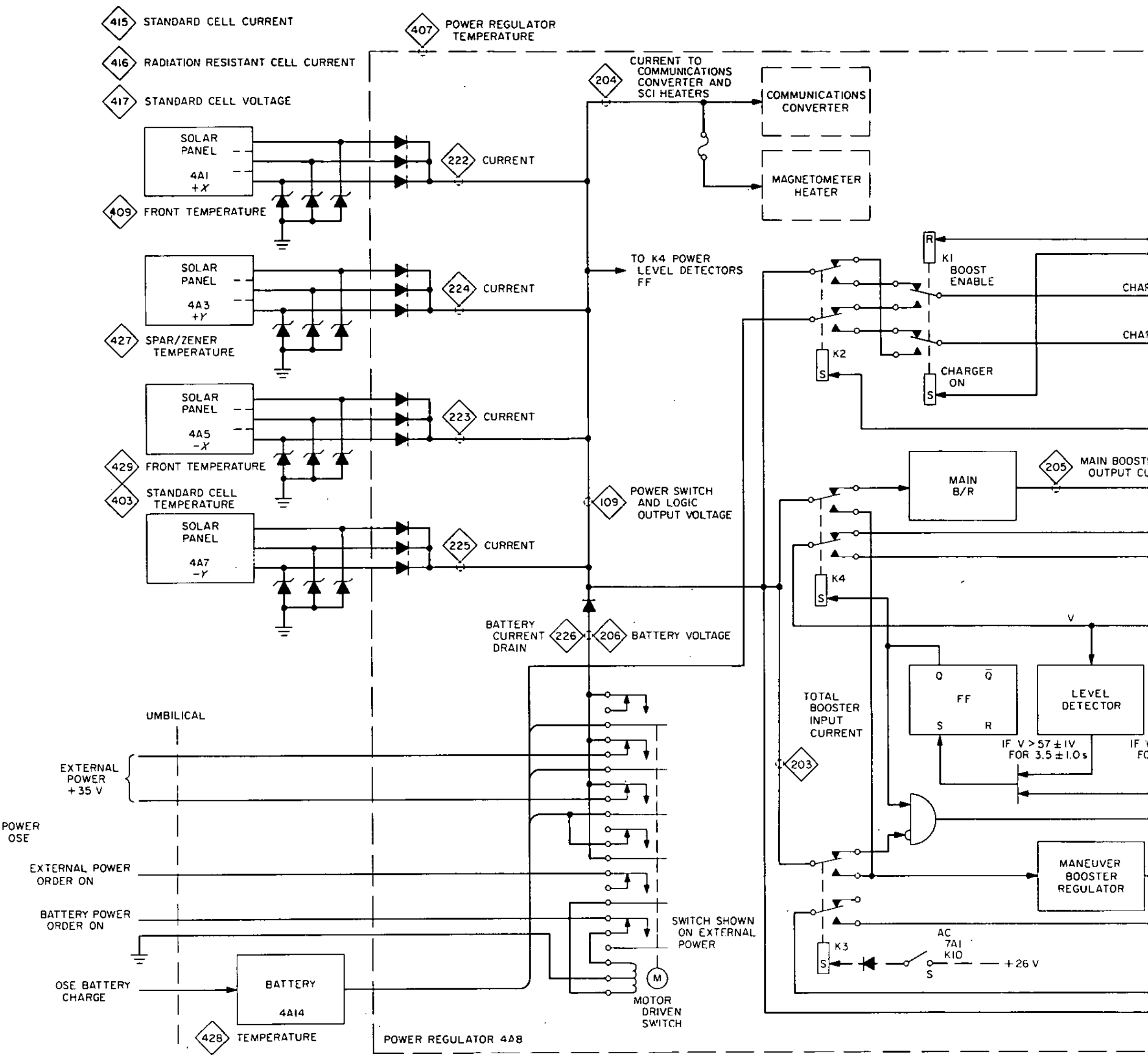

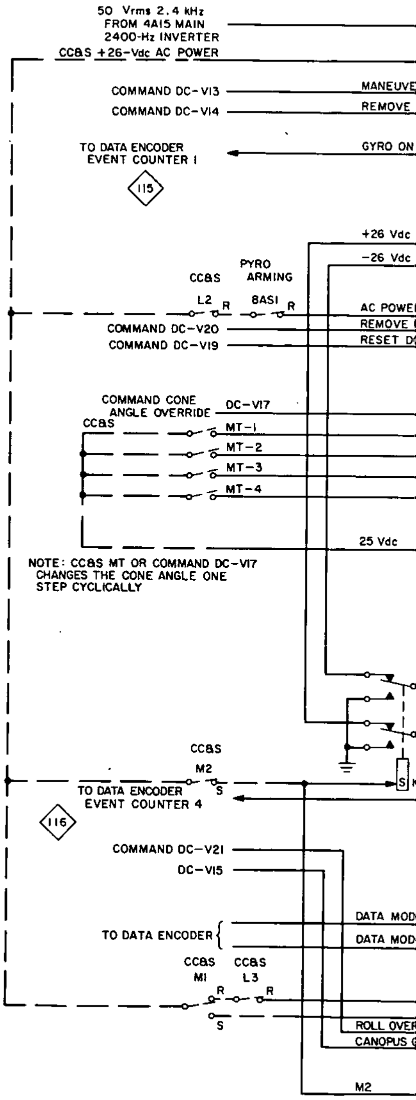
50 Vrms 2.4 kHz FROM 4A15 MAIN 2400-Hz INVERTER
CC&S +26-Vdc AC POWER
COMMAND DC-V13
COMMAND DC-V14
MANEUVE
REMOVE
TO DATA ENCODER EVENT COUNTER 1
GYRO ON
115
+26 Vdc
-26 Vdc
PYRO ARMING
CC&S
L2
8AS1
R
AC POWE
REMOVE
RESET D
COMMAND DC-V20
COMMAND DC-V19
COMMAND CONE ANGLE OVERRIDE
DC-V17
CC&S
MT-1
MT-2
MT-3
MT-4
25 Vdc
NOTE: CC&S MT OR COMMAND DC-V17 CHANGES THE CONE ANGLE ONE STEP CYCLICALLY
CC&S
M2
S
TO DATA ENCODER EVENT COUNTER 4
116
COMMAND DC-V21
DC-V15
TO DATA ENCODER
DATA MOD
DATA MOD
CC&S M1
CC&S L3
ROLL OVER
CANOPUS
M2

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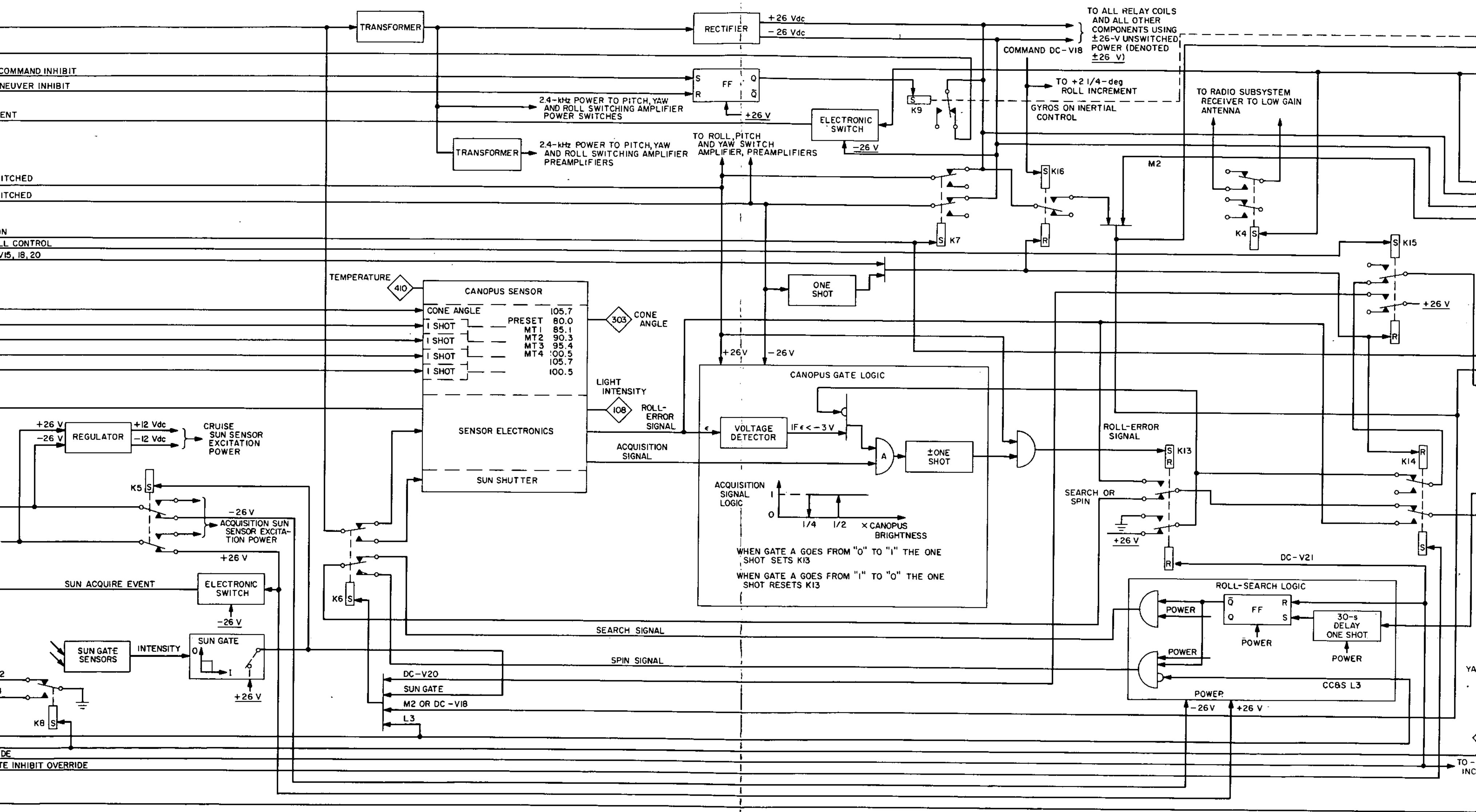

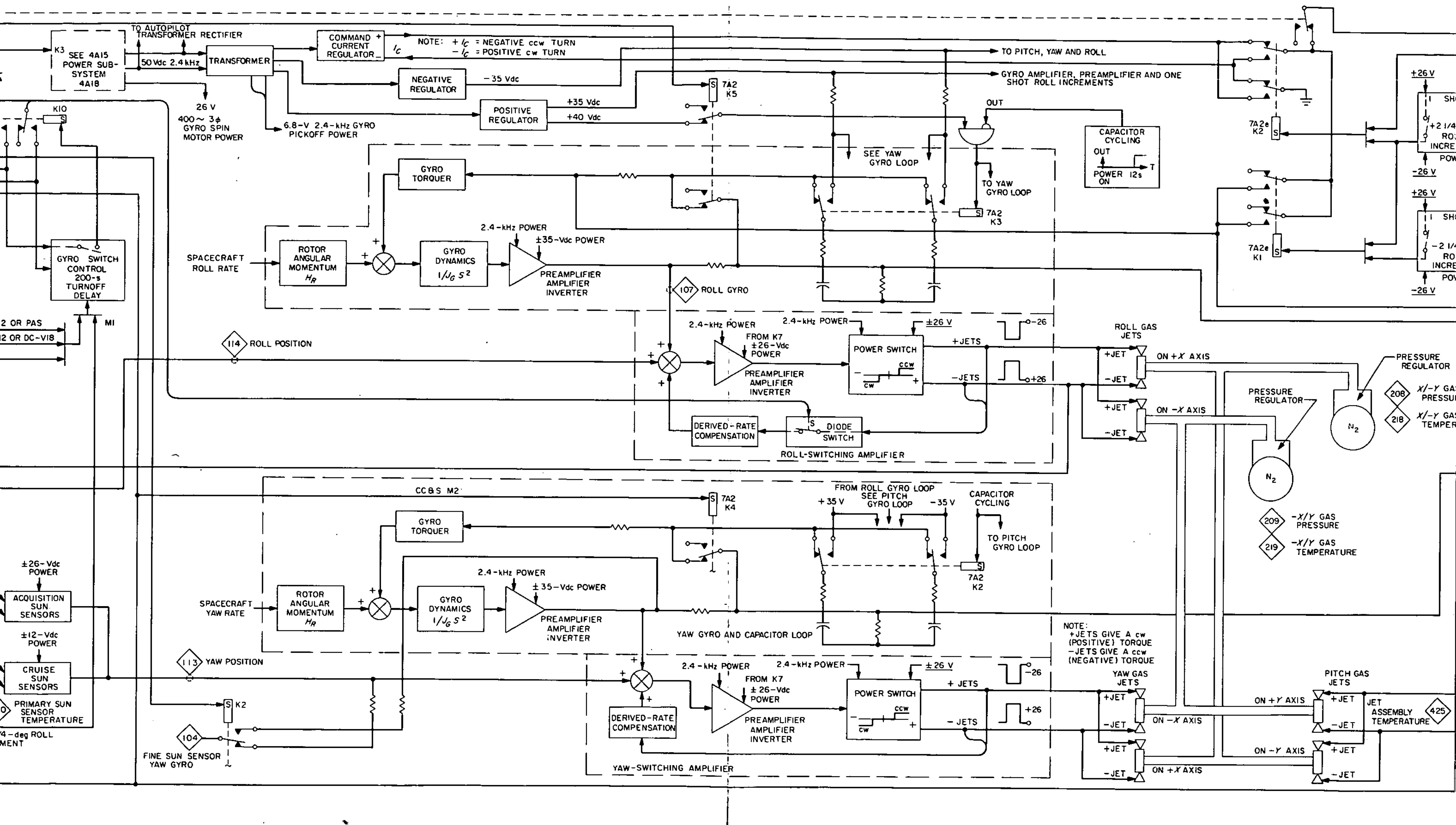
TO AUTOPILOT TRANSFORMER RECTIFIER
K3 SEE 4A15 POWER SUB-SYSTEM 4A18
50 Vdc 2.4 kHz
TRANSFORMER
COMMAND CURRENT REGULATOR
NOTE: $+I_C$ = NEGATIVE ccw TURN
$-I_C$ = POSITIVE cw TURN
TO PITCH, YAW AND ROLL
NEGATIVE REGULATOR
-35 Vdc
GYRO AMPLIFIER, PREAMPLIFIER AND ONE SHOT ROLL INCREMENTS
26 V
400 ~ 3φ GYRO SPIN MOTOR POWER
6.8-V 2.4-kHz GYRO PICKOFF POWER
POSITIVE REGULATOR
+35 Vdc
+40 Vdc
7A2 K5
K10
OUT
CAPACITOR CYCLING
OUT
POWER ON
12s
T
SEE YAW GYRO LOOP
TO YAW GYRO LOOP
7A2 K3
GYRO TORQUER
7A2e K2
7A2e K1
+26 V
-26 V
2.4-kHz POWER
±35-Vdc POWER
SPACECRAFT ROLL RATE
ROTOR ANGULAR MOMENTUM H_R
GYRO DYNAMICS $1/J_G S^2$
PREAMPLIFIER AMPLIFIER INVERTER
107 ROLL GYRO
GYRO SWITCH CONTROL 200-s TURNOFF DELAY
M1
2 OR PAS
2 OR DC-V18
114 ROLL POSITION
2.4-kHz POWER
FROM K7 ±26-Vdc POWER
2.4-kHz POWER
±26 V
POWER SWITCH
+JETS
-JETS
ccw
cw
-26
+26
DERIVED-RATE COMPENSATION
DIODE SWITCH
ROLL-SWITCHING AMPLIFIER
ROLL GAS JETS
+JET
-JET
ON +X AXIS
ON -X AXIS
PRESSURE REGULATOR
N_2
208 X/-Y GAS PRESSURE
218 X/-Y GAS TEMPERATURE
209 -X/Y GAS PRESSURE
219 -X/Y GAS TEMPERATURE
CC&S M2
7A2 K4
FROM ROLL GYRO LOOP SEE PITCH GYRO LOOP
+35 V
-35 V
CAPACITOR CYCLING
TO PITCH GYRO LOOP
7A2 K2
±26-Vdc POWER
ACQUISITION SUN SENSORS
±12-Vdc POWER
CRUISE SUN SENSORS
PRIMARY SUN SENSOR TEMPERATURE
SPACECRAFT YAW RATE
YAW GYRO AND CAPACITOR LOOP
113 YAW POSITION
K2
104
FINE SUN SENSOR YAW GYRO
YAW-SWITCHING AMPLIFIER
NOTE: +JETS GIVE A cw (POSITIVE) TORQUE -JETS GIVE A ccw (NEGATIVE) TORQUE
YAW GAS JETS
PITCH GAS JETS
ON +Y AXIS
ON -Y AXIS
JET ASSEMBLY TEMPERATURE
425

AME 3

Foldout Frame 4

FOLDOUT FRAME 5

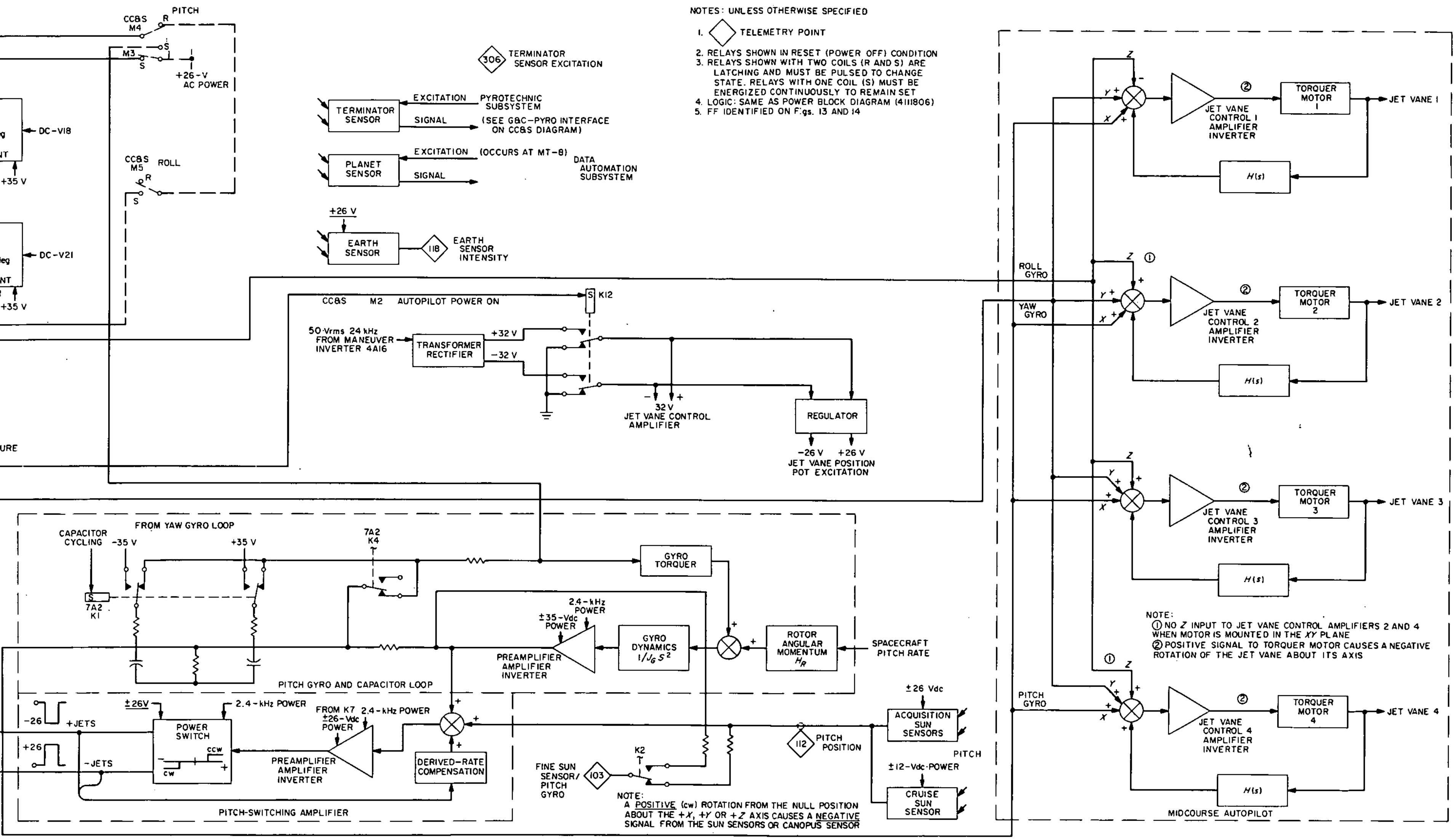

Fig. 15. G&C block diagram: attitude control subsystem

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Abbreviations

A	amperes
ac	alternating current
AC	attitude control
bits/s	bits per second
B/R	booster regulator
CC&S	central computer and sequencer
ft-cd	foot candles
Hz	cycles per second
DAS	data automation subsystem
DC-V	radio direct command
DE	data encoder
E	time of encounter in event sequence
G&C	guidance and control
h	hours
I	time of spacecraft injection in event sequence
kHz	kilocycles
L	output event of CC&S launch clock
M	start of midcourse maneuver in event sequence or output event of CC&S maneuver duration output
MC	output event of CC&S maneuver clock
min	minutes
mrad	milliradians
ms	milliseconds
MT	output event of CC&S end counter
N_2	nitrogen
OSE	operational (ground) support equipment
PS&L	power switch and logic
pulses/s	pulses per second
Pyro	pyrotechnic subsystem
QC-V	radio quantitative command
RF	radio frequency
RPV	roll, pitch, or velocity overflow signal from shift registers
S	time of spacecraft–*Agena* separation in event sequence
s	seconds
T	time of launch in event sequence
TWT	traveling wave tube
TM	telemetry
V	volts
Vdc	volts, dc
Vrms	volts, root mean square
W	watts
ϕ	phase

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