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PREFACE

This report describes the system, spacecraft, and ground installation design, as well as related studies, for the ITOS D and E meteorological satellite system. The ITOS D and E design study program has been conducted by the Astro-Electronics Division of RCA Corporation for the Goddard Space Flight Center of the National Aeronautics and Space Administration, under contract NAS5-10306.

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SECTION VII

DATA HANDLING

A. INTRODUCTION

This section presents a functional description and the principal characteristics of the data handling equipment. The data handling equipment is listed below:

- Scanning radiometer processors (SRPR)

  There are two processors associated with each scanning radiometer. Both processors are packaged together as a dual unit.

- Very high resolution radiometer processor (VHRRP)

  There is one unit.

- Digital data processors (DDP)

  There are two redundant units. Both processors are packaged together as a dual unit.

- Scanning radiometer recorders (SRR)

  There are three redundant units. Each recorder is composed of a transport assembly and an electronics unit.

- Very high resolution radiometer recorder (VHRRR)

  There is one unit. The recorder is composed of a transport assembly and an electronics unit.

The SRPR serves to format and condition the scanning radiometer (SR) signals for recording on any of the three SR recorders (SRR's). In addition, it contains the interface between the SR recorder and the real-time vhf transmitter.

The VHRRP has three functions, (1) to format and condition the very high resolution radiometer (VHRR) signals for transmission via the real-time S-band link, (2) to format VHRR data for recording on the VHRRR and (3) to channel the data from the multiplexer to the selected S-band transmitter during ground-commanded playback.

The DDP serves to collect, format, and route to the operating SRR, the following digital data:

- Vertical temperature profile radiometer (VTPR) data
- Solar proton monitor (SPM) data
- Housekeeping telemetry, digitized within the DDP

In addition, the DDP serves as an analog commutator for beacon link housekeeping telemetry.

The scanning radiometer recorder (SRR) provides the storage capability for the data from the scanning radiometer (SR) and the digital data processor (DDP). The very high resolution radiometer recorder (VHRRR) provides the storage capability for the data from the very high resolution radiometer (VHRR).

B. SCANNING RADIOMETER PROCESSOR

1. General

The SR processor (SRPR) is designed to interleave the scanning radiometer's video data with telemetry data (generated within the radiometer and SRPR) in order to efficiently utilize the spacecraft's available communication channel bandwidth. The SRPR also forms the necessary interfaces between the scanning radiometers (SR's), the SR recorders (SRR) and the real-time vhf transmitters of the spacecraft. Two complete SRPR's, each associated with one SR, are contained within one dual SRPR module. Only the processor associated with the radiometer in use will operate at a given time. Each processor consists of a dual commutator, a balanced am modulator, and a 7-pulse sync generator to identify the start of radiometer data.

a. FUNCTIONAL DESCRIPTION

The SRPR real-time modes of operation are described in paragraphs (1) and (2). Each mode is initiated upon receipt of a ground signal from one of three independent switching transistors within the CDU.

(1) MULTIPLEX MODE

The SRPR is used to subcommutate the radiometer's and SRPR's telemetry signals with the radiometer's visible and infrared (IR) data. Separate commutators are used for the IR and visible channels together with their respective telemetry signals.

The input data from the radiometer consists of a video signal, band-limited to 1200 Hz (visible channel) with a voltage-calibration staircase and synchronization pulse inserted (refer to Figure VII-1). The processor generates and adds a 7-pulse, 300-Hz square wave synchronization signal to the IR and visible signals during the dc restore period, before they are subcommutated with telemetry. The resultant composite video signals are supplied, via cross-strapping, to three redundant SRR's. Within a selected recorder, the composite IR and visible signals are fed, individually, to spatially separated recording

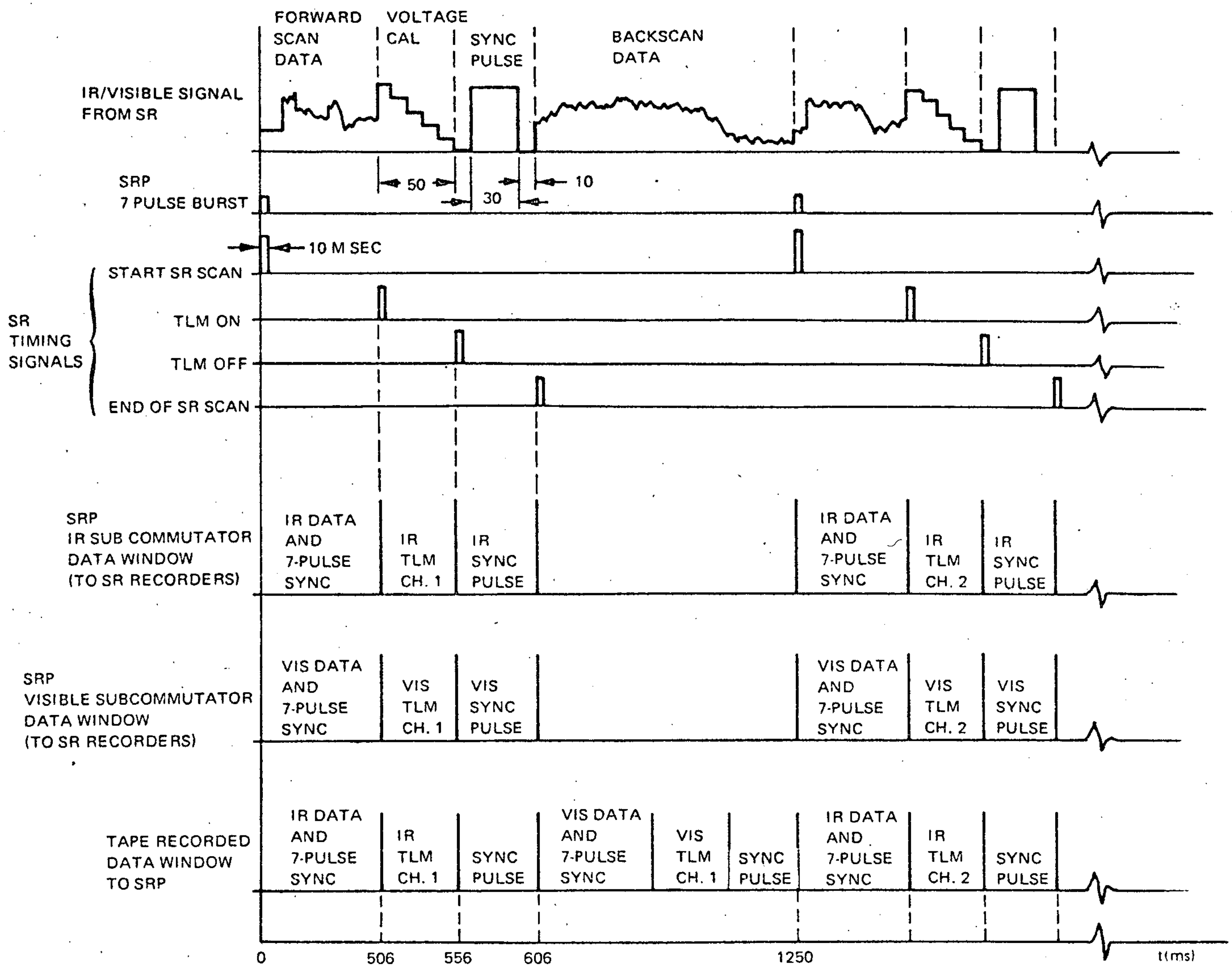


Figure VII-1. SRPR Input-Output Data Format heads which modulate a single track. The recorded signal is read, during recording, by a single playback head to provide the SRPR with a time-division multiplexed input signal of visible, IR, and telemetry information for subsequent input to the processor's 2400-Hz modulator.

The telemetry signals interleaved with video data within the commutators consist of various housekeeping and status signals generated within the radiometer and SRPR. Two additional telemetry signals are directed to telemetry time slots. They are the spacecraft's 120-Hz time code, buffered within the processor to 400 Hz, and the amplitude of the backscan data on the IR channel. Refer to Table VII-1 for commutator channel assignments.

The am modulator operates at a carrier frequency of 2.4 kHz generated within the time base unit (TBU) and serves to modulate the spacecraft's 137-MHz transmitters with SR processed data.

(2) IR/VISIBLE BACKUP MODE

The capability will exist to select either the IR or visible radiometer signals with synchronization (seven pulse burst) to modulate the vhf transmitters instead of the multiplexed IR-Visible-Telemetry signal from a recorder. This ancillary function assures that commutator and/or recorder failures will not preclude direct transmission of radiometer video information.

b. DUAL PROCESSOR

Two SRPR's, each slaved to an SR, are carried aboard the spacecraft for redundancy. Both units are identical with the exception that a minus 5-volt reference is telemetered to indicate that SR number 1 is in service, whereas the in-service voltage reference telemetered for SR number 2 is 0 volts. The video data and telemetry signal list for SR number 1 and the associated timing states of the listed signals are shown in Table VII-1.

2. Requirements

a. FUNCTIONAL OPERATION

A functional block diagram of the SRPR is shown in Figure VII-2.

(1) INPUT/OUTPUT FUNCTIONS

Table VII-2 lists the input and output functions for each side of the dual SRPR.

TABLE VII-1. VIDEO, TELEMETRY TIMING STATES

Timing State	IR Channel Signal	Visible Channel Signal
1	IR	VIS
2	Voltage Cal	Voltage Cal
3	IR	VIS
4	Voltage Cal	Voltage Cal
• • • •	Alternate IR, Voltage Cal	Alternate VIS, Voltage Cal
30	Identifier (100 Hz)	Identifier (600 Hz)
32	Time Code	Time Code
34	SRPR 0 Cal (0V)	SRPR 0 Cal (0V)
36	SRPR FS Cal (-5V)	SRPR FS Cal (-5V)
38	Ref A Temp	Scanner Electronics Temp
40	Det. Temp	Module Electronics Temp
42	Ref B Temp	Ref D Temp
44	Ref C Temp	VIS Calibration Target (Inhibit Command Issued)
46	IR Det Bias	Spare
48	Sample-and-Hold Backscan	Spare
50	RAD No. 1 Identifier (-5V)	RAD No. 1 Identifier (-5V)

Notes: 1. IR data occupies all odd states.
2. Visible data occupies all odd states.

(2) INTERNAL FUNCTIONS

Each half of the SRPR requires:

- two 25 pole commutators to subcommutate IR and visible data with IR and visible telemetry, respectively.
- a 7-pulse, 300-Hz generator signal to be added to both visible and IR channels to provide ground synchronization.

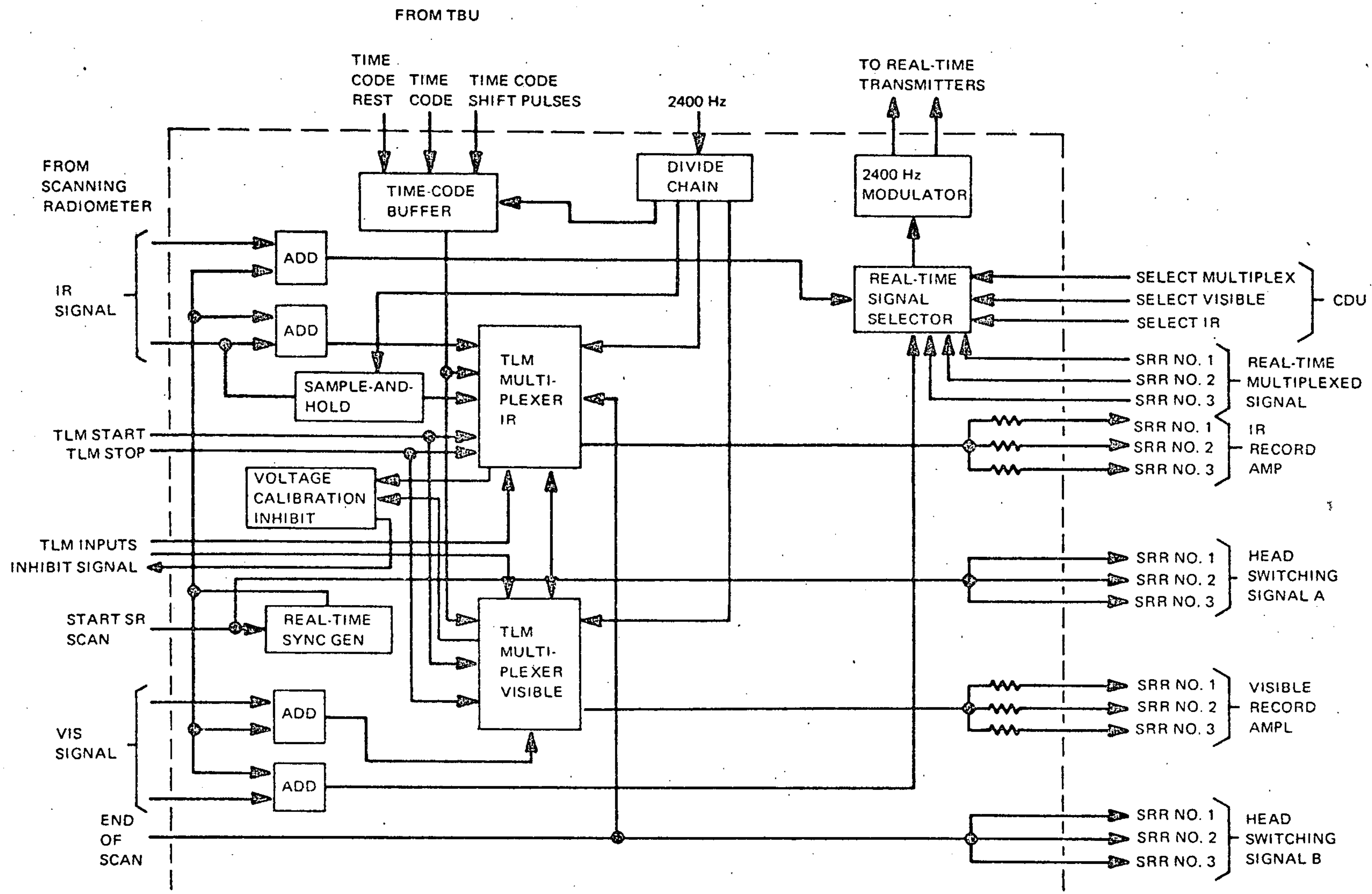


Figure VII-2. SRPR Functional Block Diagram

TABLE VII-2. SR PROCESSOR INPUT AND OUTPUT FUNCTIONS

Input Functions	Output Functions	Mode (CDU Control)
Start SR Scan Telemetry On	IR Composite Signal (3) (to recorders)	Multiplex
Telemetry Off End of SR Scan	Visible Composite Signal (3) (to recorders)	Multiplex
IR Data Visible Data	AM Signal, IR and VIS Composite (2) (to 137 MHz transmitters)	Multiplex
IR Telemetry (8) Visible Telemetry (8)	AM Signal, IR or VIS (2) (to 137 MHz transmitters)	Single Channel Backup
Full-Scale Calibration (2) Zero-Scale Calibration (2)	Visible Channel Voltage Calibrate Inhibit	
Radiometer No. 1 or No. 2 Identifier (2) -24.5 Volts	Head Switching Signal (6) (to recorders)	
Ground ( ) Select Multiplex Signal	Test Point	
Select IR Signal Select Visible Signal	Spacecraft Housekeeping Telemetry (2) (to DDP)	
-24.5 Volt Modulator Power 2.4 kHz Clock		
Time Code		
Time Code Shift Pulses Time Code Rest		

- a time-code buffer to allow the 24 bit time code (200 ms duration) to be inserted into a 50 ms telemetry window.
- a 100 and 600 Hz square wave generator to identify IR and visible channel multiplexed data, respectively.
- a 50 ms voltage calibration inhibit signal to inhibit the visible channel voltage calibrate signal once per 25 scan lines and allow the visible calibration target signal to be passed instead. (This pulse is available from the logic associated with the dual commutator.)
- a sample-and-hold network so that the amplitude of the backscan data on the IR channel can be telemetered via a telemetry window. This data is used for radiance calibration.
- Cross-strapping between each half of the dual SRPR and the three SR recorders.
- A real-time signal selector to supply multiplexed, IR (plus sync) or visible (plus sync) data to the SRPR's balanced modulator. The operating mode is determined by the CDU.

- a balanced modulator with associated limiting, filtering, and buffering to modulate the 137 MHz. Spacecraft transmitters.

(3) COMMUTATOR

Each half of the SRPR contains two commutators of 25 telemetry gates each. The sequencing of the commutation gates is controlled by a 6-stage counter and steering logic to provide interleaving of the radiometer data with telemetry. The telemetry and scan-line on-off pulses are stored and gated to provide identical timing windows for IR and visible data as shown in Figure VII-1.

The telemetry ON pulse advances the counter one count while the logic disables the video output of the radiometer and enables the output of the selected commutation gate. The telemetry OFF pulse re-enables the video output and disables the telemetry gate. The outputs of the video and sync gate and the 25 telemetry gates are summed and distributed to the SRR's as shown in Figures VII-1 and VII-3.

(4) SEVEN-PULSE SYNC GENERATOR

Each of two circuits (one associated with each radiometer) generates a 7-pulse train at a frequency of 300 Hz and inserts it at the beginning of each scan line of both the IR and visible data. The pulse train is synchronized by means of the Start SR Line scan pulse. The sequencer controls the generation of the 7-pulse train, its insertion into the data stream, and its termination.

(5) TIME-CODE BUFFER

The time-code (TC) buffer circuit accepts the spacecraft's 24-bit NRZ time-code of 200-ms duration and processes it to provide a 50-ms duration signal at 400 Hz for transmission via the SRPR's commutated telemetry slot. Fifty ms is not a sufficient time interval for all 24 bits to be transmitted, therefore, the time-code bits will be distributed over both the IR data telemetry slot and the visible data telemetry slot (commutator position 16) in the following manner. The IR telemetry slot will contain the least significant 19 or 20 time code bits, while the visible telemetry slot will contain bits 9 through 24 of the time code followed by zeroes (3 to 4) to fill up the time slot. Figure VII-4 is a block diagram of the proposed time-code buffer. The time from start of line scan to start of telemetry time slot is 506 ms. During this time period, the buffer logic looks for the Time Code Rest pulse. At the termination of this pulse, an Update TC signal is generated which allows TC data to be shifted into the buffer register at a 120-Hz rate. The next occurrence of the TC Rest pulse

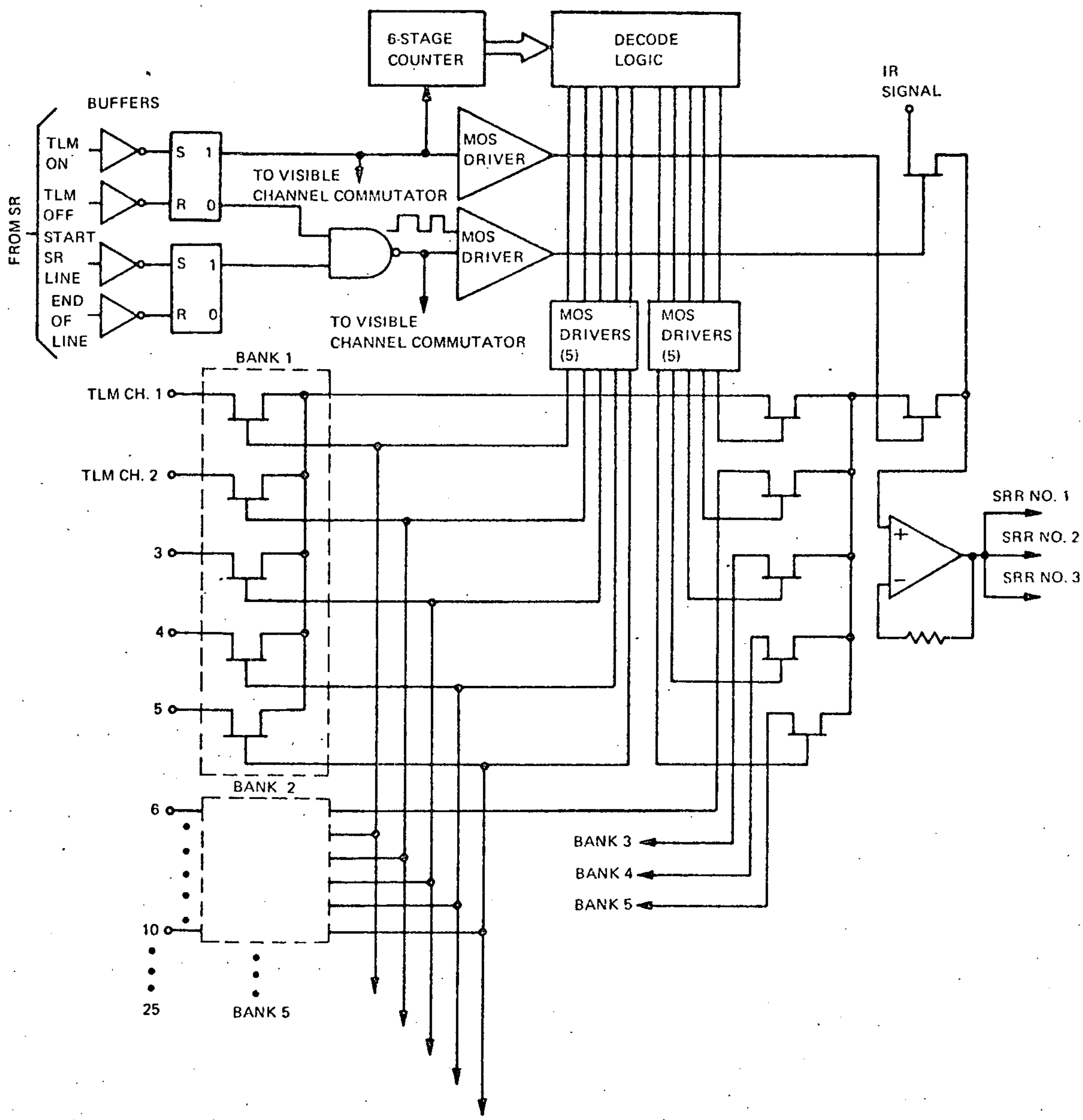


Figure VII-3. IR Channel Commutator, Simplified Diagram

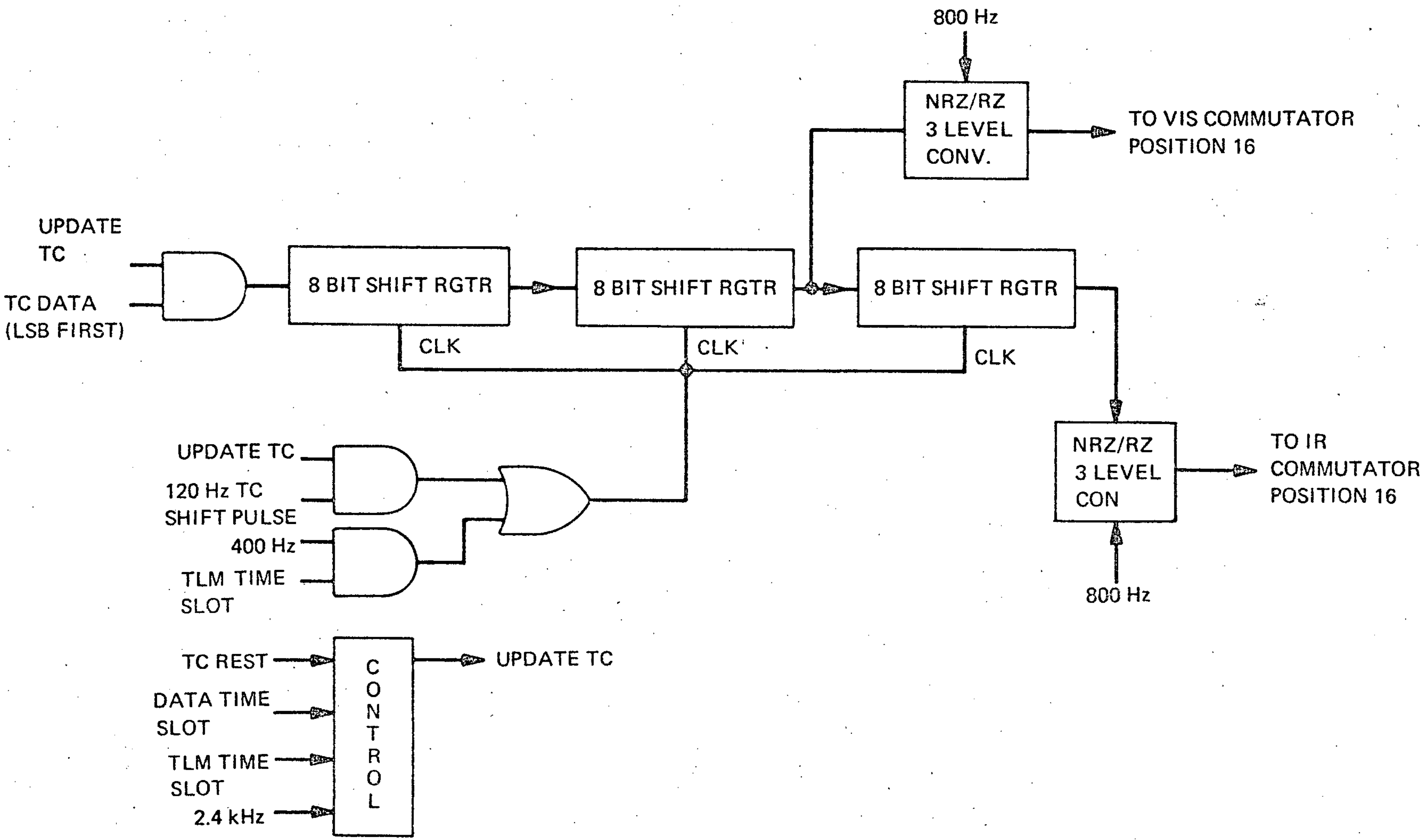


Figure VII-4. Time-Code Buffer, Block Diagram indicates that 24 bits of data have been transferred, and the Update TC signal is terminated. When the telemetry time slot occurs, a 400-Hz clock is enabled to shift data out to the commutators. An eight bit offset is provided in the data by tapping off an interior section of the 24-bit shift register for the visible commutator time code.

(6) EIGHT-STAGE DIVIDE CHAIN

An eight-stage counter is used to generate clock pulse signals for various components of the SRPR in addition to the 100- and 600-Hz, IR and visible channel identifiers, respectively. A simplified block diagram of the eight-stage divide chain is shown in Figure VII-5.

The 800- and 400-Hz signals are used in the time-code buffer system. The 20-Hz clock is used to drive the sample-and-hold circuit.

(7) SAMPLE-AND-HOLD NETWORK

The sample-and-hold network provides one 50 ms sample per commutator frame of the IR data during the backscan period. This signal is synchronized by means of the End Of SR Line pulse. The appropriate delay (200 to 250 ms) is provided by a 3-stage counter clocked at 20 Hz and whose output is decoded and subsequently applied to the hold network. A simplified block diagram of the sample-and-hold network is shown in Figure VII-6.

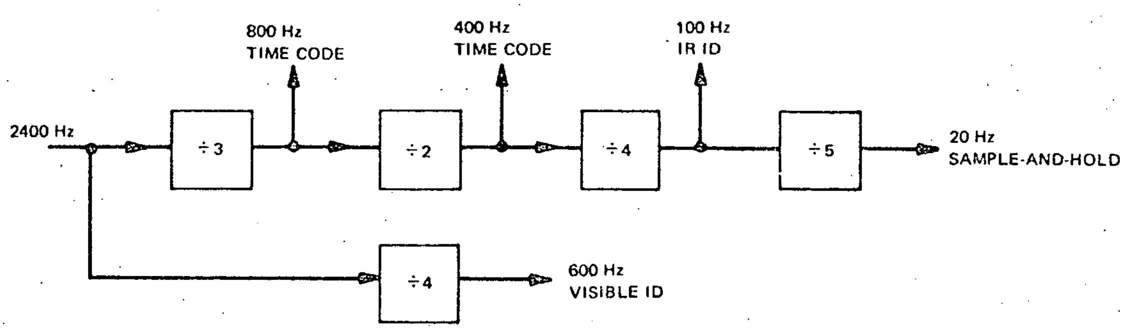


Figure VII-5. Eight-Stage Divide Chain, Simplified Block Diagram

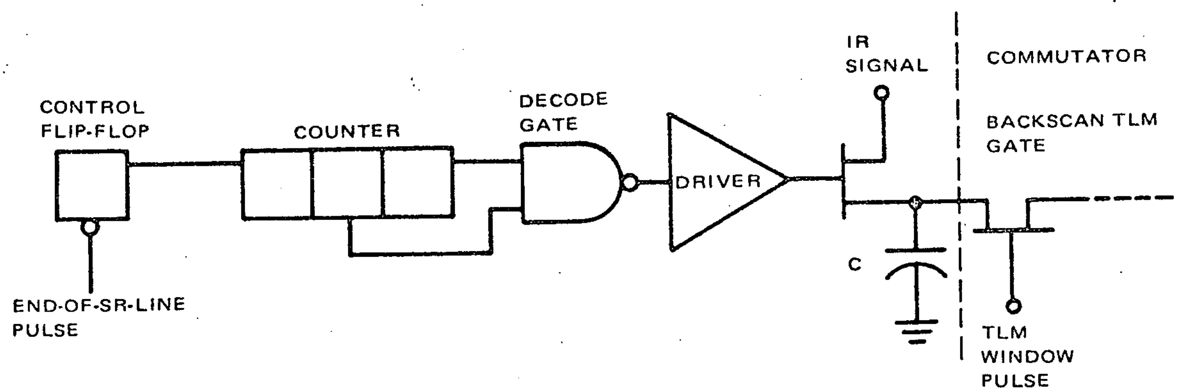


Figure VII-6. Sample-and-Hold Network, Simplified Block Diagram

(8) SIGNAL-SELECT NETWORK

The command distribution unit (CDU) has control of the SRPR's operating mode. Three modes of operation are possible. They are:

- Select multiplexed data only (real-time),
- Select IR (plus sync) data only (real-time), and
- Select visible (plus sync) data only (real-time).

A simple data selection network is shown in Figure VII-7.

(9) BALANCED MODULATOR SYSTEM

The balanced modulator system consists of a limiter, modulator, filter, and buffer. The limiter prevents overmodulating the spacecraft's transmitters and hence excessive generation of spurious sideband components in the modulator's output. The filter further reduces the odd harmonics of the fundamental generated within the modulator. A block diagram of the balanced modulator system is shown in Figure VII-8.

b. INPUT/OUTPUT INTERFACE SIGNALS

The SRPR will have the following interfaces with the scanning radiometer, SR recorders, and the vhf transmitters. Each half of the dual SRPR will be connected to its associated radiometer.

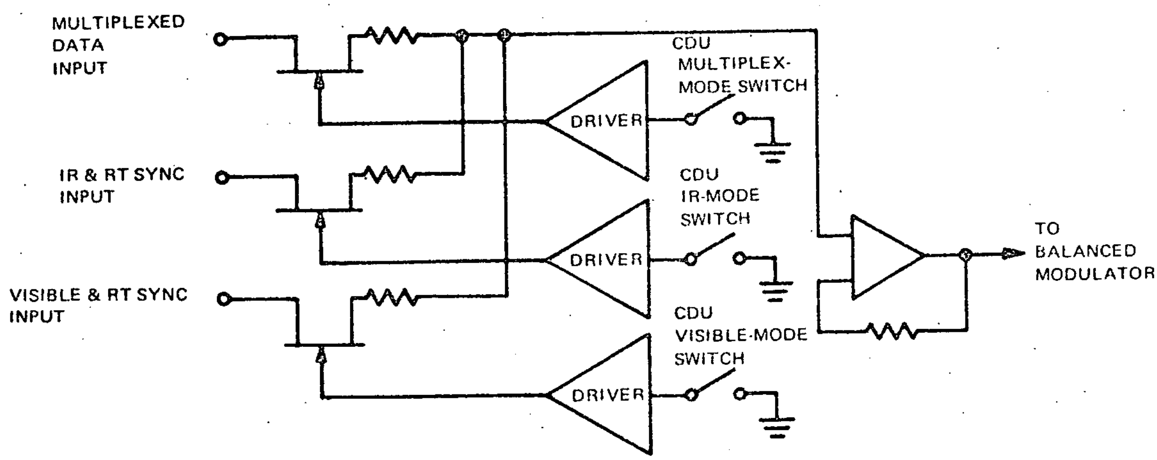


Figure VII-7. Signal-Select Mode Network

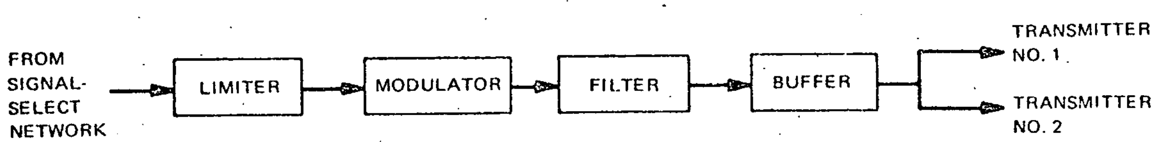


Figure VII-8. Balanced Modulator System, Block Diagram

(1) INPUT SIGNALS

From each SR to its associated processor:

1. IR Channel Output No. 1
2. IR Channel Output No. 2
3. VIS Channel Output No. 1
4. VIS Channel Output No. 2
5. Start SR (Scan) Line. This timing pulse will initiate the Real Time Synchronization pulse.
6. TLM (Window) Start. This timing pulse occurs after the earth scan is completed, about 500 milliseconds after the Start SR Line.
7. TLM (Window) Stop. The timing pulse indicates the start of the Post Earth Synchronization signal. The time between TLM Start and TLM Stop, nominally 50 milliseconds, is the telemetry window.
8. End of Scan Line. The End of Scan Line timing signal indicates the completion of the Post Earth Sync signal. The period between Start SR Line and End of Line signals is the useful scan period which is to be recorded on the tape recorders.
9. Reference A Temperature Sensor TLM
10. Reference B Temperature Sensor TLM
11. Reference C Temperature Sensor TLM
12. Reference D Temperature Sensor TLM
13. Detector Temperature Sensor TLM
14. Scanner Electronics Temperature TLM
15. Electronic Module Temperature TLM
16. IR Detector Bias Voltage TLM
17. -24.5 volt power. Power is applied to one half of SR processor when power is switched on in SR electronics.

From time base unit (TBU); 1 set of inputs for each half of the dual SRPR

18. Time Code
19. Time Code Rest

20. Time Code Shift pulses

21. 2400 Hz Square Wave signal

From SR recorders; one set of inputs to each half of SRPR

22. Real-Time Multiplexed Signal from SRR No. 1

23. Same as 22, except from SRR No. 2

24. Same as 22, except from SRR No. 3

From command distribution unit (CDU); one set of command signals per half of SRPR.

25. Select MUX (multiplexed) Mode

26. Select VIS (only) Mode

27. Select IR (only) Mode

(2) OUTPUT SIGNALS

To scanning radiometer; one output per half of SRPR direct to associated radiometer:

1. Visible Channel Voltage Calibration Signal Inhibit

To real time vhf transmitter; one set of outputs per half of SRPR

2. Modulated Signal to RT vhf Xmtr No. 1

3. Modulated Signal to RT vhf Xmtr No. 2

To SR recorders; one set of outputs per half of SRPR

4. IR signal with multiplexed TLM signal to SR recorder (SRR) No. 1

5. Same as 4, except to SRR No. 2

6. Same as 4, except to SRR No. 3

7. Visible signal with multiplexed TLM signals to SRR No. 1

8. Same as 7, except to SRR No. 2

9. Same as 7, except to SRR No. 3

10. Head Switching Signal A to SRR No. 1. Both IR and VIS record heads will start to record at the time this signal is initiated.

11. Same as 10 except to SRR No. 2

12. Same as 10 except to SRR No. 3

13. Head Switching Signal B to SRR No. 1. This timing signal indicates the end of useful scan data. Both visible and IR head should stop recording at this time.

14. Same as 13 except to SRR No. 2

15. Same as 13 except to SRR No. 3

c. TELEMETRY

The Electronics Power On/Off telemetry point is directed to the spacecraft's telemetry system.

3. Electrical Characteristics

a. CIRCUIT ELEMENTS

Low power 54L series TTL logic devices and operational amplifiers such as type μA741 will be utilized, where applicable, within the SRPR, because of their low power requirements and space-proven reliability at operating voltages presently available within the spacecraft.

b. POWER REQUIREMENTS

In the normal operational mode, the SRPR will require approximately 1 watt of power.

4. Physical Characteristics

The dual SRPR will consist of 6 boards and will have an approximate total weight of 6 pounds.

C. VERY HIGH RESOLUTION RADIOMETER PROCESSOR

The very high resolution radiometer processor (VHRRP) is required to place the analog infrared (IR) and visual (VIS) signals received from the very high resolution radiometer (VHRR) electronics package into a format suitable for transmission over the real-time S-band communication link. Also, the VHRRP must supply the VHRR output signals to the VHRR recorder with spacecraft time code information gated into the video at the start of each record cycle.

In addition, the VHRRP is to direct, during playback, the output of the dual multiplexer (MUX) to the S-band transmitter that has been selected for use. A block diagram of the processor configuration is shown in Figure VII-9. The following paragraphs describe the operation of the VHRRP in performing the three functions listed above.

1. Real-Time Processing of VHRR Video

There are two major real-time VHRRP operating modes, the normal mode and the back-up mode. In the normal mode a time-multiplexed (IR 1-VIS 2 or IR 2-VIS 1) signal will be present at the input to either VCO 1 or VCO 2. A 230-kHz subcarrier is frequency modulated with the 35-kHz video information (35-kHz peak deviation). The fm signal is then linearly translated down in frequency to yield an effective fm subcarrier at 80 kHz. A 150-kHz reference tone from the time base unit (TBU) is used for this translation.

The translated fm spectrum is sent to the signal routing unit (SRU) in the VHRRP where it is directed to the summing amplifiers. Only the summing amplifier associated with the selected S-band transmitter will be powered. Since there are two time-multiplexed waveforms and two transmitters that may be chosen, there are four sub-modes which may be selected.

In the back-up mode, the IR and VIS signals come from the same radiometer (IR 1 and VIS 1 or IR 2 and VIS 2). These signals are not time-multiplexed, as in the normal mode, but are available at separate inputs to the VHRRP. The IR signal is sent to one VCO and the VIS signal is sent to the other. The fm spectrum associated with the IR signal is translated to a lower frequency range (as in the normal mode) while the VIS spectrum is left at 230 kHz. Both fm spectra are sent to the SRU where they are summed, with different gain factors used to produce the proper deviations in the S-band transmitter. The summed signal is then sent to the summing amplifiers where it is directed to the selected S-band transmitter. Again there are two choices for input signal and two transmitter choices, so the back-up mode consists of four sub-modes. Table VII-3 summarizes the eight sub-modes described above.

The routing of the VHRR input signals to the proper VCO, the routing of the fm subcarrier signals through the SRU to the proper VHRRP output, and the application of power to only those VHRRP functions required for the selected sub-mode are controlled by signals from the CDU.

There are four mode selection signals: IR 1 - VIS 2 Mode, IR 2 - VIS 1 Mode, IR 1 - VIS 1 Mode, and IR 2 - VIS 2 Mode. An "ON" pulse on one of these input lines indicates which pair of sub-modes has been selected. These pulses are used to switch latching relays that route the power and signals as outlined in Table VII-3.

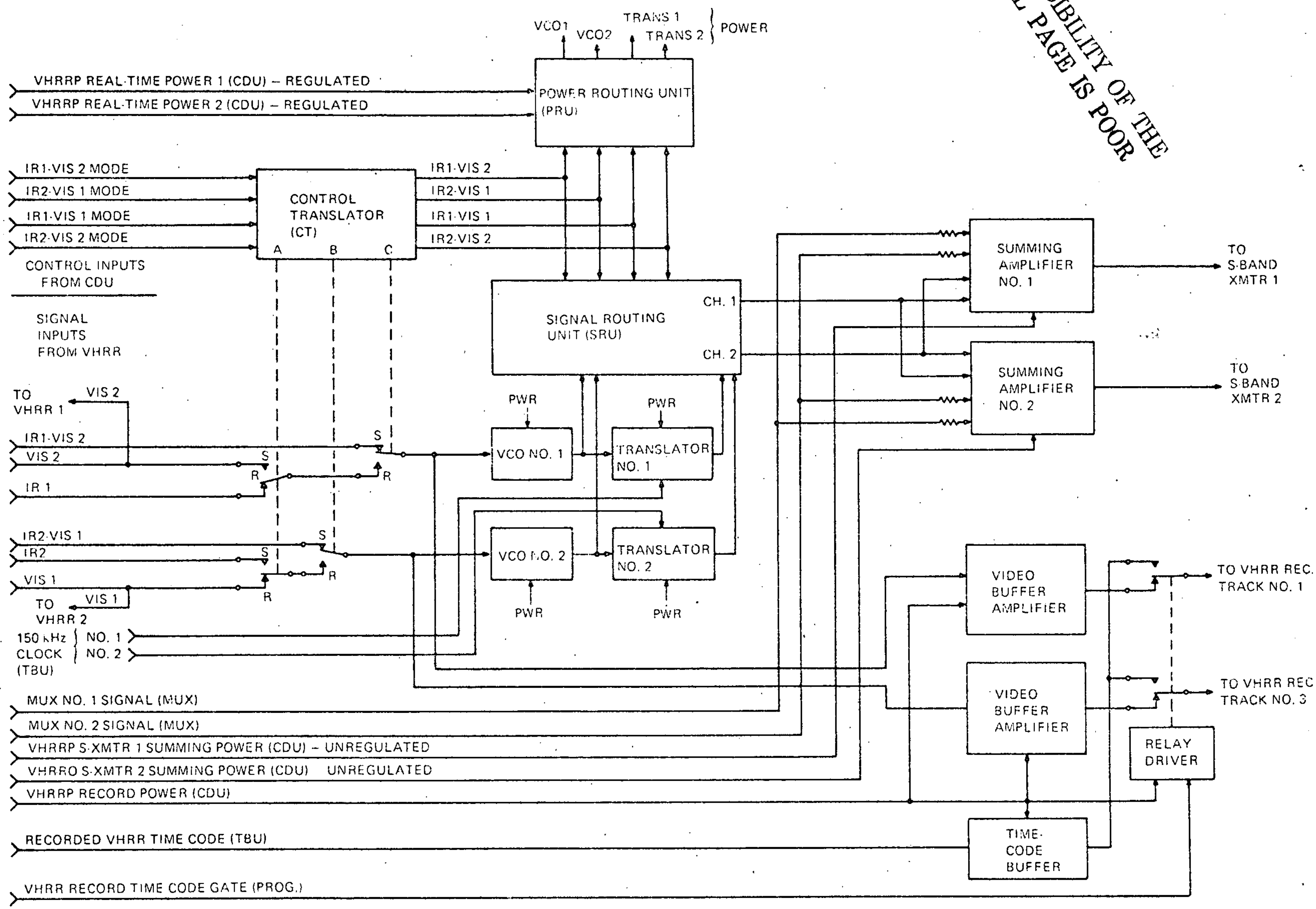


Figure VII-9. VHRR Processor Configuration

TABLE VII-3. VHRRP REAL-TIME OPERATING MODES

Mode	Sub-Mode Designation	No. of Subcarriers	Signal Present at Input to		S-band Xmtr Selected	Data on Subcarrier at		Signal Processing Units On
			VCO 1	VCO 2		80 kHz	230 kHz	
NORMAL	1a	1	IR 1 - VIS 2	None	1	IR - VIS	None	VCO 1, Translator 1
	1b	1	IR 1 - VIS 2	None	2	IR - VIS	None	VCO 1, Translator 1
	2a	1	None	IR 2 - VIS 1	1	IR - VIS	None	VCO 2, Translator 2
	2b	1	None	IR 2 - VIS 1	2	IR - VIS	None	VCO 2, Translator 2
BACK UP	3a	2	IR 1	VIS 1	1	IR	VIS	VCO 1, Translator 1 VCO 2
	3b	2	IR 1	VIS 1	2	IR	VIS	VCO 1, Translator 1 VCO 2
	4a	2	VIS 2	IR 2	1	IR	VIS	VCO 1, Translator 2 VCO 2
	4b	2	VIS 2	IR 2	2	IR	VIS	VCO 1, Translator 2 VCO 2

There are two transmitter control signals: VHRRP S-Band XMTR 1 SUMMING POWER and VHRRP S-band XMTR 2 SUMMING POWER. An unregulated bus voltage level on one of these lines will indicate that a certain S-band transmitter has been powered for use. These signals are each used to power one summing amplifier and thereby send the desired signal to the proper S-band transmitter.

There are also two real-time power signals: VHRRP REAL-TIME POWER 1 and VHRRP REAL-TIME POWER 2. The POWER 1 signal supplies power to those functions associated with the processing of IR 1 data, while the POWER 2 signal supplies power to those functions associated with the processing of IR 2 data.

The four control signals described above are directed to the control translator (CT) function. The CT uses these control signals to power latching relays which route the VHRR signals to the proper VCO. These control signals are also sent to the power routing unit (PRU) and SRU.

The PRU routes regulated power to those VCOs and translators required in the selected sub-mode. As indicated before, the SRU routes the translated fm subcarrier, or adds and routes the translated and untranslated fm subcarriers to the summing amplifiers. The SRU also adjusts the level of the signals it processes to effect the required S-band transmitter deviations. Table VII-4 operating modes. The output signal levels are based on a 500 kHz/volt transmitter deviation sensitivity.

TABLE VII-4. S-BAND TRANSMITTER DEVIATIONS FOR THE VHRRP OPERATING MODES

Mode Description		Deviation Required (kHz)	VHRRP Output Signal Level (volts)
One Subcarrier	80 kHz	300	0.60
Two Subcarriers	80 kHz	50	0.10
	230 kHz	150	0.30

Figures VII-10, VII-11, and VII-12 show schematic representations of the CT, SRU, and PRU functions, respectively. Figure VII-13 shows, in more detail, the VCO and translator signal conditioning functions.

2. VHRR Video Recording

Another function of the VHRRP is to supply the video signals from the VHRR to the VHRR recorder during the record mode. The input to each VCO is buffered, fed through the time code relay, and supplied as an output to the VHRRR (one output to each recorder track). Upon command from the spacecraft programmer (VHRR Record Time Code Gate) the relay is energized and spacecraft time code data (received from the TBU), in a return-to-bias format, is supplied to the VHRRR. Separate power is required for the record circuitry (video buffer amplifiers, time code buffer amplifier, time code relay, and the relays which route the input signals to the VCO's) because record may be initiated when real-time VHRR data is not being processed.

Table VII-5 lists the four IR - VIS modes and the signal which will be recorded on each VHRRR track in that mode.

Figure VII-10 shows schematically the signal routing during both the real-time and record VHRR modes. One restriction imposed by this design of the VHRRP is that during simultaneous real-time/record operation, the same mode must be recorded that is being transmitted to ground.

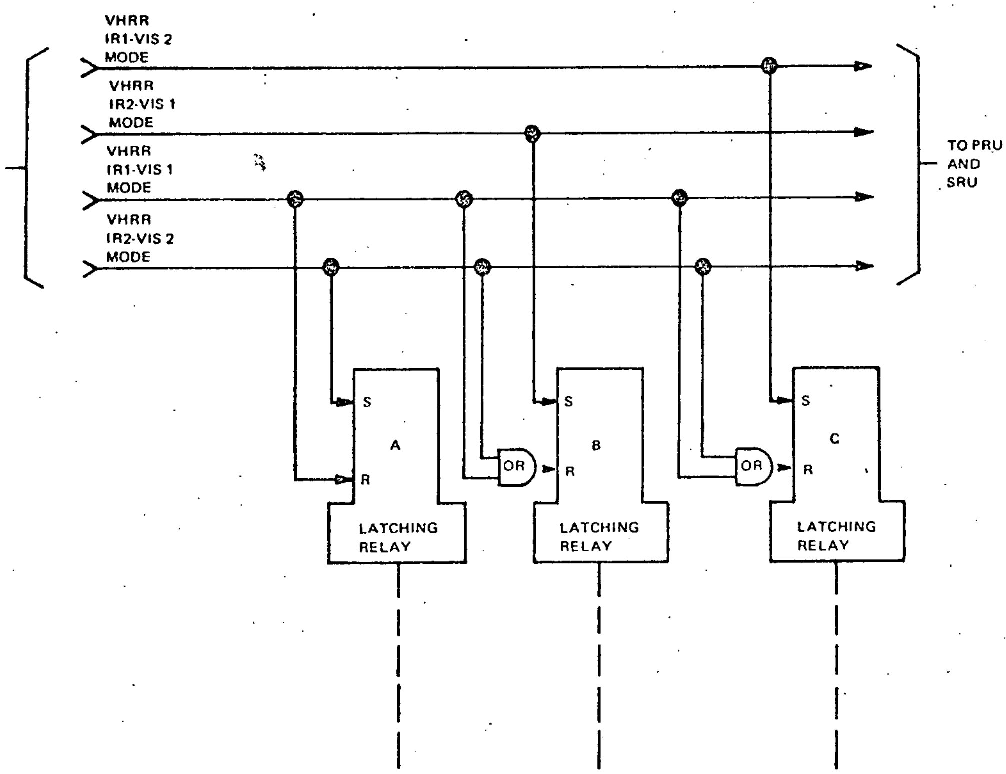


Figure VII-10. Control Translator (CT), Schematic Representation

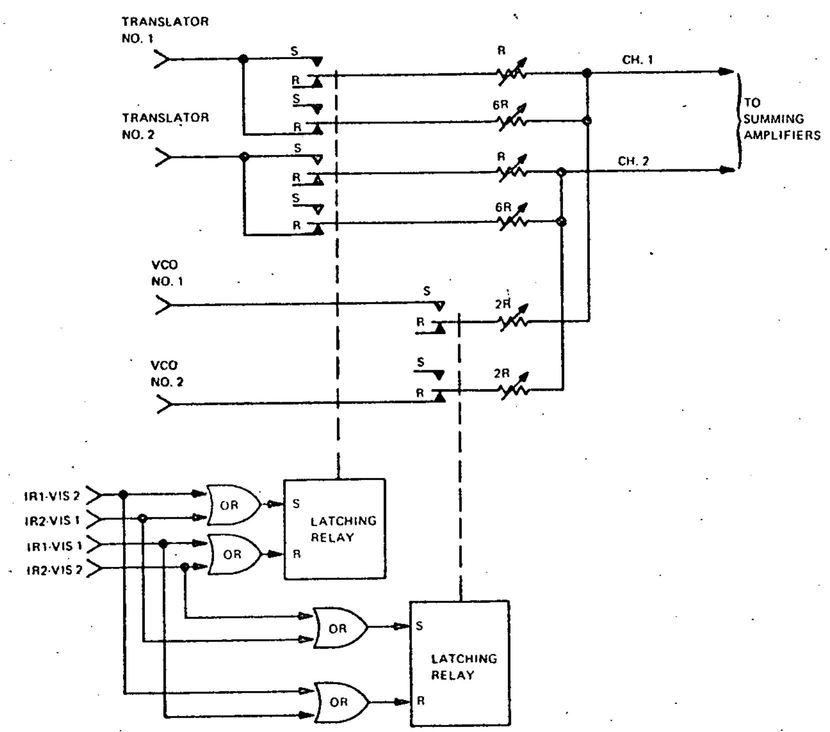


Figure VII-11. Signal Routing Unit (SRU), Schematic Representation

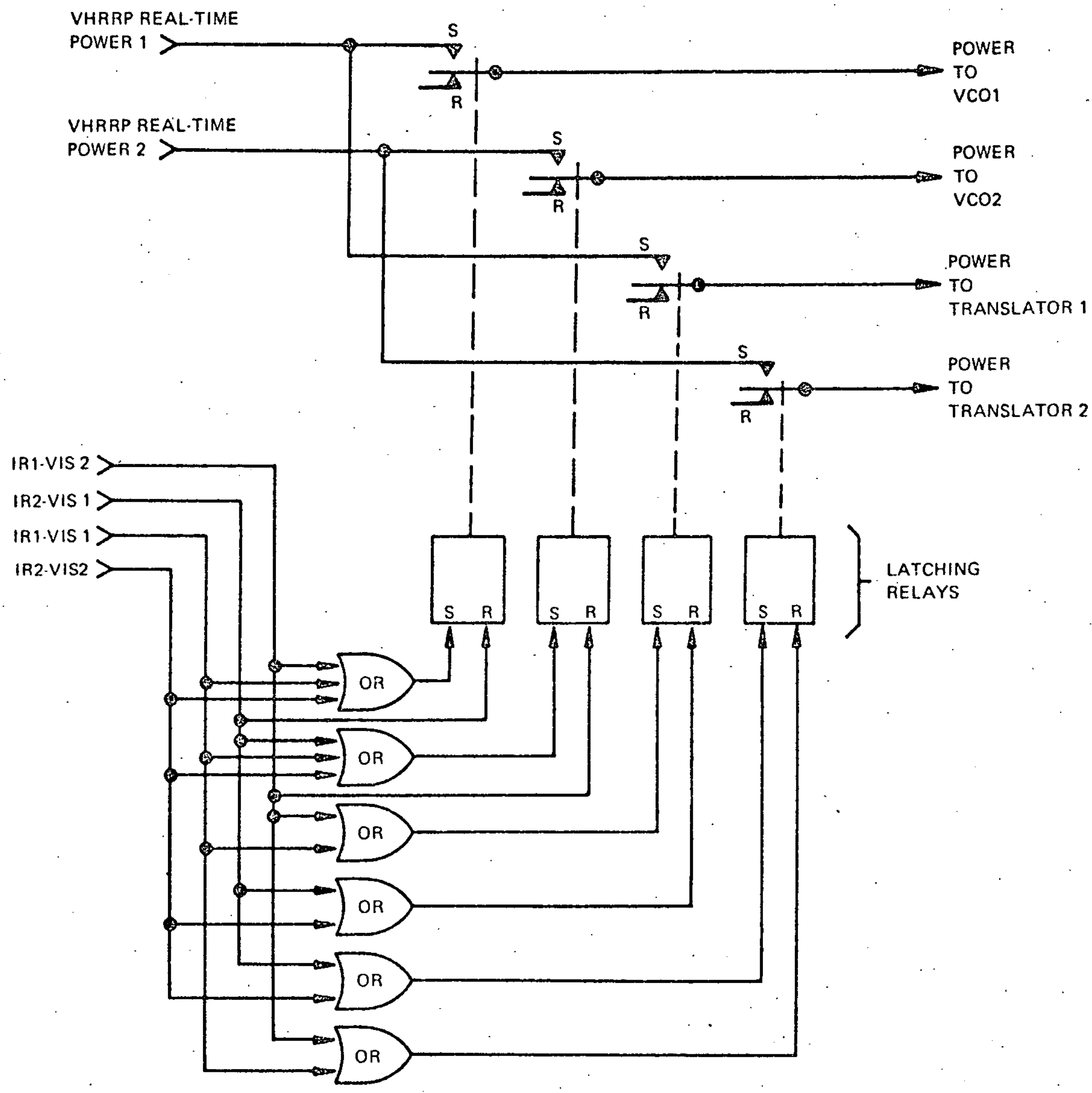


Figure VII-12. Power Routing Unit (PRU), Schematic Representation

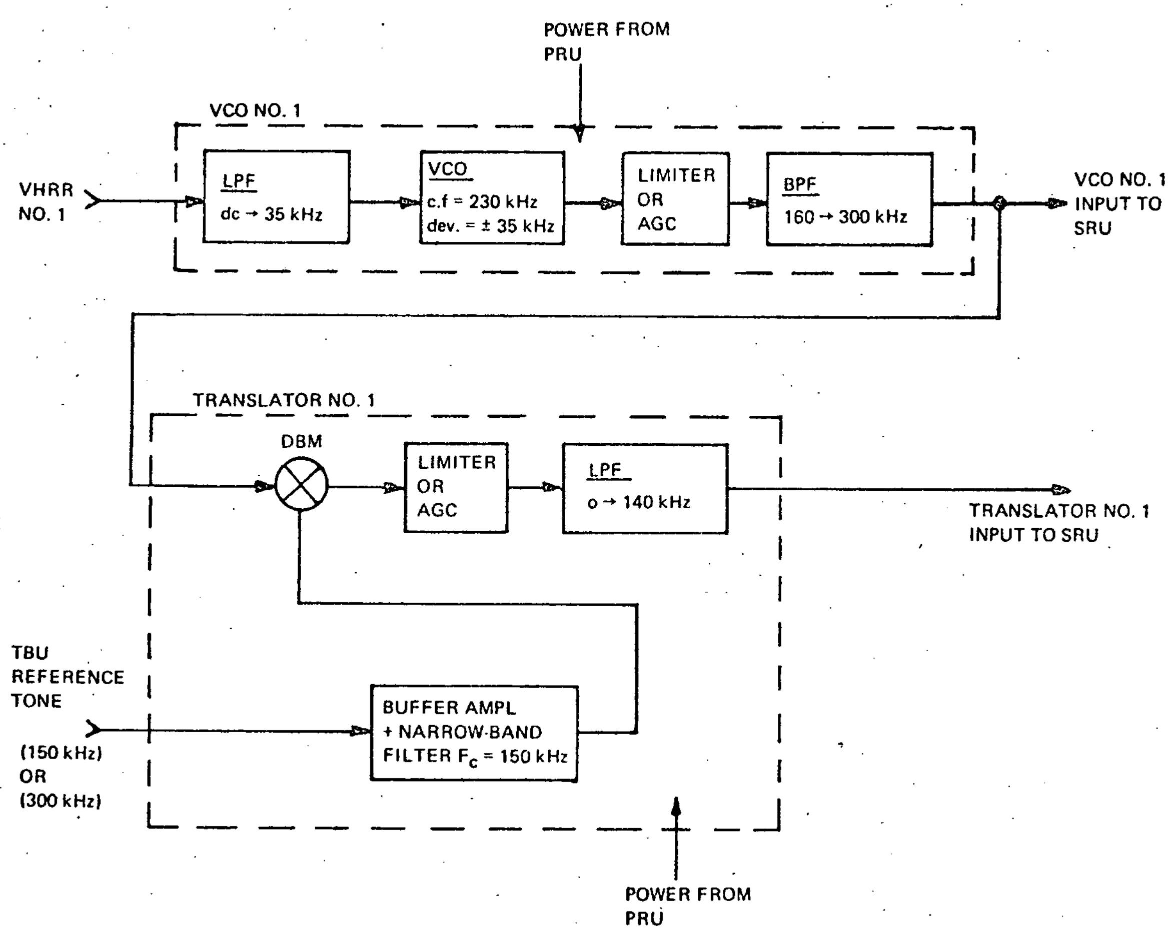


Figure VII-13. Signal Conditioning Functions (Channel No. 1 Only), Block Diagram

TABLE VII-5. SIGNALS SENT TO VHRRR AS A FUNCTION OF MODE SELECTED

Mode Selected	Signal at VHRRR Track 1	Signal at VHRRR Track 3
IR 1 - VIS 2	IR 1 - VIS 2	None
IR 2 - VIS 1	None	IR 2 - VIS 1
IR 1 - VIS 1	IR 1	VIS 1
IR 2 - VIS 2	VIS 2	IR 2

3. Playback

The final function of the VHRRP is to direct the output of the dual multiplexer (MUX) to the selected S-band transmitter during playback of the spacecraft recorders. In playback, there are no real-time power signals present. Therefore, there are no signals at the summing amplifier inputs except for the composite MUX playback signal.

There are two redundant MUX outputs, only one of which is active at any given time. As shown in Figure VII-9, each of these outputs is cross-strapped to both summing amplifiers. The same command which powers the selected S-band transmitter also turns-on the associated summing amplifier. Thus, regardless of which MUX output is active, it will be directed to the proper S-band transmitter. This method of switching is identical to the method used in the TIROS M dual multiplexer except that it has been placed in the VHRRP. This was done so that the summing amplifiers may be used as transmitter drivers for the VHRR signals in real-time, as well as the MUX signals during playback. The signal level of each component in the MUX output is given in the dual multiplexer section of this report.

D. DIGITAL DATA PROCESSOR

1. General Description

a. SYSTEM FUNCTION

The main purpose of the digital data processor (DDP) is to accept data from various systems aboard the spacecraft and to prepare the data for digital recording on a single recorder channel. The data which are multiplexed are:

- Vertical temperature profile radiometer (VTPR) data,
- Solar proton monitor (SPM) data,

- Spacecraft time code, and
- Analog housekeeping telemetry points (digitized by the DDP).

Of these, the VTPR is the most important source of data, and all of the DDP frame timing is based upon the VTPR cycle.

The DDP has a secondary function of generating a real-time telemetry frame containing only housekeeping telemetry points. This signal is already available at the output of the DDP telemetry commutator, before it is digitized for recording. It is buffered and the output goes to the beacon subcarrier oscillator for transmission.

b. FRAME DESCRIPTION

(1) RECORDED DIGITAL FRAME

The DDP frame timing is constrained by the VTPR timing.

The VTPR completes one cycle of operation every 12.5 seconds. Each cycle is divided into 25 time increments consisting of 23 mirror positions plus 2 for flyback time. Each increment is separated into 8 subdivisions for the insertion of various optical filters making a total of 200 subdivisions per cycle. During the time for each subdivision, it is desired to record a 16-bit word of VTPR information on the tape recorder. This means that a total of 16 x 200 = 3200 bits every 12.5 seconds, or 256 bits per second are generated by the VTPR. Since other data is time-multiplexed with the VTPR data, a higher bit frequency of 512 Hz was chosen for the DDP recorded data. Every other word in the frame is a VTPR word as shown in Figure VII-14. One DDP frame takes 12.5 seconds to complete and contains one VTPR cycle.

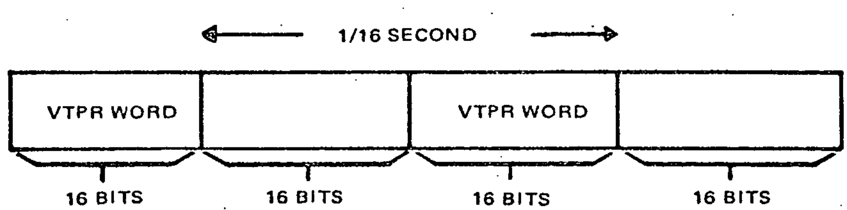


Figure VII-14. Recorded Data Word Sequence

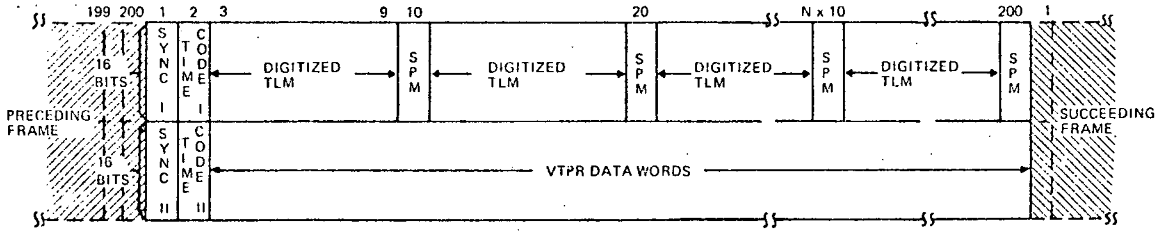


Figure VII-15. Recorded Digital Frame

A complete frame of DDP recorded data is shown in Figure VII-15. The first two words transmitted are Sync I and II as shown in the upper and lower positions of column 1. These words are comprised of a 31-bit maximal length pseudo-random sequence followed by a 32nd bit added at the end of the sequence to complete the two words. The 16th and 32nd bits are chosen to give odd parity to each word. This sync code provides near-optimum performance and has the added advantage of being relatively simple to generate in the spacecraft. The 3rd and 4th words are Time Code I and II which contain 24 bits of time code as shown in Figure VII-16. Odd parity is added by the DDP.

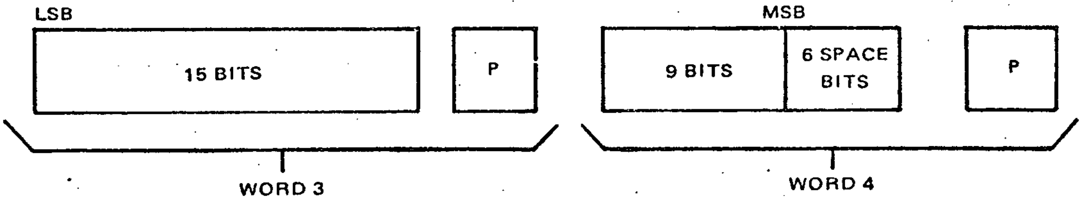


Figure VII-16. Recorded Time Code Words

From this point on in the frame, the upper word in every column is either the digitized output of the telemetry commutator or the SPM data word, while the lower word in each column is the VTPR data word. SPM words are inserted at 10-column intervals in the upper tier of the frame (i.e., once every 20 words). With this arrangement, a complete 20 word SPM frame is contained in each DDP frame. The structure of these three recorded words is shown in Figure VII-17. The VTPR words contain 10 data bits, 5 position bits, and an odd parity bit inserted by the DDP. The SPM words contain 9 bits of data, 6 spare bits, and a parity bit inserted by the DDP. The digitized telemetry words contain 7 bits of data, which define the analog voltage at the output of the telemetry commutator with a precision of 1 part in 128. These bits are followed by an 8-bit address to identify the commutator position. The 8 bits are coded in such a way that two commutator positions correspond to each address. Although a unique addressing technique could be employed, the resulting increase in hardware does not justify the minor system improvement to be gained. Parity is again added by the DDP to complete the 16-bit word.

The recorded telemetry frame and the telemetry words have been defined above; a description of the subsystem synchronization necessary to produce the frame follows.

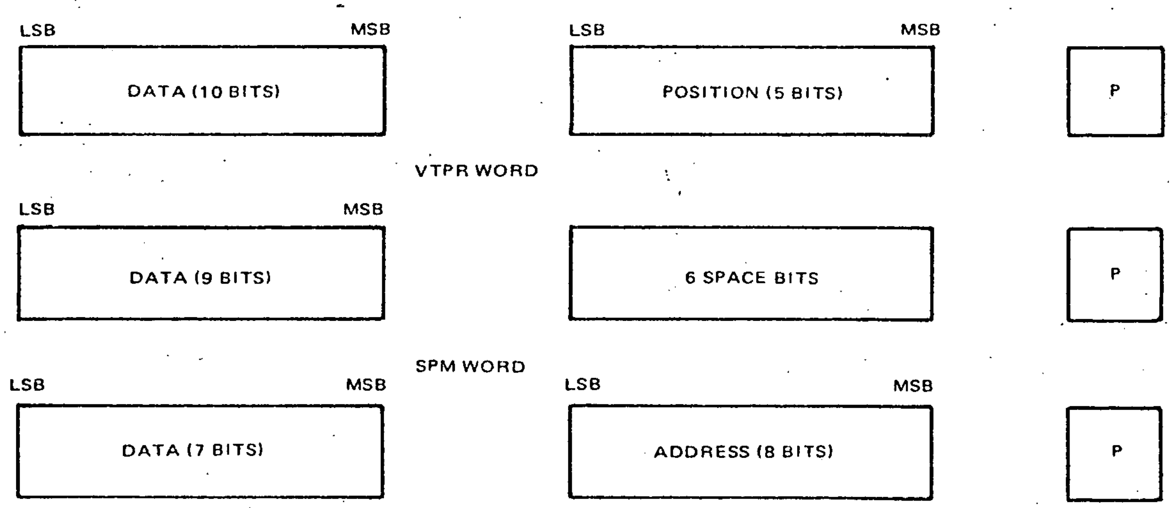


Figure VII-17. Digitized Telemetry Word

During the VTPR flyback time, a frame pulse is sent to the DDP which causes a new frame to be started regardless of what part of the frame the DDP is generating at the time. This causes sync and time code to be inserted into the words that would otherwise be filled with VTPR data, but because of the presence of flyback time, no information is lost. The VTPR then adjusts the timing of its output register so that data is available to be shifted out when VTPR data enable and shift pulses are generated by the DDP. The enable and shift pulse timing is shown in Figure VII-18. Once this synchronization is established, no further adjustment is necessary because the two units share a common source of timing signals and have identical cycling times. This feature is important because during the VTPR calibration mode the frame pulse is inhibited for several frames and synchronization must be maintained.

The DDP supplies a 16-Hz clock to the SPM, which is used for assembling the SPM data. At this rate the SPM can assemble its 9 data bits in 9/16 second (562.5 ms). Once every 20 DDP words, a request for data is made to the SPM. This leaves 19 word times (593.75 ms) for SPM word assembly, which is in excess of the time required. A modification is being made to the SPM which enables it to enter a standby condition after data has been assembled. This condition is maintained until the DDP-generated data enable request occurs during each 20th word. At this time, data from the SPM output buffer register is shifted into the DDP at a 512-Hz rate (see Figures VII-17 and VII-18). The

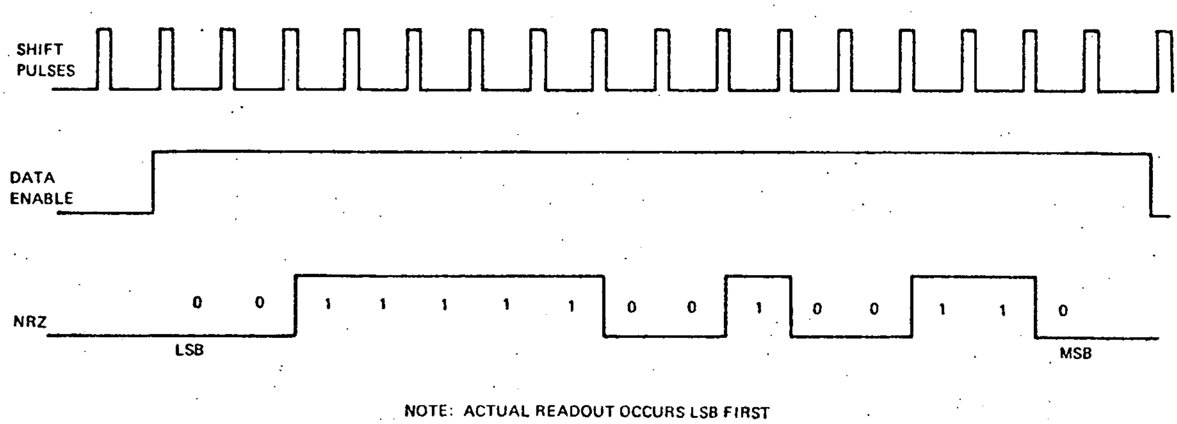


Figure VII-18. Digital Sensor and DDP Interface

DDP is expecting 15 data bits, so the SPM logic has provisions for causing all bits following the 9 data bits to be logical zeros. At the termination of the data request the SPM begins to assemble the next word.

The DDP also provides the SPM with a frame pulse which enables the first SPM word (Barker sync) to be located in the first SPM word position of each DDP frame.

Synchronization of the telemetry words is done automatically. All telemetry inputs are available to the commutator continuously and can be selected for transmission at any time.

The time code is generated every quarter second at a 120-Hz rate. This bit rate is incompatible with the DDP data rate of 512 Hz. Therefore, the DDP has a buffer register to receive and store the time code for transmission at the proper time and rate. Approximately 450 ms before the time code is to be recorded, the register is allowed to update from the time base unit readout. The 450-ms interval guarantees one complete time code readout. Once a complete readout is received, the register input is inhibited and the register stores the data until the DDP shifts it out during the time code word positions of the frame. Thus, synchronization of the time code is achieved.

(2) REAL-TIME TELEMETRY FRAME

The real-time telemetry frame shares the following characteristics with the recorded digital frame:

- The frames are generated simultaneously and both take 12.5 seconds for a complete cycle, and
- Both contain the same telemetry point information.

However, the following characteristics of the real-time frame are different from the recorded frame:

- There is no VTPR, SPM, or time code contained in the frame,
- Only analog levels are contained in the frame, and
- The 32-bit pseudo-random sync is replaced by a voltage-level sync.

A real-time telemetry frame is shown in Figure VII-19. This figure defines the DDP output in the normal mode, which is its operational mode. The numbers at the top of the diagram correspond to the same column numbers as in the digital recorded frame. However, since there is now no VTPR data included, the entire column is devoted to the telemetry data.

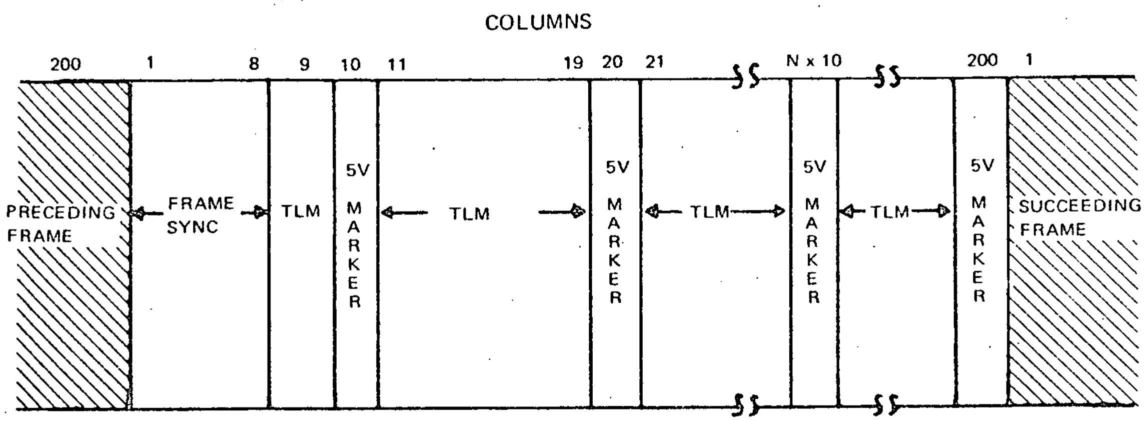


Figure VII-19. Real-Time Telemetry Frame, Normal Mode

The first eight columns of the frame contain -5 volts, which is the most negative signal in the frame, and is easily recognized as level sync at the ground station. The ninth column of the frame contains 0 volt, thus, providing a pronounced transition from the level sync. The tenth column and every tenth column thereafter, which in the recorded frame are devoted to SPM data, contain -5 volts. As a result, these columns serve as markers, dividing the frame into groups which facilitates interpretation of the data at the ground station. The eleventh through the fifteenth columns contain dc voltages for calibrating the system, and the sixteenth column contains a satellite identification voltage. The remaining columns contain analog levels from the telemetry commutator. A list of the commutator inputs with pertinent information can be found in Table VII-6. The digital equivalent of every column of the real-time telemetry frame, with the exception of the first two and the markers, is contained in the upper half of the equivalently numbered columns in the recorded frame.

TABLE VII-6. COMMUTATOR INPUTS FOR REAL-TIME TELEMETRY

Chan. No.	Telemetry Function	Values	Source
1	Frame Sync	-5.0V dc	DDP
2	Frame Sync	-5.0V dc	DDP
3	Frame Sync	-5.0V dc	DDP
4	Frame Sync	-5.0V dc	DDP
5	Frame Sync	-5.0V dc	DDP
6	Frame Sync	-5.0V dc	DDP
7	Frame Sync	-5.0V dc	DDP
8	Frame Sync	-5.0V dc	DDP
9	Calibration	0V dc	DDP
10	Marker	-5.0V dc	DDP
11	Calibration	-0.5V dc	DDP
12	Calibration	-1.5V dc -3.5V dc	DDP 1 DDP 2
13	Calibration	-2.5V dc	DDP
14	Calibration	-3.5V dc -1.5V dc	DDP 1 DDP 2
15	Calibration	-4.5V dc	DDP
16	Satellite I.D.	-4.5V: ITOS D -0.9V: ITOS E	Spacecraft Terminal Board
17	Decoder Selection	0V: Both Off -0.9V: 2 On -2.7V: 1 On	Dec 1 & 2
18	Dec 1 Enable Tone Detector	-3.3V: Enabled -4.3V: Not enabled	Dec. No. 1
19	Dec 2 Enable Tone Detector	-3.3V: Enabled -4.3V: Not enabled	Dec. No. 2
20	Marker	-5.0V DC	DDP
21	Comm Rcvr No. 1 AGC	Curve	Rcvr No. 1
22	Comm Rcvr No. 2 AGC	Curve	Rcvr No. 2
23	Solar Panel No. 1 Current	Curve	PSE
24	Solar Panel No. 2 Current	Curve	PSE
25	Solar Panel No. 3 Current	Curve	PSE
26	Solar Array Voltage	Curve	PSE
27	Unreg Bus Voltage	Curve	PSE
28	Reg Bus Voltage	Curve	PSE
29	Shunt Dissipator Current	Curve	PSE

TABLE VII-6. COMMUTATOR INPUTS FOR REAL-TIME TELEMETRY (Continued)

Chan. No.	Telemetry Function	Values	Source
30	Shunt Lim Contr Amp & Mode Sel	-1.8: CA1 & Mode 1 -2.7: CA2 & Mode 1 -3.7: CA1 & Mode 2 -4.5: CA2 & Mode 2	PSE
31	-24.5V Reg Sel & Chrg Mode	-1.8V: Reg 1 & Trkl Ch -2.8V: Reg 1 & Norm Ch -3.7V: Reg 2 & Trkl Ch -4.4V: Reg 2 & Norm Ch	PSE
32	S.L. No. 1 Diss Temp	Curve	PSE
33	S.L. No. 2 Diss Temp	Curve	PSE
34	S.L. No. 3 Diss Temp	Curve	PSE
35	Batt No. 1 Volt	Curve	PSE
36	Batt No. 1 Charg Cur	Curve	PSE
37	Batt No. 1 Temp	Curve	PSE
38	Batt No. 2 Volt	Curve	PSE
39	Batt No. 2 Chrg Cur	Curve	PSE
40	Batt No. 2 Temp	Curve	PSE
41	Solar Pan No. 1 Temp	Curve	PSE
42	Solar Pan No. 2 Temp	Curve	PSE
43	Solar Pan No. 3 Temp	Curve	PSE
44	Digital Tlmy Bus Status	V1: Disabled V2: Enabled	CDU
45	TBU & Bcn Xmtr Selection	0V: TBU 1, Bcn 1 -0.9V: TBU 2, Bcn 1 -2.7V: TBU 1, Bcn 2 -3.6V: TBU 2, Bcn 2	TBU&CDU
46	Prog 1 Orbit Status	0V: Off -0.9V: Stdby -1.8V: Cnting t_o delay -2.7V: Cnting Day -3.6V: Cnting Night	Prog
47	Prog 2 Orbit Status	0V: Off -0.9V: Stdby -1.8V: Cnting t_o delay -2.7V: Cnting day -3.6V: Cnting night	Prog
48	QOMAC Prog 1 or 2 Status	-0.9V: Stdby -1.8V: Cnting t_o (norm) -2.7V: Cnting t_o 1/4(norm) -3.6V: Cnting t_o (uni) -4.5V: Cnting 1/4 (uni)	Prog

TABLE VII-6. COMMUTATOR INPUTS FOR REAL-TIME TELEMETRY (Continued)

Chan. No.	Telemetry Function	Values	Source
49	R. T. Inhibit Status, Prog 1 or 2	-1.5V: Normal -2.4V: SR inhibit -3.3V: VHRR inhibit -4.1V: SR&VHRR inhibit	Prog
50	QOMAC, Pwr & Mode Status	0 V: Off, Lo torq -0.9V: Off, Hi torq -1.8V: On, Lo torq -2.7V: On, Hi torq	CDU
51	Mag Bias Pwr & Mode Status	0 : Off, Pos -0.9V: Off, Neg -1.8V: On, Pos -2.7V: On, Neg	CDU
52	Mag Bias Switch Position	-0.6V: 1 -1.0V: 2 -1.4V: 3 -1.8V: 4 -2.2V: 5 -2.6V: 6 -3.0V: 7 -3.4V: 8 -3.8V: 9 -4.2V: 10 -4.6V: 11 -5.0V: 12	MBS
53	Mom Coil No. 1 Status	0 0V: 1 On, Pos -2.8V: 1 Off, Pos -3.4V: 1 Off, Neg -4.7V: 1 On, Neg	CDU
54	Mom Coil No. 2 Status	Same as mom coil No. 1	CDU
55	Real-Time Xmtr SR Day Data Selection	V1: Multiplex VIS & IR V2: IR day V3: VIS day	CDU
56	SR Power Status	0V: Neither SR on -0.9V: SR 2 on -2.7V: SR 1 on	SRPR
57	SR No. 1 Motor Voltage	Curve	SRE 1
58	SR No. 2 Motor Voltage	Curve	SRE 2
59	SR No. 1 Housing Temp	Curve	SRE 1
60	SR No. 2 Housing Temp	Curve	SRE 2
61	SRR No. 1 Status	V1: Not selected V2: Selected V3: In record V4: In playback	SRR No. 1
62	SRR No. 1 Motor Current	Curve	SRR No. 1

TABLE VII-6. COMMUTATOR INPUTS FOR REAL-TIME TELEMETRY (Continued)

Chan. No.	Telemetry Function	Values	Source
63	SRR No. 1 EOT Status	V1: Not EOT V2: EOTR V3: EOTPB	SRR No. 1
64	SRR No. 1 Pressure	Curve	SRR No. 1
65	SRR No. 1 Temperature	Curve	SRR No. 1
66	VHRR Recorder Selection	V1: Disabled V2: Enabled	CDU
67	VHRR Recorder Status	0V: Off -0.9V: Stdby -1.8V: Record -2.7V: Playback	VHRRR
68	VHRR Recorder Motor Current	Curve	VHRRR
69	VHRR Recorder Pressure	Curve	VHRRR
70	VHRR Recorder Temperature	Curve	VHRRR
71	SRR No. 2 Status	V1: Not Selected V2: Selected V3: In record V4: In playback	SRR No. 2
72	SRR No. 2 Motor Current	Curve	SRR No. 2
73	SRR No. 2 EOT Status	V1: Not EOT V2: EOTR V3: EOTPB	SRR No. 2
74	SRR No. 2 Pressure	Curve	SRR No. 2
75	SRR No. 2 Temperature	Curve	SRR No. 2
76	SRR No. 3 Status	V1: Not selected V2: Selected V3: In Record V4: In Playback	SRR No. 3
77	SRR No. 3 Motor Current	Curve	SRR No. 3
78	SRR No. 3 EOT Status	V1: Not EOT V2: EOTR V3: EOTPB	SRR No. 3
79	SRR No. 3 Pressure	Curve	SRR No. 3
80	SRR No. 2 Temperature	Curve	SRR No. 3
81	VHF Xmtr Selection	0V: Neither Sel -0.9V: Xmtr 1 -1.8V: Xmtr 2	CDU
82	VHF Xmtr No. 1 Power Output	Curve	VHFT 1
83	VHF Xmtr No. 1 Temperature	Curve	VHFT 1
84	VHF Xmtr No. 2 Power Output	Curve	VHFT 2
85	VHF Xmtr No. 2 Temperature	Curve	VHFT 2

TABLE VII-6. COMMUTATOR INPUTS FOR REAL-TIME TELEMETRY (Continued)

Chan. No.	Telemetry Function	Values	Source
86	Multiplexer Selection	-0.9V: MUX 1 -1.8V: MUX 2	CDU
87	S-Band Xmtr Selection	-1.2V: STX 1 -2.4V: STX 2	CDU
88	S-Band Xmtr 1 or 2 Power Output	Curve	STX 1&2
89	S-Band XMTR No. 1 Temp	Curve	STX 1
90	S-Band Xmtr No. 2 Temp	Curve	STX 2
91	VHRR Processor Status	V1: Off V2: R.T. VC01 V3: R.T. VC02 V4: R.T. VC01 & 2 V5: Playback mode	VHRR PR
92	VHRR No. 1 Electr Pwr Status	0V: Power off -1.0V: Electr off -2.0V: VIS on, IR off -3.0V: IR on, VIS off -4.5V: VIS on, IR on	VHRR 1
93	VHRR No. 1 Motor Pwr Status	0V: Power off -0.9V: Motor off -2.0V: Motor sync -3.8V: Motor auto	VHRR 1
94	Spare		
95	VHRR No. 1 2nd Stage Patch Temp	Curve	VHRR 1
96	VHRR No. 1 300°K Target Temp 1	Curve	VHRR 1
97	VHRR No. 1 300°K Target Temp 2	Curve	VHRR 1
98	VHRR No. 1 240°K Target Temp 1	Curve	VHRR 1
99	VHRR No. 1 240°K Target Temp 2	Curve	VHRR 1
100	Spare		
101	VHRR No. 1 IR Detector Bias	Curve	VHRR 1
102	VHRR No. 1 Scan Housing Temp	Curve	VHRR 1
103	Spare		
104	VHRR No. 2 Electr Pwr Status	0V: Power off -1.0V: Electr off -2.0V: VIS on, IR off -3.0V: IR on, VIS off -4.5V: VIS on, IR on	VHRR No. 2
105	VHRR No. 2 Motor Pwr Status	0V: Power off -0.9V: Motor off -2.0V: Motor sync -3.8V: Motor auto	VHRR No. 2
106	Spare		
107	VHRR No. 2 2nd Stage Patch Temp	Curve	VHRR No. 2

TABLE VII-6. COMMUTATOR INPUTS FOR REAL-TIME TELEMETRY (Continued)

Chan. No.	Telemetry Function	Values	Source
108	VHRR No. 2 300°K Target Temp 1	Curve	VHRR No. 2
109	VHRR No. 2 300°K Target Temp 2	Curve	VHRR No. 2
110	VHRR No. 2 240°K Target Temp 1	Curve	VHRR No. 2
111	VHRR No. 2 240°K Target Temp 2	Curve	VHRR No. 2
112	Spare		
113	VHRR No. 2 IR Detector Bias	Curve	VHRR No. 2
114	VHRR No. 2 Scan Housing Temp	Curve	VHRR No. 2
115	Spare		
116	VTPR No. 1 Power Status	0V: Off -4.2V: On	VTPR No. 1
117	VTPR No. 2 Power Status	0V: Off -4.2V: On	VTPR No. 2
118	VTPR No. 1 Motor Rotation Status	-0.5V: Stalled -4.0V: Rotation	VTPR No. 1
119	VTPR No. 2 Motor Rotation Status	-0.5V: Stalled -4.0V: Rotation	VTPR No. 2
120	VTPR No. 1 Calibration Mode	V1: Enable V2: Disable	VTPR No. 1
121	VTPR No. 1 Patch Cal Status	V1: Off V2: On	VTPR No. 1
122	VTPR No. 2 Calibration Mode	V1: Enable V2: Disable	VTPR No. 2
123	VTPR No. 2 Patch Cal Status	V1: Off V2: On	VTPR No. 2
124	VTPR No. 1 Electronics Temp	Curve	VTPR No. 1
125	VTPR No. 2 Electronics Temp	Curve	VTPR No. 2
126	Pitch Loop & Pitch Sensor Sel	-1.7V: PS1, Norm -2.7V: PS2, Norm -3.4V: PS1, XED -4.5V: PS2, XED	PCE
127	Pitch Loop Mode & Gain Sel	0V: Open, coarse -1.8V: Open, normal -2.7V: Closed, coarse -3.3V: Closed, normal	PCE
128	Pitch Loop Dual Motor Mode Status	0V: Enabled -1.8V: On -4.0V: Disabled	PCE
129	Pitch Loop No. 1 Motor Volt	Curve	PCE

TABLE VII-6. COMMUTATOR INPUTS FOR REAL-TIME TELEMETRY (Continued)

Chan. No.	Telemetry Function	Values	Source
130	Pitch Loop No. 2 Motor Volt	Curve	PCE
131	PCE DC-DC Converter	Curve	PCE
132	Pitch Loop 1 or 2 Gain Switch	0V: Coarse -0.9V: Fine	PCE
133	MWA Motor No. 1 Brush Reserve	Curve	1 SGT
134	MWA Motor No. 2 Brush Reserve	Curve	2 SGT
135	MWA Flywheel Bearing Temp	Curve	PCE
136	MWA Housing Temp	Curve	PCE
137	SPM Output Power	Curve	SPM
138	SPM Bracket Temp	Curve	SPM
139	ATC Flap No. 1 Position	Curve	TTT
140	ATC Flap No. 2 Position	Curve	TTT
141	ATC Flap No. 3 Position	Curve	TTT
142	ATC Flap No. 4 Position	Curve	TTT
143	Baseplate Temp (Near PSE)	Curve	TTT
144	Baseplate Temp (Near MBS)	Curve	TTT
145	Panel No. 1 Temp	Curve	TTT
146	Panel No. 2 Temp	Curve	TTT
147	Earth Panel Temp	Curve	TTT
148	Thermal Fence Temp (Fin)	Curve	TTT
149	Thermal Fence Center Temp	Curve	TTT
150	Thermal Fence Alzak Temp	Curve	TTT
151	ATC No. 1 Reservoir Temp	Curve	TTT
152	ATC No. 3 Reservoir Temp	Curve	TTT

In addition to the normal mode, the DDP can operate in the random access mode. In this mode, only one ground-selected telemetry point appears continuously at the real-time output. This mode is a useful diagnostic tool when one parameter is of special interest, and continuous monitoring is desired. The DDP mode also affects the recorded digital frame but to a lesser extent. In that frame the normal mode allows sequencing of all the telemetry points. In the random access mode all the digitized telemetry words are the digital equivalent of the one analog point which is selected in the real time frame. However, in the recorded frame none of the other data is affected by the change of mode.

c. TELEMETRY MODES OF OPERATION

As previously indicated, there are two fundamental telemetry modes of operation of the DDP: the normal (automatic advance) mode and the random access mode. The difference between the modes is that in the normal mode up to 172 telemetry points are multiplexed into both the real time and recorded telemetry frames, while in the random access mode only one of these points is selected. Since the DDP has only one commutator for telemetry point selection, both the real-time and recorded frames, which are generated simultaneously, must be in the same mode.

When the DDP power is applied by the CDU, the DDP automatically enters the normal mode. Both recorded and real-time frame outputs are immediately made available, and stay available as long as the DDP power remains on. The DDP continues through its first frame until a VTPR frame pulse is received. The DDP immediately reverts back to the beginning of its frame, synchronized with the VTPR frame, and succeeding frames are generated without interruption.

Once the DDP is operating in the normal mode it will continue to do so until it is commanded otherwise. If a random access mode command is received, the DDP is alerted to look for data from the decoder indicating the commutator channel to be addressed. Although the decoder sends 28 bits, only the first 9 contain the address. Consequently the data verification output which the DDP develops remains active for only 9 bits. As soon as the 9th address bit is received, the DDP enters the random access mode, and the commutator immediately makes a transition to the proper channel. If it is now desired to go to a different commutator position, it is only necessary to send a new random access command, followed by the new address. To return to normal mode operation, the DDP must receive an automatic advance command which will immediately cause the commutator to sequence through the channels, starting at whatever point in the frame the DDP is generating at that time.

Although the two frame outputs are constantly being generated, they are not necessarily both used. The recorded digital frame output goes to each SR recorder and is recorded as long as any one of the three is in the record mode. The real-time telemetry frame is routed to the CDU telemetry priority tree which controls its selection.

The selection of the real-time telemetry frame is dependent on several factors including the DDP telemetry mode and the status of the telemetry request and enable tone telemetry request (ETTR) lines from the CDU. When the telemetry request line is in its active state it indicates that the DDP has been selected by the tree for real-time downlink transmission. If the ETTR line is active, it indicates that the DDP was selected for telemetry by an enable tone. Otherwise the selection was done by command. The ETTR line is needed by the DDP because its response may depend on the means of selection.

If the DDP is in the normal mode and is selected for downlink transmission, it searches for the termination of two frames of data, ensuring one complete frame. At the end of the second frame, a frame pulse is sent to the CDU which should remove the DDP output from the priority tree and simultaneously return the telemetry request line to its inactive state. If the line remains active after this pulse occurs the DDP will continue to generate pulses, once per frame, until the line returns to its inactive state, thus removing the DDP from the priority tree. In the normal mode the operation does not depend on the ETTR line. This is not true in the random access mode.

If the DDP is in the random access mode, selected by the priority tree, and the ETTR line is inactive, then no CDU frame pulses are generated. Therefore, the DDP will continue to be connected to the priority tree until the CDU either resets the tree or returns the DDP to normal mode which in turn will reset the tree.

If the DDP is in the random access mode, and selected by the priority tree because the ETTR line has gone to its active state, then the DDP immediately switches to the normal mode frame format. As a consequence, CDU frame pulses are generated as previously described until the telemetry request line returns to its inactive state. The DDP then returns to the random access format, re-selecting the same channel as before the enable tone was sent.

2. Interface Description

Figure VII-20 shows the interface diagram of the DDP, including inputs, outputs, and some internal wiring. The dual unit is divided into 3 parts: DDP 1, DDP 2, and the signal conditioner. Those units aboard the spacecraft which have provided separate interfaces to DDP 1 and DDP 2 are shown on the left hand side of the diagram. Those units whose outputs must be combined or split to provide separate outputs to the DDP's are shown along the upper right hand side of the diagram. The derived signals are shown going between the signal conditioner and the DDP's. Those outputs from the DDP's which have been combined to provide one or more outputs are shown along the lower right hand side of the diagram. The signals which are used to generate these outputs are shown coming into the signal conditioner from the two DDP's. The last interface consists of up to 172 telemetry points shown in the middle of the right hand side of the diagram.

Tables VII-7 and VII-8 enumerate the interfaces shown in Figure VII-20 and describe them in greater detail. Also, these tables reference illustrations (Figures VII-21 through VII-26) which show the input/output configurations of the circuits either driving, or being driven by, the DDP interface signal lines.

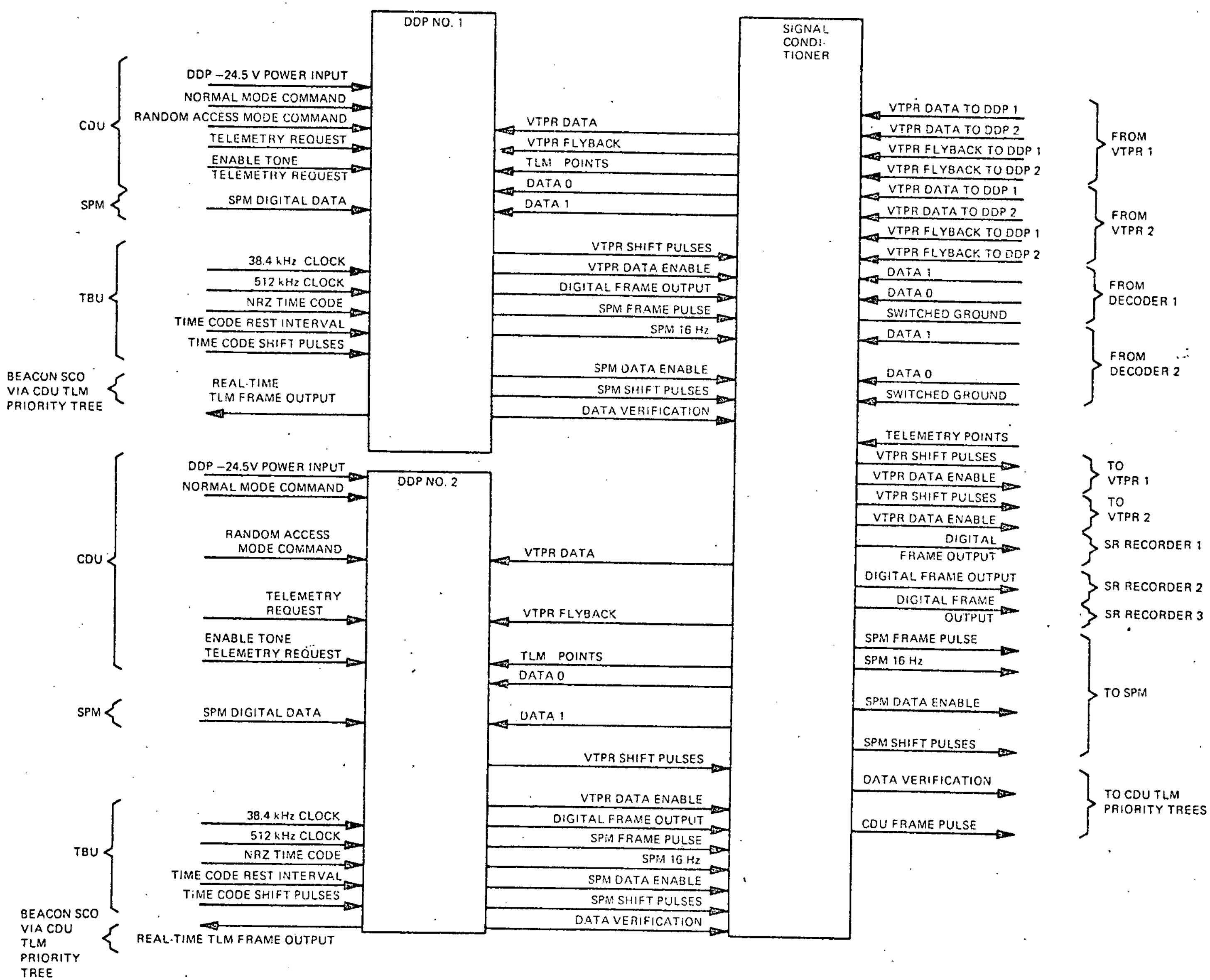


Figure VII-20. DDP Interface Diagram

TABLE VII-7. DDP INTERFACE SIGNAL INPUTS

Signal	Inputs- Single (S), Dual (D)	Source	Function	Output Configuration Figure No. VII-
Normal Mode Command	D	CDU	Commands the DDP into the normal mode	26
Random Access Mode Command	D	CDU	Commands the DDP into the random access mode	26
Telemetry Request	D	CDU	Informs the DDP that real-time telemetry is selected by priority tree	22
Enable Tone Telemetry Request	D	CDU	Informs the DDP that enable tone telemetry signal is being received	23
DDP-24.5V Power Input	D	CDU	Provides switched -24.5v regulated to DDP	22
SPM Digital Data	D	SPM	Provides SPM digital data for multiplexing into the recorded digital frame	21
38.4 kHz Clock	D	TBU	Provides hi-frequency clock for A/D conversion	21
512 Hz Clock	D	TBU	Provides clock for frame and bit generation	21
NRZ Time Code	D	TBU	Provides time code digital data for multiplexing into the recorded telemetry frame	21
Time Code Shift Pulses	D	TBU	Provides pulses to shift time code data into register. Pulses are gated with presence of data.	21
Time Code Rest Interval	D	TBU	Informs DDP that time code is being generated	21
VTPR Data	D*	VTPR 1, 2	Provides VTPR digital data for multiplexing into the recorded digital frame	21
VTPR Flyback Pulse	D*	VTPR 1, 2	Informs the DDP that the VTPR is in the flyback mode, and the DDP frame should be starting	21
DATA 1	S	Decoder 1, 2	Provides 9-bit code for selection of single telemetry point in random access mode	24
DATA 0	S	Decoder 1, 2	Provides 9-bit code for selection of single telemetry point in random access mode	24
Switched ground	S	Decoder 1, 2	Informs the DDP which decoder is being used, and inhibits the data input when data is not available	22
Telemetry Points	S	--	Provides telemetry signals to the DDP for inclusion in the recorded and real-time frames	-

* Two VTPR outputs must be tied together ("or"ed) in signal conditioner

TABLE VII-8. DDP INTERFACE SIGNAL OUTPUTS

Signal	Outputs- Single (S), Dual (D)	Destination	Function	Output Configuration Figure No. VII-
Digital Frame Output SRR Nos. 1, 2, 3	T*	SRR Nos. 1, 2, 3	Provides digital frame to SR recorders	21
SPM Frame Pulse	S	SPM	Synchronizes SPM Barker word with DDP recorded frame	21
SPM 16 Hz	S	SPM	Provides 16 Hz clock to assemble words in the SPM	21
SPM Data Enable	S	SPM	Allows data to be shifted out of SPM output register	21
SPM Shift Pulses	S	SPM	Provides clock for shifting data from SPM output register	21
VTPR Nos. 1, 2 Data Enable	D	VTPR	Allows data to be shifted out of VTPR output register	21
VTPR Nos. 1, 2 Shift Pulses	D	VTPR	Provides clock for shifting data from VTPR output register	21
Real-time Tlm Frame Output	D	Beacon SCO via CDU tlm priority tree	Provides real-time analog telemetry frames for beacon transmission	25
Data Verification, Decoders 1, 2	D	CDU tlm priority tree	Provides data verification window for the 9 active random access channel selection bits.	21
CDU Frame Pulse	D	CDU tlm priority tree	Informs CDU that at least one complete tlm frame has been transmitted	21

*3 Isolated outputs are provided.

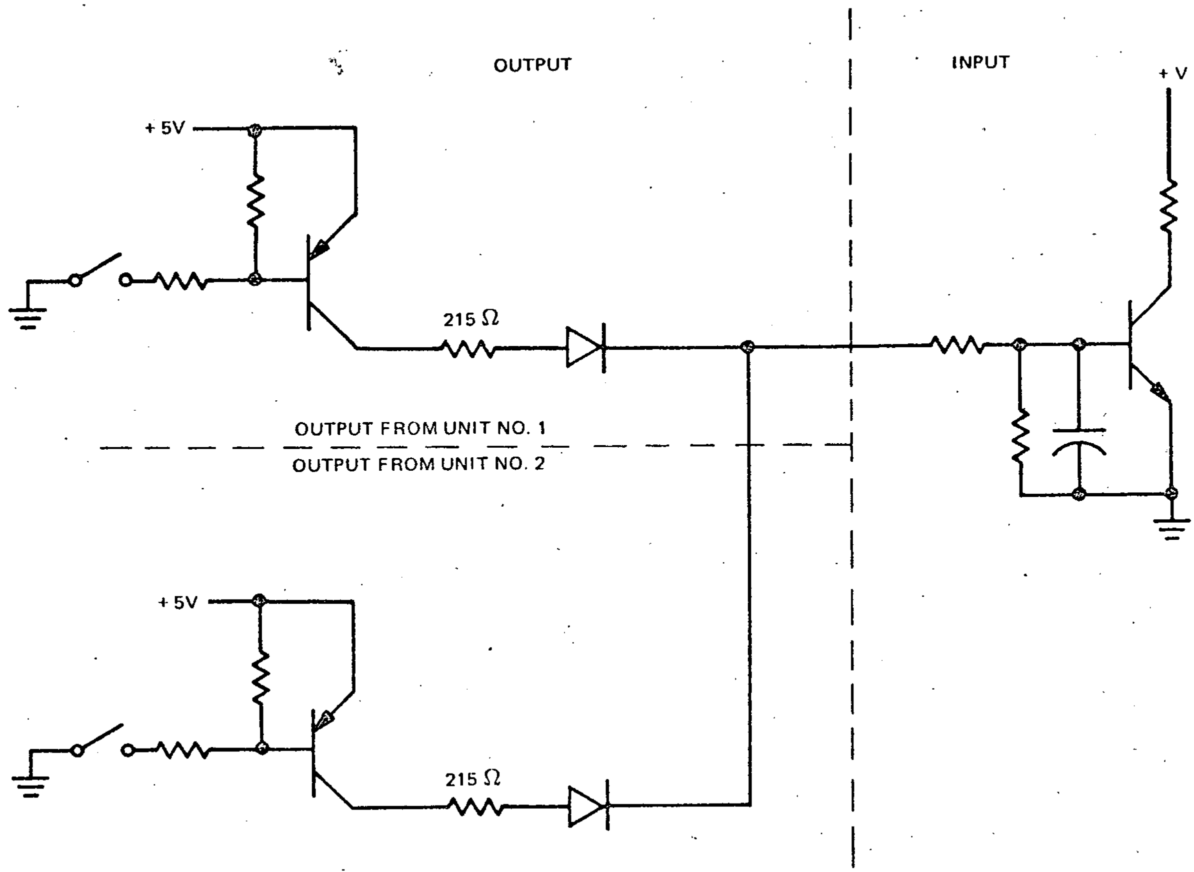


Figure VII-21. Standard Interface

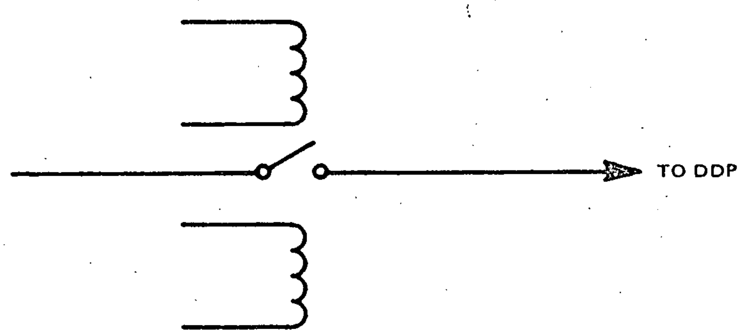


Figure VII-22. Relay Closure Output

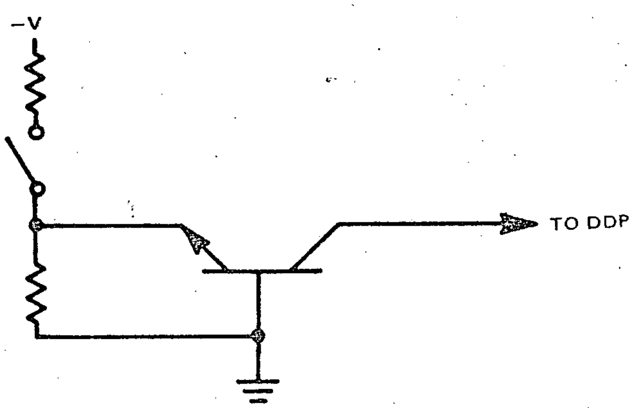


Figure VII-23. Grounded Base Transistor Output

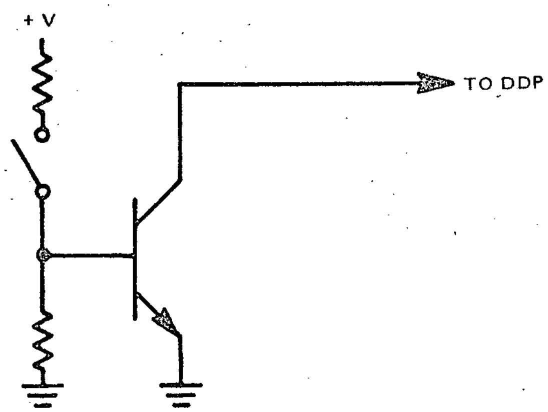


Figure VII-24. LP/DTL Output

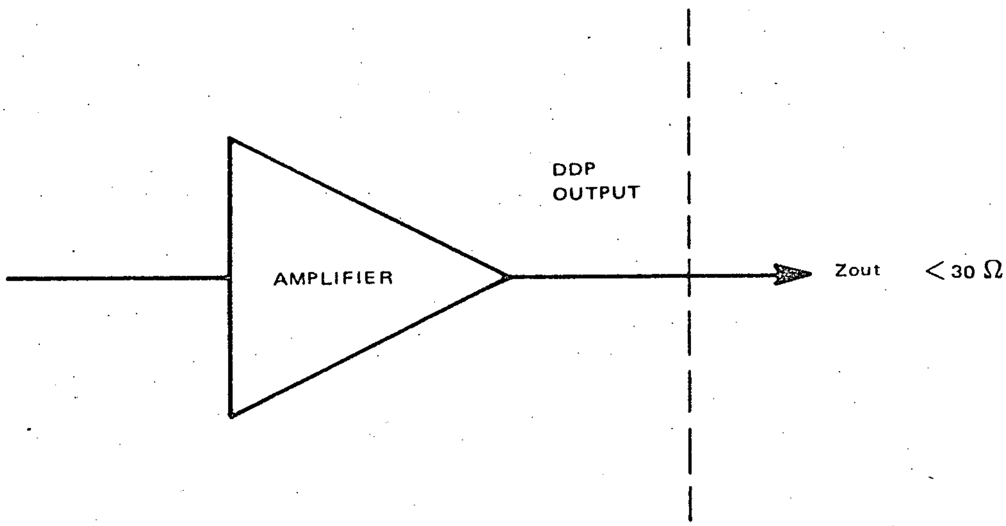


Figure VII-25. Analog Telemetry Output

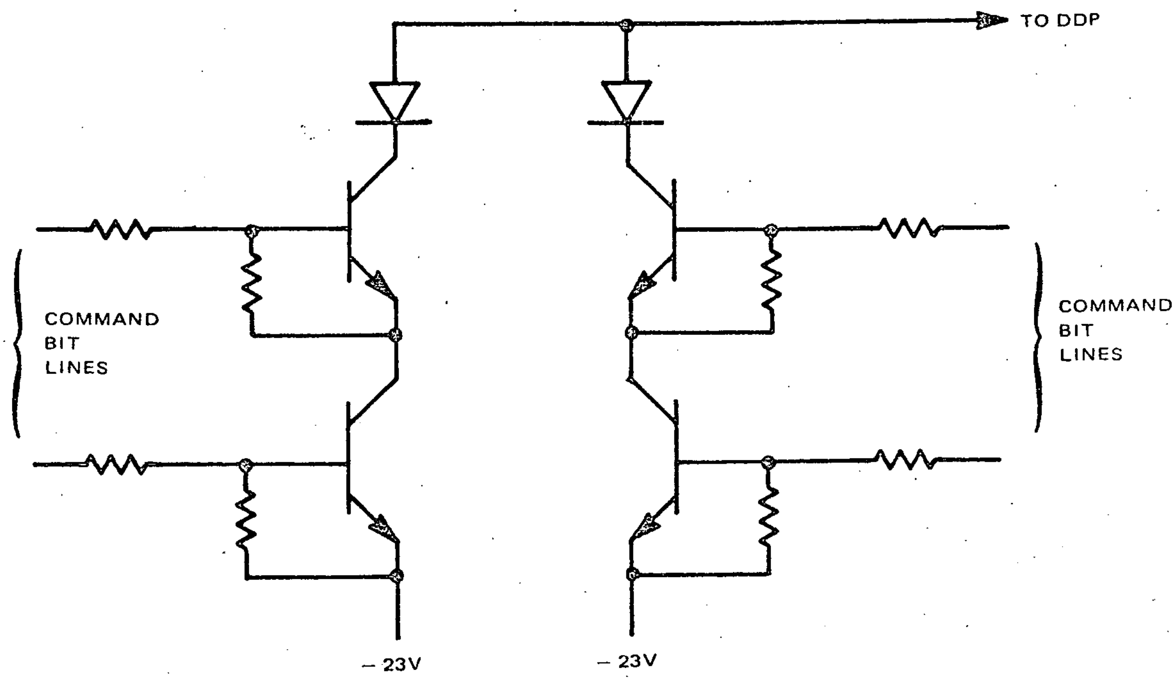


Figure VII-26. CDU Command Output

3. Functional Operation

A block diagram of the DDP is shown in Figure VII-27. The operation of the various blocks are as follows:

a. FRAME COUNTER

The frame counter cycles through 6400 unique states at a rate of 512 states per second. The cycle time is therefore 12.5 seconds, which is the time required for one DDP frame. The counter is subdivided into 5 stages, which simplifies the decoding process. The input to the first stage, shown in Figure VII-27, is a 512-Hz clock from the TBU. This frequency, which is the bit rate of the digital telemetry, is divided by 16 which results in the digital telemetry word rate. The succeeding stage is a divide-by-two whose 16-Hz output frequency is the rate at which the commutator advances from slot to slot. The next stage is a divide-by-ten which cycles at the SPM word rate. The final two stages divide-by-twenty to produce a total period of 12.5 seconds.

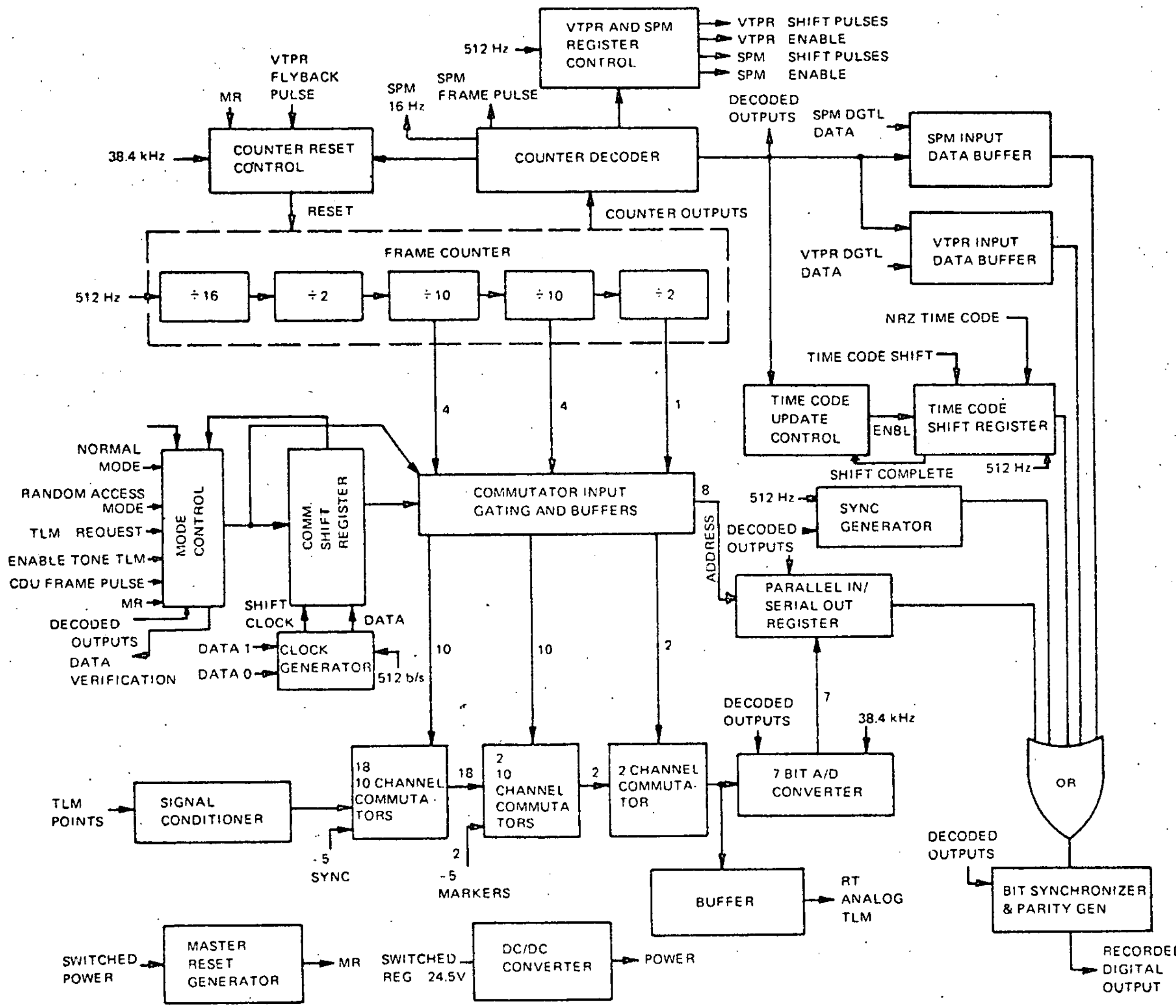


Figure VII-27. Digital Data Processor, Block Diagram

b. COUNTER DECODER

The counter decoder takes the outputs of the frame counter and generates all of the timing signals necessary to generate a DDP frame. It also decodes signals which go to the VTPR and SPM, controlling the transfer of data to the DDP from their output registers. In addition, the SPM 16 Hz signal is developed to clock the SPM, and the SPM frame pulse is generated to ensure that the Barker word will consistently occupy the same position in the DDP frame.

c. COUNTER RESET CONTROL

The reset control initializes the frame counter with a reset pulse upon receipt of a level from the master reset generator, or if the VTPR flyback pulse is not coincident with a "window" generated by the counter decoder. Once the DDP frame counter synchronizes onto the correct VTPR phase, the reset generator does not generate additional pulses because the free-running frame counter maintains the proper phase unaided.

d. COMMUTATOR SHIFT REGISTER

The commutator shift register is only used in the random access mode. In that mode its function is to accept 9 serial bits of channel selection information from the command decoder, and to provide 9 parallel outputs which determine the commutator position. Once the register has received 9 bits it provides an overflow signal indicating that the complete number has been received and ignores the remaining 19 bits of the message. The shift register retains this number until a new random access mode command is received, at which time the number is updated.

e. MODE CONTROL

The mode control uses four signals from the CDU plus internally developed signals to control the operation of the DDP. This control function consists of specifying the source of the commutator channel selection and enabling the commutator shift register. The mode control also generates CDU frame pulses and the data verification output as described in Paragraph D.1.c.

f. CLOCK GENERATOR

The clock generator accepts RZ data 1 and data 0 outputs from the command decoder, and derives NRZ data and a clock from them for shifting the 9 bits of data into the commutator shift register.

g. COMMUTATOR INPUT GATING AND BUFFERS

This logic accepts 9 bits of parallel data from either the frame counter or the commutator shift register, depending on the status of the mode control. These 9 bits are decoded into two 1-out-of-10 decoded outputs and a 1-out-of-2 decoded output which provide 200 unique addresses to the commutator. All outputs are buffered with drivers which convert the logic levels to levels compatible with the P-MOS commutator integrated circuits.

h. COMMUTATOR AND OUTPUT BUFFER

The commutator completes its multiplexing in three levels. The first level consists of eighteen 10-channel commutators which can accept up to 180 inputs (including 8 slots for sync). The 18 outputs of these commutators plus 2 additional -5 volt markers, inserted into the SPM data slots, make up the inputs to the second level which consists of 2 more 10-channel commutators. All the 10-channel commutators will be made up of P-MOS integrated circuits. This will allow the first two commutation levels to be realized with 20 devices. The third level is a 2-channel commutator which alternates between these two channels providing one output. The output goes to both a buffer and an A/D converter. The buffer is an isolation amplifier which routes the real-time telemetry signal to the beacon via the telemetry tree. The A/D converter is used in the generation of the recorded telemetry frame.

The commutator and buffer amplifier combination has the following characteristics, providing a nominal source impedance of 3 kilohms:

• Input Impedance	2 megohms minimum
• Input Range	0 to -5V with no damage occurring for input swings from +5V to -36V
• Source Impedance Sensitivity	1 millivolt per kilohm
• Gain	1 ± 0.005
• Linearity	± 0.5 percent
• Offset	± 10 millivolts
• Scatter	± 5 millivolts
• Crosstalk	0.5 percent of full scale with up to 500 Hz sinewave applied to inputs

i. SIGNAL CONDITIONER

The signal conditioner is common to both DDP's and performs a variety of functions. It distributes the single telemetry inputs to both commutators. For those telemetry points whose outputs do not extend over the 0 to -5V range, it rescales the input appropriately. The signal conditioner combines multiple telemetry points into one point using resistive ladder networks. The conditioner is also used to combine signal outputs from DDP 1 and 2, and additionally, to provide isolated drivers for the various receivers of the signals. In the interest of clarity this latter function is not shown on the block diagram.

j. SEVEN-BIT A/D CONVERTER

The A/D converter encodes each telemetry voltage from the commutator into a seven-bit binary weighted code. The converter uses the "successive approximation" technique and performs the digitizing in a fraction of a millisecond. Because of the low duty cycle and the relatively high power required, power is applied to the unit only while the conversion is taking place.

The A/D converter has the following characteristics:

• Range	Count 0 for 0 volts or more positive; Count 127 for -4.960 volts or more negative
• D-C Accuracy	$\pm \left[1/2 \text{ bit} + \begin{matrix} 0.5\% \\ 1.0\% \end{matrix} \right]$ beginning of life / end of life
• Differential Linearity	± 8 millivolts

k. PARALLEL IN/SERIAL OUT REGISTER

This register accepts 7 bits of digitized telemetry from the A/D converter and 8 bits of address from the commutator input gating identifying each telemetry point. These 15 bits are then shifted out serially to the bit synchronizer to be incorporated in the recorded digital frame.

l. SYNC GENERATOR

The sync generator is a 5-stage shift register which is used to generate the 32-bit sync code in the recorded digital frame. Its output goes to the bit synchronizer where it is incorporated into the frame.

m. TIME CODE UPDATE CONTROL AND SHIFT REGISTER

The purpose of these is to obtain and store the most recent time code information for insertion into the recorded digital frame both at the proper time and at the 512 bit-per-second rate. Toward the end of the frame the update control enables the shift register input to accept the complete time code readout which follows. The data transfer is controlled by the time code rest-interval line. When the readout is complete the enable is removed and the register holds the 24 bits until required by the bit synchronizer, during the second commutator slot of the frame which follows.

n. SPM AND VTPR INPUT BUFFER

These buffers gate the outputs of the sensors from which they receive their data. Signals from the counter decoder produce the gating signals. The buffer outputs go to the bit synchronizer for inclusion into the recorded digital frame.

o. BIT SYNCHRONIZER

The bit synchronizer accepts all the digital data which comprises the recorded digital frame and combines it into one digital bit stream. It then adds odd parity to all words, and reclocks the bit stream into a biphase format for recording on the SR recorders.

p. VTPR AND SPM REGISTER CONTROL

This logic generates enable and shift pulses for the VTPR and SPM. The two sensors use these pulses to clock the digital data from their output registers.

q. MASTER RESET GENERATOR

The master reset generator produces a pulse whenever the DDP undergoes a transition from a power-off to a power-on state. This pulse initiates the frame counter and causes the DDP to start off in the normal sequence mode.

r. DC-DC CONVERTER

The dc-dc converter accepts the regulated -24.5 volts switched by the CDU and develops the logic supply voltage, two analog supply voltages, and an output buffer supply. Each output has its own regulator for isolation.

4. Electrical Characteristics

a. POWER

The nominal power consumption for the DDP will be less than 2.0 watts. This number includes the dc-dc converter inefficiencies and is contingent upon the operational requirement that only one DDP is powered at a time.

b. LOGIC

The DDP uses low power transistor-transistor logic (54L Series) manufactured by Texas Instruments. The choice was made from among the 54L Series, low power diode-transistor logic (LP/DTL), and complementary symmetry MOS logic (C-MOS). C-MOS has to be eliminated almost immediately because only three high reliability devices would be available by the time the hardware phase starts. A comparison of the 54L Series and LP/DTL logic elements follows:

(1) LOW POWER

The power consumed by the highest powered TTL gate is nominally 1 milliwatt. On some devices, with gates internally connected, the power is much lower, dropping to 0.28 milliwatt per gate in one instance. TTL flip-flops have a power dissipation of 3.8 milliwatts. The equivalent power numbers for LP/DTL are 1 milliwatt per gate and 3.3 milliwatts per flip-flop. Based on power considerations, there is no clear-cut advantage of either logic line over the other.

(2) DESIGN FLEXIBILITY

The LP/DTL line has only 6 different devices in the line. In comparison the 54L line has 17 devices from which to choose, which makes for a more efficient design.

(3) MEDIUM SCALE INTEGRATION (MSI)

There are no MSI devices in the LP/DTL line. The 54L line has dual flip-flops, multi-stage counters and registers, and gating arrays containing as many as six 2- and 3-input gates. This feature should increase the reliability of the system since fewer connections and fewer devices will be used.

(4) RELIABILITY

A comparison of the LP/DTL and the 54L Series shows no appreciable advantage of one over the other. This is primarily due to the similar processes used to manufacture the two product lines. In addition, Series 54L has been approved as a standard part by NASA for applications in the Apollo series of missions.

On the whole, the choice of Series 54L appears to offer the best overall performance.

5. Packaging

The DDP will consist of from 14 to 16 boards, contained in a box whose dimensions are approximately 6 by 11 by 10 inches. The weight will be a maximum of 12 pounds.

E. SCANNING RADIOMETER RECORDER

1. General

The scanning radiometer recorder (SRR) provides the storage capability for the data from the scanning radiometer and the digital data processor. The record speed is 1.3 inches per second and the playback speed is 27.1 inches per second, a ratio of 20.833 to 1. This unit provides 209 minutes of record time on 1360 usable feet of 1/4-inch magnetic tape. Each SRR is comprised of two units, the transport and the electronics. The transport contains the tape transport and several component boards mounted within a pressurized spun aluminum dome and base pan enclosure. The enclosure is 14 inches in diameter and approximately 6.5 inches deep; it is pressurized to 16.5 psi with a mixture of 90-percent air and 10-percent helium. The electronic unit contains the majority of the signal and drive circuits, mounted on plug-in printed circuit boards. The maximum total weight of the SR recorder is approximately 18.7 pounds; the transport weighing approximately 13.3 pounds and the electronics weighing approximately 5.4 pounds.

The functions of the SRR are:

- To record and play back signals supplied by the spacecraft.
- To time multiplex the visible and IR signals from the scanning radiometer by interleaving the data on a single data track.

A simplified block diagram of the SRR electronics is shown in Figure VII-28. Three channels of data storage are provided. One channel (A) records and time multiplexes sensor video data which is in the form of frequency modulated subcarriers provided from the SRPR. Channel (B) records and time multiplexes a pilot tone (1.2 kHz signal) from which tape speed variations (flutter-and-wow) are detected and compensated for in the ground equipment. The third channel (C) records biphase digital data from the spacecraft digital data processor (DDP). The DDP combines the vertical temperature profile radiometer sensor data, solar proton monitor sensor data, digital housekeeping telemetry, and spacecraft time code information into a single digital data stream.

The tape passes over the erase head, over the record heads, and then over the reproduce heads. The record circuits are powered during the record cycle only. However, while in the record mode and a real-time transmission command is received, power is also applied to the playback circuit. When the playback command is received, power is applied to the playback circuits and it is simultaneously removed from the record circuits. The direction of tape reverses and all three tracks may be played back simultaneously at a speed of 27.1 inches per second (20.83 times the record speed).

The input command and control signals, as well as their SRR related functions are listed in Table VII-9. The characteristics of the SRR are summarized in Table VII-10.

a. ELECTRICAL DESIGN

With the exception of minor interface changes, the following areas of electrical design were utilized for the TIROS M SR recorder:

- The IR and visible channel fm modulators are identical and were used on the TIROS M program. The IR and visible channel preamplifier and limiter were used on the TIROS M program. In both cases, minor interface and frequency changes were made.

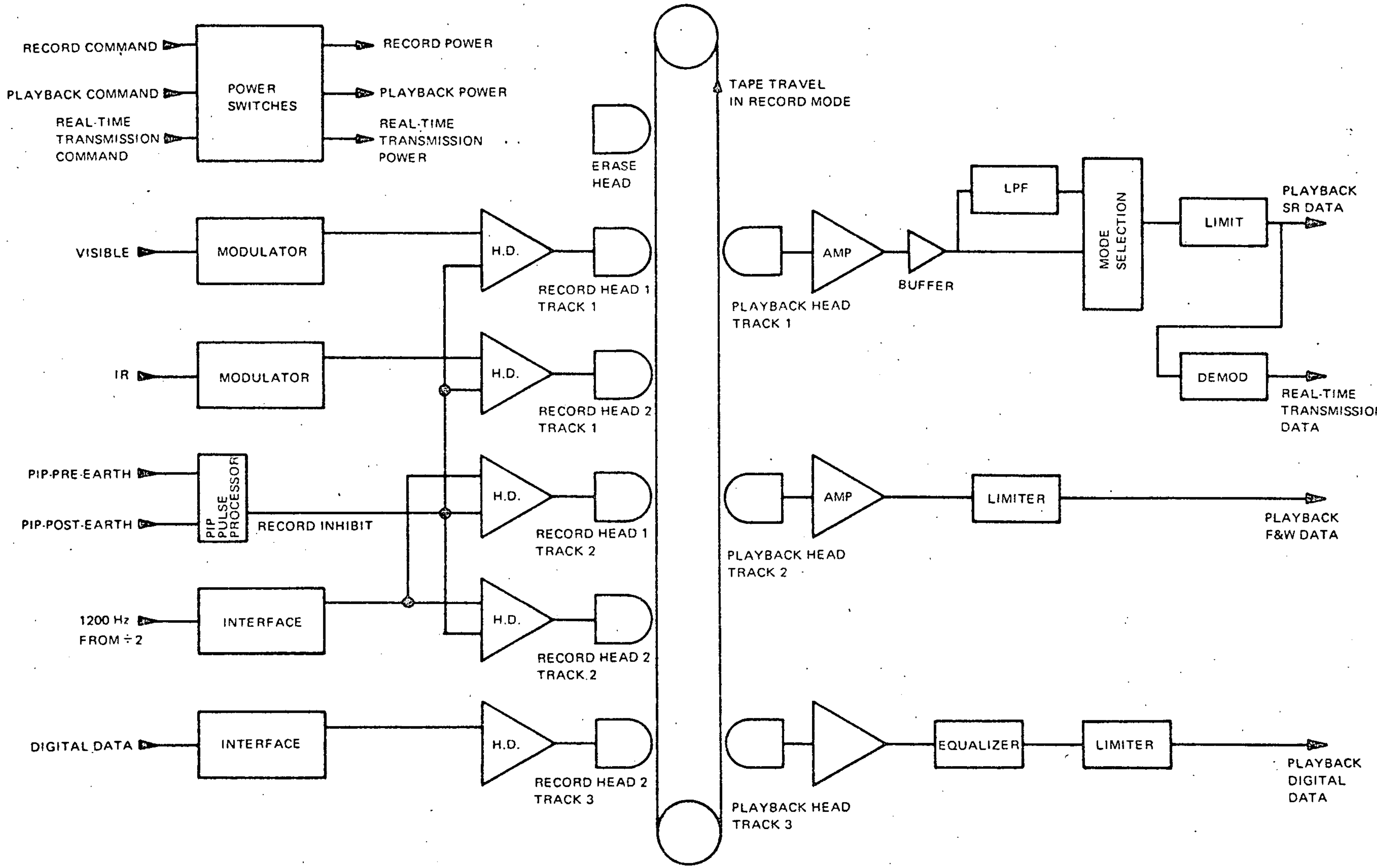


Figure VII-28. Signal Electronics, Block Diagram

TABLE VII-9. SR RECORDER COMMAND AND CONTROL SIGNALS

Type	Function
1. Record Command	To activate tape recorder in the record mode.
2. Playback Command	To activate tape recorder in the playback mode and supply power to SR, DDP, and flutter-and-wow playback electronics.
3. Playback End-of-Tape Signal (output)	To indicate completion of playback cycle.
4. 2400-Hz Reference Signal	To provide reference frequency for motor speed control in the record mode.
5. 3125-Hz Reference Signal	To provide reference frequency for motor speed control in the playback mode.
6. Real-Time Transmission (RTT)	To apply power to the SR playback electronics and supply limiters input through a 6 kHz L. P. filter.
7. Earth Scan "PIP" Pulses	To activate record head drivers thus providing time multiplexing function.
8. Record End-of-Tape Signal (output)	To indicate completion of record cycle.

- The flutter-and-wow channel preamplifier and limiter are similar to the IR and visible channel counterparts.
- The digital data channel preamplifier and limiter are identical to those used on the TIROS M SR recorder.
- The command and control circuitry is implemented with Fairchild low-power, integrated circuit gates, and interface and level-shifting networks.

TABLE VII-10. SR RECORDER CHARACTERISTICS

Parameter	Characteristic
Input Signals:	
Data Channels	
Visible and IR	Composite video and sync signal; dual inputs single-ended amplitude: between 0 and -8.16 volts (unloaded).
F&W Channel	FM square wave subcarrier; amplitude: +4.4 ±0.6 volts, frequency: 1.20 kHz
Digital Data	512 bits/sec biphase digital data
Output Signals:	
Data Channel (A)	FM subcarrier, ac coupled; amplitude: 2.0 volts (p-p) ±12.5 percent; frequency: 101.25 kHz corresponds to 0 volts; 74.75 kHz corresponds to -8.16 volts
F&W Channel (B)	FM subcarrier, ac coupled; amplitude: 2.0 volts (p-p) ±12.5 percent; frequency: 25 kHz ±0.5 percent
Data Channel (C)	Frequency: 10.67 k bits/sec biphase; amplitude: 2.0 volts (p-p) ±12.5 percent
Track Allocation:	
Track 1	
Record Head 1 Playback Head 1	SR IR
Record Head 2 Playback Head 1	SR VIS
Track 2	Time multiplexing tracks
Record Head 1 Playback Head 1 Record Head 2 Playback Head 1	F&W
Track 3 Record Head 2 Playback Head 1	Biphase digital data

TABLE VII-10. SR RECORDER CHARACTERISTICS (Continued)

Parameter	Characteristic		
Tape Speed:			
Record	1.3 inches per second		
Playback	27.1 inches per second		
Speed Ratio	20.833		
Tape Travel:			
Record	209 minutes (maximum)		
Playback	10 minutes (maximum)		
Tape Dimensions:			
Usable Length	1360 feet (Mylar base, magnetic tape)		
Width	0.25 inch		
Thickness	0.001 inch (nominal)		
Heads	Two three-channel record heads, One three-channel playback head, and One permanent magnet erase head (full tape width)		
Data Bandwidths:	Baseband	Subcarrier (± Deviation)	FM Spectrum
Data 1: Record (incl. sync tip)	0 to 0.9 kHz	4.22 ± 0.639 kHz	2.68 to 5.76 kHz
Playback	0 to 18.75 kHz	88 ± 13.25 kHz	56 to 120 kHz
F&W Data 2: Record	———	1.20 kHz	———
Playback	———	25.00 kHz	———
Data 3: Record	———	512 bits/sec	102 to 770 Hz
Playback	———	10.667 k bits/sec	2 to 16 kHz

TABLE VII-10. SR RECORDER CHARACTERISTICS (Continued)

Parameter	Characteristic
Power Drain:	
Record	Less than 9.7 watts
Playback	Less than 8.3 watts
Telemetry Signals (Analog):	
Off (Command Status)	0.0 volt nominal
Selected (Command Status)	-0.9 volt nominal
Record (Command Status)	-1.8 volt nominal
Playback (Command Status)	-2.6 volt nominal
Transport Pressure	From -0.5 to -4.5 volts
Motor Current	From -0.5 to -4.5 volts
Transport Temperature	From -0.5 to -4.5 volts
EOT Status	EOT Status tlm Not at EOT 1.0 V Nom. EOT Record 2.0 V Nom. EOT Playback 3.0 V Nom.
Motor:	Dc torque
Running Voltage	-24.5 volts
Transport:	
Angular Momentum (uncompensated)	Less than 0.02 inch-pound second in either direction
Acceleration	Less than 1.0 second (record mode): Less than 3.0 seconds (playback mode)
Deceleration	Less than 1.0 second (record mode): Less than 5.0 seconds (playback mode)
Mission Life	1 year
Pressurization Transport	16.5 psia (90-percent nitrogen and 10-percent helium)

TABLE VII-10. SR RECORDER CHARACTERISTICS (Continued)

Parameter	Characteristic
Seal: (Transport)	O-ring, flange, and pressure fitting
Weight:	18.7 pounds total (approx.)
Transport	13.3 pounds
Electronics	5.4 pounds
Size:	
Transport	14-inch diameter by 6.5-inch height
Electronics	9.75 by 4.75 by 4.68 inches

- The tape drive consists of a phase-locked servo drive system using a dc torque motor and an optical encoder connected to the capstan. This type of design greatly reduces the mechanical complexity while still retaining the advantages of the basic RCA coaxial reel-to-reel concept.

The electronics circuitry was designed for minimum power consumption, weight and volume, and for high reliability. The circuit elements described in the following paragraphs make up the total servo drive (Figure VII-30).

The optical encoder shaper is a hard limiter which produces a 5-volt square wave output upon application of a 5- to 100-microampere sinewave current input. The optical encoder output currents range between 20 and 37 microamperes, over the operating temperature range. The function of the motor driver circuit is to supply a current to the dc motor that is proportional to the 12-kHz pulse width. On the same board is a 500-Hz critically damped (worst-case) supply line filter to attenuate high-frequency current components from the supply line, and a relay and relay driver to reverse the motor current in the playback mode (the relay is not energized in the record mode). The motor driver circuit is essentially a power Darlington pair, with a saturating switch at the input to handle a playback turn-on current transient of 1.3 amperes, and yet provide an efficient drive during the record mode when only 20 mA of current is drawn from the supply line.

Phase frequency detection as well as digital control of the servo loop are accomplished with low-power flip-flops and gates. A -5.6-volt Zener-regulated supply powers all the IC elements and provides signal clipping bias voltage at the interface circuits to eliminate excessive voltage being applied to the IC elements.

The phase and frequency detector is implemented by flip-flops and gates. The flip-flops are interconnected via gate elements such that if the reference frequency is greater than the encoder frequency, (this happens when either a record or playback command is applied), then the output is at -5 volts. The output remains at -5 volts until the encoder frequency is greater than or equal to the encoder frequency plus a count of 2 (or more than 2). When the encoder frequency plus a count of 2 is greater than or equal to the reference frequency, then the output becomes 0 volt and it remains at 0 volt until the encoder frequency equals the reference frequency. At that time, the output consists of a train of pulses. The pulse width is then proportional to the time difference between the reference and encoder pulse negative edges. This type of detector has the advantage of applying 100-percent error voltage to the system when needed, which is very desirable for quickly attaining the desired tape speed.

The low-pass filter is a three-stage linear phase filter (LC) that attenuates the 1200 Hz and higher frequencies by 50 dB. The frequency and phase detector output is applied to the input of the LC filter. In front of the filter is a saturating and inverting switch followed by a 6-volt Zener diode, which standardizes the error amplitudes, followed by an emitter-follower filter driver.

The gain set and operational amplifier circuits stabilize the servo loop. Two operational amplifiers are used that have a gain of approximately 1 at very low frequency, but the gain and the phase lead increase with increasing frequency. Maximum phase lead (75 degrees) occurs at 150 Hz. This phase lead is necessary to oppose the phase lag from the 1200-Hz filter and motor electrical time constant, and to provide a phase margin. The phase lead is accomplished with simple lead-lag networks. A 600-Hz band stop filter (BSF) between the operational amplifiers attenuates the half-frequency components that result from doubling the 600-Hz encoder output frequency.

The sawtooth generator and differential comparator provide a pulse output at 12 kHz, whose duration is proportional to the dc level output from the operational amplifiers. The sawtooth output is 8 volts and swings between -8 and -16 volts. The sawtooth circuitry is similar to the IR and visible fm modulators; the 12-kHz frequency is well above any resonant frequency and yields low switching losses and low incremental speed variations (flutter). The 8-volt sawtooth amplitude was a compromise between the amount of tolerable noise and the loop gain. The differential comparator is a conventional one-stage amplifier with a constant current source to handle large voltage swings at either input.

b. MECHANICAL DESIGN

The basic transport mechanism design is similar to the SR recorder used on the TIROS M program. The electronics container consists of a machined frame instead of a casting, for the electronic circuit boards.

Servo loop stability calculations were made to determine overall gain and closed loop response. Measurements were made to determine overall gain and the ability of the loop to correct flutter resulting from torque perturbations. The servo motor drive closed loop response curve (shown in Figure VII-29) was obtained from the worst-case analysis.

The detailed servo loop stability calculations involved an analysis of the servo drive system in both the record and playback modes of operation. An overall gain margin of 7 to 10 dB and a phase margin of from 42 to 55 degrees were realized. The parameters and circuit components considered (shown in Figure VII-30) in the servo loop calculations are as follows:

- Gain calculation at one radian per second,
- Encoder,
- Phase and frequency detector,
- Servo loop frequency response
- Operational amplifiers and loop compensating networks,
- Capstan maximum torque at -10°C and minimum torque at +50°C,

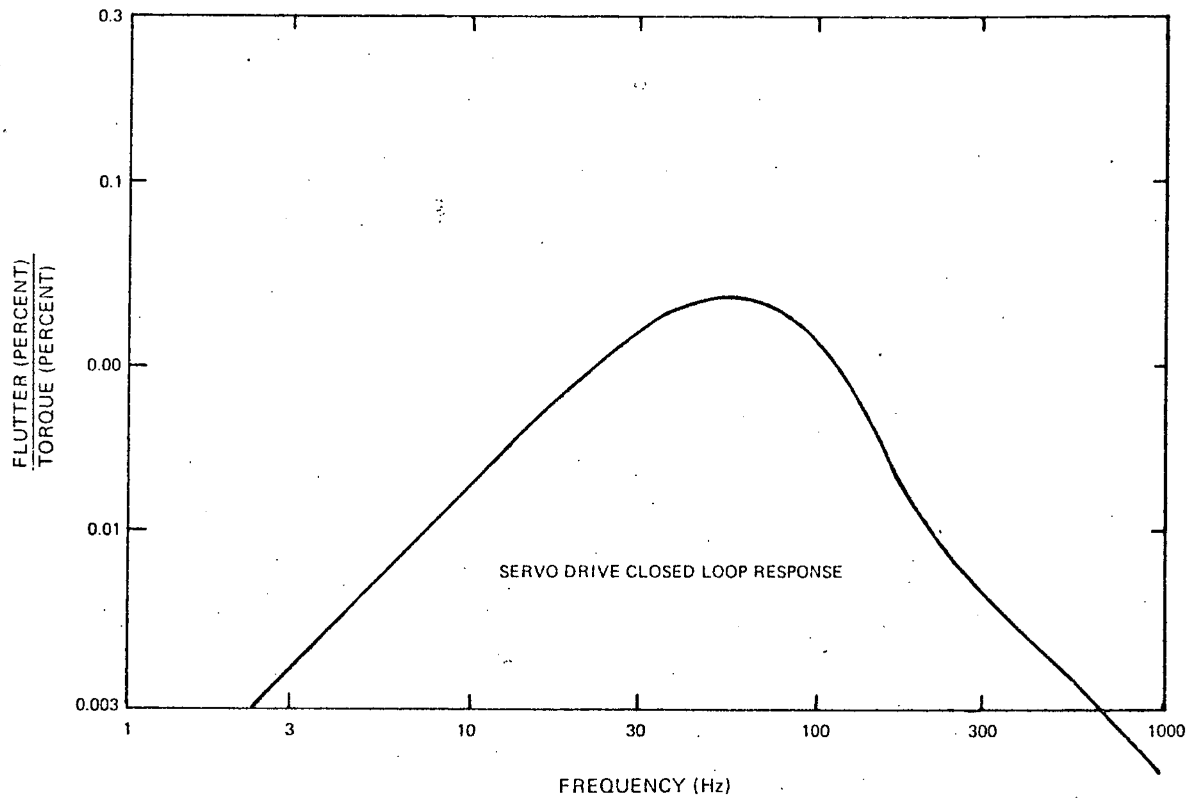


Figure VII-29. Flutter-to-Torque Ratio versus Frequency

- Record and playback modes torque margins,
- Record and playback modes worst-case stopping times,
- Record and playback modes start times, and
- Applied tape tension and slippage during playback acceleration.

In the record mode, the 2400-Hz square wave input reference frequency is divided by two and applied to the phase and frequency detector, which effects the turn-on of the motor current. This condition prevails until the encoder produces 600 pulses per second and, hence, motor speed is 0.6 revolution per second. At that time, both input frequencies applied to the frequency and phase detectors are equal, but the encoder output pulses are lagging in phase and the incremental change of the lag is determined by the change of torque variation or by any other servo loop parameter change.

The encoder and phase detector has a gain of 1591 volts per radian, because the encoder output is multiplied by two and the pulse output amplitude is 5 volts.

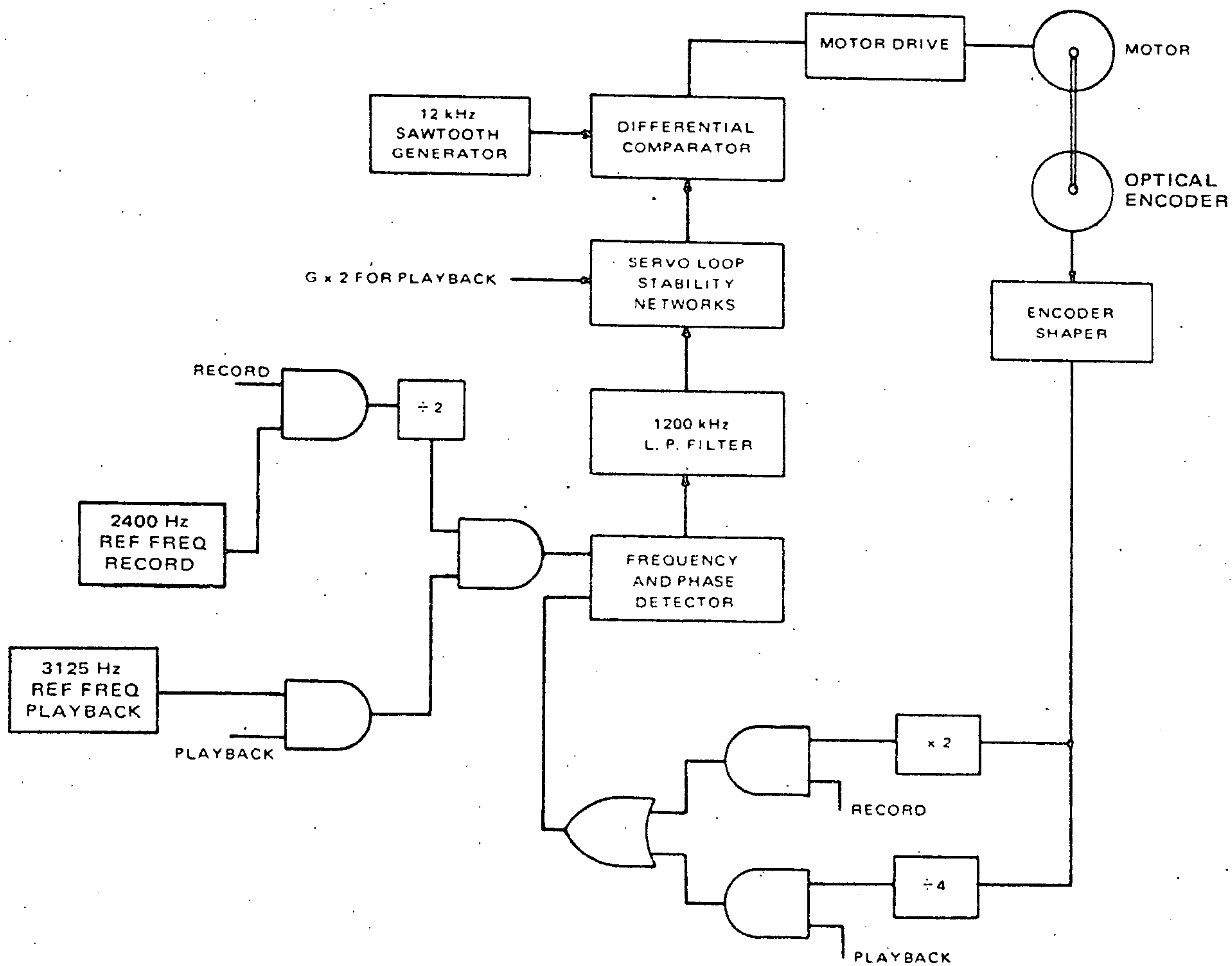


Figure VII-30. Simplified Servo Drive, Block Diagram

Therefore, the spatial error is 1/2000 of a revolution. The three-stage, 1200-Hz cutoff filter was designed and computer analyzed, yielding the following essential parameters:

Frequency (Hz)	1	10	50	100	200	300
Phase lag (degrees)	0.26	2.6	13	27	50.3	74

There is no amplitude change up to the frequencies of interest and the attenuation at 1200 Hz is 50 to 54 dB.

The two operational amplifiers and the associated loop compensation networks provide phase lead to counteract the lags introduced by the mechanical time constant, the LC filter, and the electrical time constant. Also included in the servo loop are two lead-lag networks and a 600-Hz band stop filter. The networks were designed and then computer analyzed on a nodal program.

The total loop gain at 1 radian-per-second was calculated to equal 82.4 dB. The 1 radian-per-second gain variations over the life and temperature limits were calculated to be ±25 percent or ±2 dB.

The servo loop frequency-determining components were worst-case analyzed with regard to life and temperature and an equivalent circuit was prepared suitable for nodal analysis on a computer. The computer plot showed that the gain and phase margins were adequate for worst-case conditions. Therefore, the servo loop was considered stable in the record mode.

In the playback mode, the 1 radian-per-second loop gain margin, 20 dB, is 12 dB below the record gain margin.

The required torque at the capstan in the record mode is made up as shown in Table VII-11.

TABLE VII-11. RECORD MODE REQUIRED TORQUE

	Max. Torque at -10°C (inch-ounces)	Min. Torque at +50°C (inch-ounces)
Negators	-1.1	+0.69
Motor Brushes	-1.1	-0.70
Heads and EOT Posts	-0.39	-0.19
Bearings	-1.6	-0.08
Total	4.19	0.28

Hence, the maximum required torque at the capstan is 4.19 inch-ounces, and the minimum retarding torque is 0.28 inch-ounce.

The minimum torque capability in the record mode with regard to the 12-kHz, 8-volt sawtooth signal was calculated to equal 7.1 inch-ounces. Consequently, the record torque margin is 2.91 inch-ounces, and the retarding or deceleration torque is 0.28 inch-ounce. Both of the margins were considered adequate.

The maximum required torque in the playback mode is made up as shown in Table VII-12.

TABLE VII-12. PLAYBACK MODE MAXIMUM REQUIRED TORQUE

	Maximum Required Torque (inch-ounces)
Motor Brush	1.10
Load Torque	2.17
Motor Losses	2.40
Encoder	0.20
Total	5.87

The minimum torque capability in the playback mode equalled 14.0 inch-ounces, which was considered an adequate margin.

The record mode maximum stopping time was determined to be 0.847 second, and the playback mode maximum (worst-case) stopping time was calculated to be 3.07 seconds. The record and playback start times are considerably less, because the acceleration torque is higher than the deceleration torque. The maximum tension applied to the tape during playback acceleration was calculated to equal 8.64 inch-ounces.

Because the capstan and tape interface coefficient of friction is not known, a simple test was performed to determine the tape slippage properties during playback acceleration. Data was recorded on tape at 2900 Hz per inch and many cycles of playback starts were recorded. The tape was then played back and the playback signal was presented on the oscilloscope along with the encoder output (320 pulses per inch). No slippage was observed on the presentations from recordings made at -10 or +25°C.

2. New Design

The following list is of the newly designed electronic circuitry for the ITOS D and E SRR. A brief description of the reasons for these new designs follows:

- Write amplifiers
- Command and control
- PIP pulse processor
- 6000-Hz lowpass filter
- Mode selection
- Limiter
- Demodulator
- Equalizer
- Digital data interface

The write amplifiers require redesign to accommodate the switching requirement for time multiplex operation. The signals (visible and IR) to both record heads are applied simultaneously for a period slightly greater than one-half the radiometer scan period. The record head signals are then inhibited during the remainder of the period. The data, which was recorded simultaneously, appears in sequence along the data track. Since a period of one-half the scan period was used for the commutation, each block of data contains one earth scan.

The command and control section is very similar to that used in the TIROS M SRR. Slight changes are required because of the different speed ratio and different command structure. The SRR controls the tape speed by phase locking the encoder output with a reference frequency from the spacecraft. To change the absolute tape speed and/or the tape speed ratio, it was necessary to route the reference frequency and the encoder frequency through various divide networks in the command and control section of the recorder. A new command for the ITOS D and E SR recorder is to play back while recording for real-time display of the time multiplexed visible and IR channel data.

The PIP pulse processor is an entirely new circuit for ITOS D and E. The function of this circuit is to receive pre- and post-earth scan signals and use them to turn the write amplifiers on and off at the correct intervals to perform the time multiplexing.

The preamplifier output buffer is a newly required circuit. Its function is to lower the output impedance of the preamplifier so that it can drive the 6000-Hz low-pass filter. The 6000-Hz low-pass filter is used only during the real-time transmission of the time multiplexed radiometer data. This filter is required to remove the 12-kHz motor spikes, crosstalk or pickup from the data before it is limited.

Mode selection is required so that the limiter input can be switched from the 6000-Hz low-pass filter output to the preamplifier output. This is necessary since the frequency spectrum in playback is 20.83 times higher than in record.

The data track limiter is basically the same as the existing design, except that the gain is increased to handle the real-time transmission capability. When the recorder is running at record speed, the signal level coming from the head is approximately 21 times lower than the signal level at the playback tape speed. This 21-to-1 difference is accommodated by increasing the limiter gain by 26 dB. The flutter-and-wow track, which does not have to play back at the record tape speed, retains the existing limiter design. In order to improve the bit error rate on the digital data track, the higher gain limiter is used for playback from that track.

The demodulator recovers the baseband information of the SR signal for real-time transmission, since during the record cycle the visible and IR data are frequency modulated prior to being time multiplexed on the tape. Since the time multiplex serializes the visible and IR data into a nearly continuous stream, only one demodulator is necessary.

Equalization on the digital data track is necessary to retain the zero crossings of the playback data. After equalization, the data is limited. Thus, the bit error rate of this playback channel is better than 1 in 10^5. The digital data interface is necessary to accept the biphase data from the spacecraft and shift it to the voltage levels used in the recorder.

The following mechanical items require modification for the ITOS D and E recorder:

- Capstan diameter reduction to 0.69 inch
- New head mount design

The speed ratio required for ITOS D and E is 20.833 to 1, while a 16-to-1 ratio was required for the TIROS M application. The new ratio was obtained by lowering the record speed to 1.3 inches per second (from 1.875 inches per second) and lowering the playback speed to 27.1 inches per second (from 30 inches per second). The speed change in the record mode is obtained by operating the capstan at the same angular velocity as in TIROS M but reducing the capstan diameter from 1 inch to 0.69 inch. The speed is adjusted in the playback mode by changing the angular velocity of the capstan.

The time multiplex function requires the plac^ment of an additional record head in the ITOS D and E SR recorder. This additional head necessitates the relocation of all heads in the SR recorder. The head locations are similar to the configuration used successfully in the High Data Rate Storage System (HDRSS) recorder flown in the NIMBUS spacecraft. During real-time transmission of sensor data, the playback head is operated and the data is routed to the VHF real-time transmitter.

3. Functional Description

a. GENERAL

The SR recorder is normally off and remains so until activated, if selected, by either the record command or the playback command. While in the off state, a -24.5-volt level is supplied to the end of tape (record) gate, so that a determination of the status of the recorder can be obtained by the programmer. The -24.5-volt motor drive power is obtained from the spacecraft power supply. A reference frequency for control of the motor speed during the record and playback modes, respectively, is derived from the 2400-Hz and 3125-Hz reference frequency input signals of the time base unit.

b. RECORD MODE

The record signal electronics are composed of the IR and visible FM modulators, record head drivers (write amplifiers), flutter-and-wow record head drivers, digital data head drivers, PIP pulse processor, two record heads, logic gates, and the servo drive circuitry.

When a record command is applied, assuming the 2400-Hz reference signal and the -24.5-volt motor drive power are also applied, the following sequence takes place. The record power switch turns on, and in turn effects the turn on of the following items: (1) the record circuitry, IR and visible fm modulators and video write amplifiers; (2) the flutter-and-wow record head driver; and (3) the transport drive servo circuitry, the dc motor, optical encoder, encoder shaper, frequency and phase detector. The servo loop and record mode switches control the turn-on current from the -24.5-volt supply line for selecting the motor speed, the direction of motor rotation, and the motor torque during starting and running.

The IR and visible radiometer input signals (0 to 8.16 volts) from the SR processor are applied to respective modulators where they each frequency modulate a subcarrier. The modulated signals are applied to their respective record amplifiers. At the same time, the 1.2-kHz signal is applied to the flutter-and-wow record amplifier. A permanent magnet erase head provides a saturated erase condition at the tape immediately before the tape passes the record heads. If a playback command is not received, the tape continues to move until it reaches the metallic strip which shorts the "end-of-tape" (EOT) signal to ground and forces a logic gate output high. This, in turn, disables the record power switch, the servo power switch, and the record mode servo gates. The recorder then turns itself off.

c. PLAYBACK MODE

The playback signal electronics are comprised of one playback head (3 tracks), three preamplifiers, three limiters, an equalizer, a buffer, a low-pass filter, and a mode selector. The servo loop switch and the two operational amplifier switches are enabled. One of the switches multiplies the 1 radian-per-second loop gain by 2 and the other switch shifts the bias voltage from -12 to -17 volts. At the same time, a playback enable gate is operated which allows the 3125-Hz reference frequency to be applied to the frequency and phase detector. The dc torque motor is powered in reverse direction and the encoder generates output pulses, in a similar manner to the record mode, until the number of pulses reaches 12,500 per second. At this time, the frequency and phase detector receive 3125 pulses per second; this is compared to the 3125-Hz reference frequency and the resultant loop control is similar to that of the record mode.

The condition continues until the EOT metallic strip shorts the EOT signal to ground. This turns off the servo loop power, playback preamplifiers and limiters, gain and bias switches, and disables the playback servo loop. The motor decelerates and the SR recorder turns itself off. When the next record command is applied, the previously described record mode conditions apply, except for the 5-second disable delay, which operates every time the recorder is switched directly from the playback to record mode. Consequently, the current applied to the motor is delayed by 5 seconds.

d. MECHANICAL DESIGN

A permanent magnet erase head, effective for all tracks, is mounted adjacent to the record head so that the recorded signal is erased immediately after playback, and immediately before recording, thus ensuring a "clean" tape and optimum signal-to-noise ratios. This head is not in contact with tape and therefore does not cause tape degradation.

Each tape transport is comprised of a machined base which contains two coaxial tape reels, mounted one above the other, a tape-driver motor, a capstan, three magnetic tape heads, a permanent magnet erase head, three tape idlers and a negator spring assembly. The two tape reels are torqued against each other by the negator spring assembly to provide constant tape tension. In the record mode, the capstan driven tape is wound from the bottom reel, past the magnetic head assembly, around the idlers to change its level, and onto the upper reel. In the playback mode, the direction is reversed, and the tape is rewound from the upper to the lower reel. All signals are played back in a direction opposite to recording. The permanent magnet erase head is mounted so that the signal is erased after playback and before record. The erase function occurs without adding time to either the record or playback function.

The idlers that change the tape level require no angular adjustments. When mounted in the transport base assembly, they are automatically set at the correct angle. Two of the idlers are crowned and stability of tape motion is aided by the self-centering effect of the crowned idlers on the tape.

Head tracking is not affected by the slight twist required to move the tape from the plane of one reel to the plane of the other reel via the tape idlers, even for significant differences in the effective diameters of the two reels. (The effective diameter of a reel is the nominal diameter plus an amount equal to twice the thickness of the tape wound on the reel.)

The record heads and the playback head are similar three-channel heads. Recording or playing back occurs on all three tape tracks simultaneously.

During the recording of the SR data, the SR playback head is enabled to provide time multiplexed SR data for real-time transmission.

The tape is 1/4-inch mylar-base tape, 1360 feet long, with an oxide coating on one side to provide the magnetic medium. The tape is wound on the tape transport such that the oxide-coated side of the tape does not contact the tape idlers or the capstan.

The motive power for the tape transport is a dc torque motor that is rated at 35 inch-ounce peak torque. The rotor is mounted directly to the capstan. Minute speed variations are sensed by a capstan driven optical encoder and correction signals are fed back so as to provide constant drive. The coupling between the motor and the capstan provides a tape speed of 1.30 inches per second for record and 27.1 inches per second for playback. The maximum record time is 209 minutes, and the maximum playback time is 10 minutes. The motor receives the excitation signals from the motor drive circuits. Starting and running torque of the motor, and the direction of rotation are controlled by the logic circuits and the motor drive circuits.

End-of-tape sensing is performed during each cycle of the SR recorder and is activated at a specific position on the tape. There is a contact type end-of-tape switch for each reel. The switches are operated when contacted by strips of conductive tape attached to the magnetic tape near both ends of the tape. As a backup, there are also microswitches located so as to be activated by a full reel of tape should the contact type switch not be activated by the conductive tape. A fail-safe tape mounting clamp is also used, the recording tape is physically clamped to the reel. The clamp, in conjunction with a buffer spring to take up the shock, would prevent the tape from leaving the reel, even if run out entirely to the end of the tape.

The design life of the motor is 12 months, continuous operation, under orbital environmental conditions. The motor drives the capstan directly. The results of an accelerated life test, performed on another program using a similar motor, indicated that the life of the motor is approximately 2 years, continuous operation.

The negator springs, magnetic tape and bearing lubrication are the same as those used on TIROS M.

e. TELEMETRY

There are five telemetry signals from each SR recorder; (1) operational status, (2) motor current, (3) temperature, (4) pressure, and (5) EOT status.

F. VERY HIGH RESOLUTION RADIOMETER RECORDER

1. General

The very high resolution radiometer recorder (VHRRR) is a one-speed unit used to store VHRR data. The recorder has 1360 usable feet of 1/4-inch magnetic tape, and operates at a speed of 30 inches per second in both the record and playback modes. The VHRR recorder is identical to the AVCS recorder of the TIROS M program.

The VHRR is comprised of two units, a transport and the electronics. The transport contains the tape transport and the playback preamplifier within a pressurized enclosure. The electronics unit contains the motor drive circuits and the record playback signal electronics.

The functions of the recorder are to record, play back, and erase signals supplied by the spacecraft's VHRR. The analog signals supplied by the VHRR frequency modulate a subcarrier before being recorded, and all playback signals are amplified and amplitude-limited. Playback and signal transmission occurs in a direction opposite from that used in recording.

VHRR recorder characteristics are summarized in Table VII-13.

2

TABLE VII-13. VHRR RECORDER CHARACTERISTICS

Item	Characteristics
Tape Speed, Record or Playback	30 inches per second.
Record Time or Playback Time	9.1 minutes maximum (end-to-end)
Heads	One 3-channel record head; one 3-channel playback head; one permanent erase head, full tape width.
Tape	1360 feet of 0.25-inch wide, 0.0011-inch thick, mylar base, instrumentation magnetic tape.
Pressurization	16.5 psia with 90-percent air (rel. humid. ≈ 35 percent) and 10-percent helium.
Seal	O-ring, sealed flange, and pressure fitting.
Weight	
Transport	13.6 pounds
Electronics	4.5 pounds
Dimensions	
Transport	15.4 inches maximum diameter by 6.5 inches in height.
Electronics	8-1/2 by 4-3/8 by 4-1/8 inches.
Motor	2-phase, reversible
Speed	12,000 rpm
Operating Voltage	48 volts p-p, 400-Hz square wave
Supply Voltage	-24.5 Vdc
Power Consumption (tape transport and electronics)	
Standby	0.9 W (37 mA)
Record	18.4 W (750 mA)
Playback	15.9 W (650 mA)
Start Mode	61.0 W (2,500 mA)

TABLE VII-13. VHRR RECORDER CHARACTERISTICS (Continued)

Item	Characteristics
Input Signals	
Data Channels (1&3)	VHRR data ranging in amplitude from -6.6 volts dc (black or hot level) to -9.7 volts dc (white or cold or sync tip level) at a base-band of 0 to 35 kHz; and time code with a pulse amplitude as follows: data "1" level -9.7 volts dc data "0" level -6.6 volts dc bias level -8.2 volts dc
Flutter-and-Wow Channel	50-kHz square wave, 4.4 ± 0.6 volts in amplitude.
Output Signals	
Data Channels (1&3)	Amplitude limited FM subcarrier ranging in frequency from 73.5 kHz to 102.5 kHz at an amplitude of 2 volts ± 1 dB p-p.
Flutter-and-Wow Channel	50-kHz square wave, 2 volts ± 1 dB p-p.
Telemetry	
Transport Pressure	-0.5 to -4.5 volts
Transport Temperature	-0.5 to -4.5 bolts
Line Current	-0.5 to -4.5 volts
Command Status	0V: Off -0.9V: Standby -1.8V: Record -2.7V: Playback

Table VII-14 is a summary of pertinent information on VHRR recorder signals.

The tape transport is mounted in an enclosure which is hermetically sealed and pressurized, and the electronics container consists of a sheet metal frame with printed circuit boards. Multipin connectors provide signal outlet to the tape transport and other spacecraft systems. The recorder is designed to operate over the temperature range from -10 to +45°C for a period of one year.

TABLE VII-14. VHRR TAPE RECORDER SIGNAL DATA

Item	Baseband	Subcarrier ± Deviations	FM Spectrum
F&W Record		50 kHz	
F&W Playback	dc to 5 kHz	50 kHz	
Record and Playback	dc to 35 kHz	±14.5 kHz	38.5 - 137.5 kHz

2. Interface Signals

The tape recorder interface signals are described in Table VII-15. The succeeding paragraphs describe in more detail the tape transport, motor drive circuit, video record and playback circuits, and the flutter-and-wow record and playback circuits, in that order.

3. Tape Transport Assembly

The tape transport assembly consists of a base casting on which the following are mounted: two coaxial reels, a capstan, record head, playback head, erase head, three tape idlers, flywheel, and negator spring assembly. A constant torque is applied to each of the two tape reels by negator springs to provide constant tape tension. As the tape unwinds from one reel, it makes a 180-degree wrap around the capstan, passes over three idlers, and then loops around the capstan again for 180 degrees, and in the opposite direction, before it is taken up by the second reel. The closed loop formed with respect to the capstan reduces flutter, since any transient changes in tape tension produce essentially equal and opposing torques at the capstan. The slight twist required to move the tape from the plane of one reel to the plane of the other is imparted by the rollers.

The tape is 1/4-inch wide, 1360 feet long, instrumentation grade magnetic tape. The tape is wound and threaded so that the oxide-coated side does not contact any part of the transport except the magnetic heads. The record and playback heads contain three tracks each. The erase head is a single permanent magnet, spanning the full width of the tape, which removes the previous recorded information after the tape passes the playback head and again before information is recorded on the tape. Therefore, the tape is erased twice before each recording operation.

TABLE VII-15. VHRR RECORDER AND SPACECRAFT INTERFACE SIGNALS

Signal	Description
Power Bus 1 (-24.5 Vdc regulated)	This voltage is present whenever the tape recorder is in the record, playback, or standby mode. Power for the signal processing circuits is drawn from this line.
Power Bus 2 (-24.5 Vdc regulated)	This voltage is present whenever the tape recorder is in the record, playback, or standby mode. Power for the motor drive circuits is drawn from this line.
Record Command	On receipt of a record command, the tape recorder operates in the record mode unless one of the playback commands is present. In this case the record command is ignored. In the record mode, the two FM modulators and the three record amplifiers are activated to process and store the incoming VHRR data and the flutter-and-wow information. The motor drive circuits are activated to drive the transport mechanism in the record direction.
Playback Command 1	On receipt of playback command 1, the tape recorder operates in the playback 1 mode. The playback amplifiers for channel No. 1 (stores IR1 and VIS 2 time multiplexed data in the normal mode of VHRR operation or IR1 or VIS 2 data in the backup mode of VHRR operation) and channel No. 2 (stores flutter-and-wow information) is activated. The motor drive circuits are activated to drive the transport mechanism in the playback direction. The record mode of operation is inhibited.

TABLE VII-15. VHRR RECORDER AND SPACECRAFT INTERFACE SIGNALS (Continued)

Signal	Description
Playback Command 2	On receipt of playback command 2, the tape recorder operates in the playback 2 mode. The playback amplifiers for channel No. 3 (stores IR2 and VIS 1 time multiplexed data in the normal mode of VHRR operation or IR2 or VIS 1 data in the backup mode of VHRR operation) and channel No. 2 (stores flutter-and-wow information) are activated. The motor drive circuits are activated to drive the transport mechanism in the playback direction. The record mode of operation is inhibited.
Motor Phase 1	This control signal is supplied continuously to the subsystem for use in the motor drive circuits. The signal is a square wave at 400 Hz.
Motor Phase 2	This control signal is supplied continuously to the subsystem for use in the motor drive circuits. The signal is a square wave at 400 Hz, delayed by 90 degrees with respect to that of phase 1.
Flutter Clock Signal	The flutter clock signal is present continuously for use in the flutter-and-wow channel during record mode. The signal is a square wave at 50 kHz.
Playback End-of-Tape	The tape recorder provides a signal indicating that the end-of-tape has been reached during playback. This signal consists of two levels: -24 volts dc when not at end-of-tape, and an open circuit when at end-of-tape during playback, or when the recorder is in the off mode.
Telemetry Power	Upon command, -24.5 volts dc regulated voltage is supplied for monitoring the pressure and temperature telemetry points.

The capstan is driven by a reversible, 2-phase, synchronous motor through a belt. The mean angular momentum of the transport is reduced to less than 0.02 pound per inch per second by means of the flywheel mounted on the shaft of the capstan. For both record and playback, speed of the 12,000-rpm motor is reduced by the pulley and belt coupling between the motor and capstan shafts to provide a tape speed of 30 inches per second.

The recorder incorporates several end-of-tape (EOT) sensing devices. The playback indicator consists of a 4-foot length of silver-coated conductive tape fastened to the magnetic tape, and is sensed by a two-contact pickup located near the reels. Should the normal playback EOT sensor fail to function, a microswitch actuated by tape reel diameter build-up will interrupt the recorder playback command, and stop the recorder. The record EOT consists of a microswitch actuated by tape build-up which interrupts the record commands and stops the recorder. A fail-safe tape mounting is also used to anchor the ends of the tape to both reels.

4. Electronics Unit

The VHRR recorder motor is driven by a solid-state power amplifier, excited by a 400-Hz square-wave synchronizing signal from the command subsystem and powered by -24.5 volts dc supplied through the power switching circuits. The motor is wound with separate "start" taps which are switched in and out by a relay, allowing the motor to accelerate rapidly to synchronous operating speed. The time allocated for acceleration is internally controlled and lasts approximately 1.3 seconds for both record and playback. At the conclusion of the 1.3 seconds, the motor drive outputs are switched to the "run" taps. Motor reversal is accomplished by reversing the phase of the 400-Hz signal at one of the two motor windings.

Data signals from the VHRR are applied to fm modulators wherein the signals are amplified and fed to voltage controlled oscillators to produce an fm subcarrier with a deviation ranging from 73.5 to 102.5 kHz. These subcarriers are then applied to the appropriate record amplifier and finally to the tape.

During playback, the recorded fm subcarrier is amplified by the playback preamplifier circuit, amplified and limited by the playback amplifier circuit, and routed to the multiplexer. During playback mode and direct mode operation, the active record and playback channels are selected by command.

During the record mode, a stable 50-kHz signal generated in the command subsystem is recorded on track 2. During readout, this signal is amplified, limited, and filtered to provide a constant-amplitude fm signal having a center frequency of 50 kHz and frequency deviations proportional to the flutter-and-wow characteristics of the recorder.

The record power switch is activated by the record command and routes power to the flutter-and-wow record head driver, the channel 1 and 3 modulators, and the signal record head devices. One of the two playback power switches are activated during playback to route power to the preamplifier and limiter.

The playback EOT circuit supplies power when the recorder is not at the end of playback, and removes power when it is. The command status telemetry indicates the VHRR recorder's mode of operation.

The motor drive circuit is a four-phase, two-bridge circuit, providing the following functions:

- Drives the motor such that the tape is moving in record direction when in record mode with no playback command present,
- Drives the motor such that the tape is moving in playback direction when in playback mode, regardless of record status,
- Provides high start-up current to the motor during record and playback start mode, and
- Stops the motor current when either record or playback end-of-tape signal has been received.

The one-shot and differentiating circuit provides a 1.3 second pulse which holds the motor drive circuits in the start mode to accelerate the tape drive mechanism. The start mode operation continues until the one-shot pulse (1.3 seconds) terminates, turning off the relay driver, which switches the relay to the run mode. The one-shot power output stage is also turned off. Operation in the run mode is similar to the start mode, except that the bridges drive the full motor winding, due to the lower torque requirement during the run mode.

Record mode operation is activated whenever a record command is present along with the 400-Hz signals, and neither of the playback commands is applied. Two motor drive outputs, with a 90° phase difference, are applied to opposite sides of the motor bridge input. The outputs of the two bridges are applied to the motor, and the sequence of the phases drives the tape in the record direction. During the start-up one-shot period of 1.3 seconds, the tape reaches its final velocity of 30 inches per second. When the one-shot pulse terminates, it causes the turn-off of the base drive current changers and turn-off of the relay driver which switches the relay to the run mode.

When the record EOT signal is received, a ground potential is applied to cause the motor power switch to turn off.

When the playback command is received, the record command is disabled and the 1.3-second start mode one-shot is enabled. The 1.3-second one-shot performs the same functions as in the record mode. At the same time, the motor power switch is enabled. One phase of the 400-Hz signal is inverted in comparison to the record mode drive signals. This phase 1 inversion reverses the motor rotating field, and, consequently, the motor direction is reversed in comparison to the record direction.

The sequence of events for the start and run modes during playback is similar to the sequence which occurs during the record operation. 1.3 seconds after the application of the playback command, the base drive current-changing transistors are switched off, and the relay driver is switched off, thus returning the relay to the run mode. The tape continues to move at 30 inches per second until the EOT playback signal is received and the motor power switch is turned off. At the same time, the EOT circuit, which was enabled during the playback mode, is disabled. The motor current telemetry circuit is a measurement of the actual motor current.

The mechanical assembly of the VHRR recorder is identical to the AVCS recorder used on TIROS M.

SECTION VIII
COMMAND SUBSYSTEM

A. FUNCTION

The satellite command subsystem processes commands transmitted from the CDA ground stations, recognizes and rejects spurious commands, accepts and decodes valid commands, and distributes the appropriate control signals and voltages, with the proper timing, throughout the satellite to effect the command operations. The command functions include those that respond immediately to ground station command and those that take place in programmed sequences of variable duration and begin at programmed orbit times. Remote VHRR record functions, SR functions, and attitude control functions are in the latter category. The command subsystem also performs ancillary timing and telemetry functions.

The command subsystem performs the following specific functions:

- Provides for selective commanding of an individual satellite in a multiple-satellite system and for the selection of one of the satellite's redundant command channels for receiving the commands.
- Provides immunity from spurious commands, including commands intended for other satellites in the same system.
- Decodes received commands and, depending on the commanded function, either processes and distributes them for real-time response or stores the command program for remote operations.
- Regenerates the commands, as detected in the satellite, for retransmission to the ground station for use in command verification.
- Routes commands and internally sequenced signals to the various subsystems of the satellite where they are required for initiation or control of operations.
- Generates timing signals from which all required satellite timing and synchronizing signals are derived and from which a coded time identification signal is generated to accompany SR, VHRR, and VTPR recorded data.
- Provides for satellite response to telemetry requests by certain specially equipped stations other than CDA stations.
- Provides storage and delayed initiation for remote VHRR recording and attitude correction commands; and for selective inhibition of SR and VHRR real-time transmission.

The command functions are implemented by components that comprise two redundant command channels. These are (1) a dual decoder unit, comprising two identical command decoders, each of which receives an input from one of two identical command receivers, (2) a dual programmer unit, comprising two identical programmers, (3) two command distribution units, (CDU's) and (4) a dual time base generator unit (TBU), comprising two identical time base generators and two time code generators. Cross-coupling within the subsystem provides for selecting individual components to make up the command receiving channel in order to prevent a single component failure from disabling the subsystem or degrading its performance. A block diagram showing the primary functional relationships among these units is presented in Figure VIII-1.

A command transmitted to the satellite by a ground station contains, in sequence two audio frequency tones, an "enable" tone and a frequency shift keying (FSK) tone, each modulated on the radio frequency carrier. The binary command message data is modulated by frequency-shift keying of the second tone. Power is always applied to both command receivers and to the enable tone detector circuitry in each decoder. The frequency of the enable tone determines which FSK tone detector becomes enabled. The frequency and duration of the ensuing unmodulated portion of the FSK tone are then checked. If the frequency and duration of the FSK tone are correct, power is applied to the FSK decoding circuits so that the modulated portion of the FSK tone, containing the command message, can be detected. The first portion of the binary FSK coded command message contains a satellite address, which is a 12-bit binary words, containing 2 data "1's" and 10 data "0's". The address is decoded, and, if the address and the format of the address (two data "1's" properly located in the 12-bit word) are both correct, decoder power is latched on, thus opening the circuits for continued command decoding and for command execution. Each command that follows must be preceded by a correct address and must contain a correct (2-out-of-12) format. If these conditions are met, the ensuing commands are decoded and routed either to the CDU's for real-time operations or to the programmers for storage and control of remote operations.

If remote operations are programmed, the programmer produces sequenced signals for control of attitude correction or radiometer operations at programmed intervals. These signals are distributed to the appropriate radiometer, recorder, or attitude control circuits. A list of the commands used for the ITOS D and E spacecraft is given in Table VIII-1.

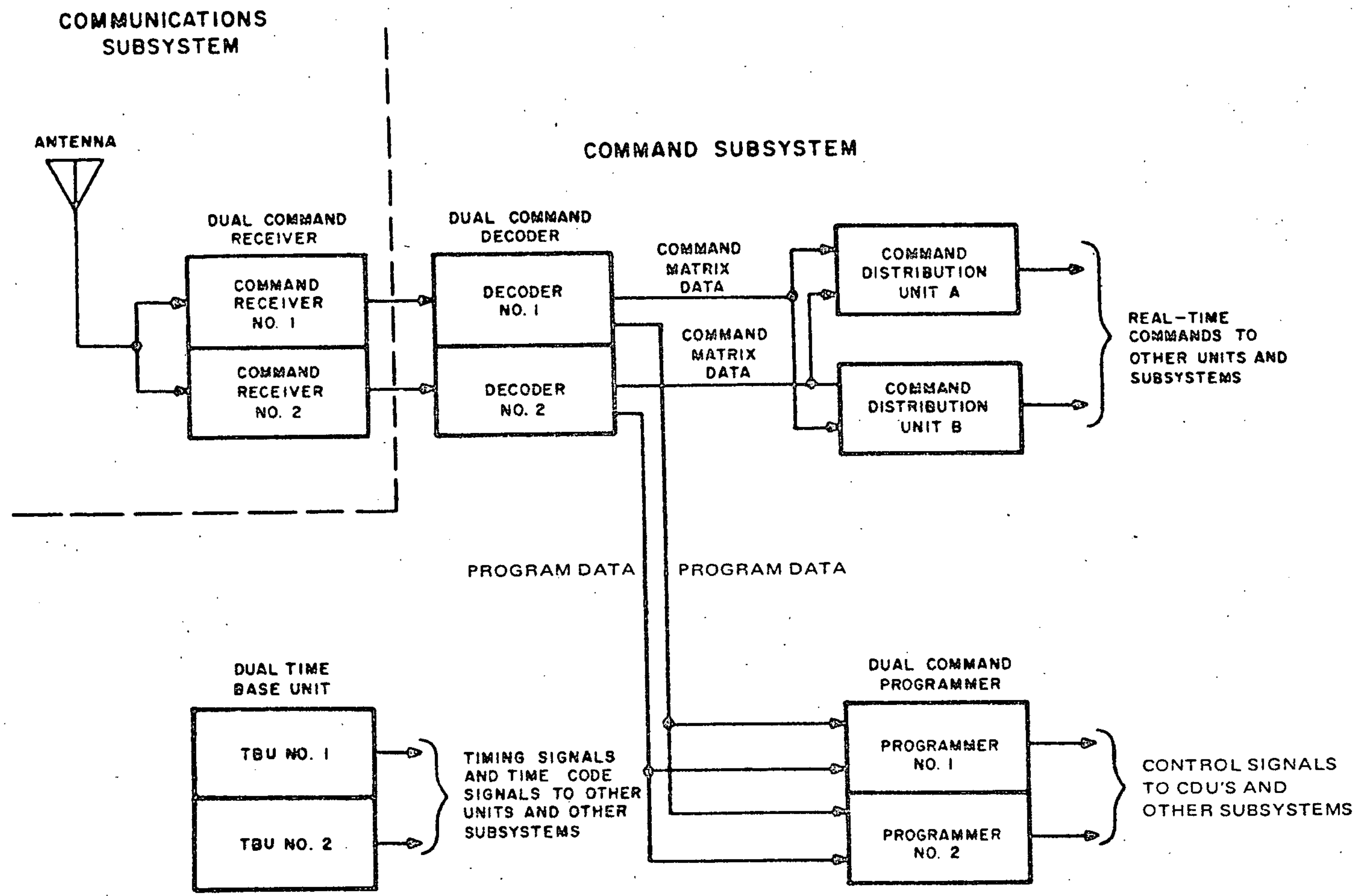


Figure VIII-1. Command Subsystem Block Diagram

TABLE VIII-1. ITOS D AND E COMMANDS

• VTPR Filter Motors 1 and 2 ON
• VTPR Calibrate Disable
• VTPR Patch Calibrate ON
• Use VTPR 1, Not 2
• Use VTPR 2, Not 1
• Use Neither VTPR
• Enable VHRR Recorder Power
• Disable VHRR Recorder Power
• Playback VHRR Recorder Data Channel 1
• Playback VHRR Recorder Data Channel 2
• Select Multiplexer 1, Not 2
• Select Multiplexer 2, Not 1
• Select S-Band Xmtr 1, Not 2
• Select S-Band Xmtr 1, Not 2
• Select S-Band Xmtr 2, Not 1
• Real Time S-Band Xmtr ON
• S-Band Xmtr OFF
• Use SR Recorder 1
• Use SR Recorder 2
• Use SR Recorder 3
• Use SR 1, Not 2
• Use SR 2, Not 1
• Use Neither SR
• SR Motors 1 and 2 ON
• SR Motor 1 OFF
• SR Motor 2 OFF
• Select Multiplexed Real -Time SR Modulation
• Select Visible Real-Time Day SR Modulation
• Select IR Real-Time Day SR Modulation

TABLE VIII-1. ITOS D AND E COMMANDS (Continued)

- Select SR Recorder 1
- Select SR Recorder 2
- Select SR Recorder 3
- Select No. SR Recorder
- Playback SR Recorder 1
- Playback SR Recorder 2
- Playback SR Recorder 3
- Use VHF Xmtr 1, Not 2
- Use VHF Xmtr 2, Not 1
- Use Neither VHF Xmtr
- Use Digital Data Processor No. 1, Not No. 2
- Use Digital Data Processor No. 2, Not No. 1
- Use Neither Digital Data Processor
- Solar Proton Monitor OFF
- Solar Proton Monitor ON
- Disable Digital Telemetry Power
- Select Programmer 1, Not 2
- Select Programmer 2, Not 1
- Select Neither Programmer
- Load Picture Program
- Load QOMAC Program
- Time Base Unit 1 ON, Not 2
- Time Base Unit 2 ON, Not 1
- Enable QOMAC Power
- Disable QOMAC Power
- Magnetic Bias System Positive
- Magnetic Bias System Negative
- Step Magnetic Bias Switch
- Disable Magnetic Bias System

TABLE VIII-1. ITOS D AND E COMMANDS (Continued)

- Momentum Coil 1 ON
- Momentum Coil 2 ON
- Disable Momentum Coils System
- Momentum Coil System Positive
- Momentum Coil System Negative
- Use Pitch Loop 1, Not 2
- Use Pitch Loop 2, Not 1
- Pitch Loop Open Loop Mode
- Pitch Loop Closed Loop Mode
- Pitch Sensors Crossed
- Pitch Sensors Normal
- Enable Dual Motor Mode
- Disable Dual Motor Mode
- Dual Motor Mode ON
- Pitch Loop Gain Coarse
- Pitch Loop Gain Normal
- Deploy Solar Panels
- Use Beacon Transmitter 1, Not 2
- Use Beacon Transmitter 2, Not 1
- Use Neither Beacon Transmitter
- Beacon Housekeeping Telemetry ON
- Beacon Housekeeping Telemetry OFF
- DDP Commutator Random Access Mode
- DDP Commutator Auto Advance Mode
- Telemeter Time Code
- Telemeter Roll Sensor No. 1 and Selected Pitch Index
- Telemeter Roll Sensor No. 2 and Selected Pitch Index
- Telemeter VTPR Analog Data
- Telemetry in Acquisition Mode
- Telemetry in Operational Mode

TABLE VIII-1. ITOS D AND E COMMANDS (Continued)

- Telemeter Pitch Sensor 1
- Telemeter Pitch Sensor 2
- Telemeter Roll Sensor 1
- Telemeter Roll Sensor 2
- Use Regulator 1 ON, Not 2
- Use Regulator 2 ON, Not 1
- Shunt Control Ampl. 1 ON
- Shunt Control Ampl. Mode 1
- Shunt Control Ampl. 2 ON
- Shunt Control Ampl. Mode 2
- Charge Control, Trickle Charge
- Charge Control, Normal Charge
- VHRR Motors 1 and 2 ON
- VHRR Motor 1 OFF
- VHRR Motor 2 OFF
- Use VHRR IR 1 and VIS 2
- Use VHRR VIS 1 and IR 2
- Use VHRR No. 1
- Use VHRR No. 2
- Disable VHRR Electronics

B. DESIGN

1. General

The ITOS D and E command subsystem is functionally similar to its counterpart on the TIROS M/ITOS-1 spacecraft.

The ITOS D and E command format has a capacity of 132 commands using a 2-out-of-12 command code format. Each command belongs to one of two "sets". Each 2-out-of-12 coding is used twice, once in each set. The set to which a particular command belongs is determined by the spacecraft address that precedes it. The normal address coding is used to select set I. Set II is selected by shifting each of the coded address bits by one bit position in the 12-bit format. The command distribution units contain a decoding circuit for each of the 2-out-of-12 codings in each set which is used in the spacecraft.

C. DUAL COMMAND DECODER

1. General Description

Each of the redundant channels of the dual command decoder, consists of tone detection and FSK demodulator sections (composed of discrete analog circuitry), command format decoding logic (composed of digital integrated circuits), and output interface buffers (composed of discrete circuitry). In the standby state, power is applied in the decoder to portions of the tone detector circuits only. Normally, only one channel is active while the satellite is in contact with a ground station. This channel, rendered operative by a tone sequence transmitted from the ground station, processes subsequent commands for all satellite functions; the other channel provides a backup capability. Each channel receives its inputs from an associated, nonredundant command receiver in the communications subsystem. The ITOS D and E decoder is basically the same as that used on the TIROS M/ITOS spacecraft. This total command capability is made possible by providing two sets of decoding gates, each of which can handle 66 two out of twelve commands. Each set is assigned a unique address, and the desired set is enabled on receipt of its address code.

a. POWER AND SIGNAL INTERFACES

The power converter section of each decoder channel consists of a DC-to-DC converter which receives power from the spacecraft's unregulated bus and provides four outputs. The converter supplies regulated -23 volts to the decoder analog circuits, to circuits in command distribution units (CDU's) A and B, and to the command receiver with which it is associated. The command receiver and portions of the decoder analog circuitry are powered continuously; the -23-volt power to the remaining analog circuits and the appropriate circuitry in CDU's A and B is switched as described below. The converter also supplies regulated +5 volts and +5.35 volts to the decoder digital and output interface buffer circuits, respectively. Both of these power outputs are switched, except for two digital integrated circuits that are powered continuously from the +5-volt output. Finally, the converter provides a square wave clock at the conversion frequency, specified as higher than 11 kHz.

The signal input to each decoder is routed directly from its associated command receiver. The audio input signal to each channel of the decoder consists of two tones, an enable tone and an FSK tone. The receipt of a valid enable tone and FSK tone, for the required durations, causes -23 volt power to be switched to

CUD's A and B and to the FSK detector in the decoder, and also causes +5-volt and +5.35-volt power to be switched to the decoder digital and buffer circuits, respectively, thus permitting the spacecraft to be addressed. The digital address, as well as the digital command data, modulates the FSK tone. The FSK tone is characterized by a center frequency tone, f_c, which is shifted to f_c +7.5 percent to represent a data "1" and to f_c -7.5 percent to represent a data "0".

Two unique tone pairs, consisting of an enable tone and an FSK tone, are available for commanding a spacecraft. Each of the four tones has a different frequency. Each set of tone pairs is recognized by only one receiver-decoder channel. If a failure occurs in one decoder channel, the second pair of tones may be used to address the second channel. The use of distinct enable and FSK tones increases the security of the system from spurious commands, without greatly increasing the number of components in the spacecraft. The arrangement described also provides maximum isolation between channels and guarantees that the opposite channel will not be enabled during commanding, which would be the case if a common enable tone were used. Since the tones are transmitted by amplitude modulation, a carrier frequency higher than those of the commercial broadcast band has been selected. The receiver bandwidth limits the upper end of the baseband spectrum to about 12 kHz.

A diagram of the decoder input and output interfaces is shown in Figure VIII-2. Brief descriptions of the signals which comprise the output interface are contained in Table VIII-2.

b. DECODER DATA FORMAT

The data format for the decoder is shown in Table VIII-3. Each data bit is denoted by a shift in the FSK tone to the data "1" frequency or to the data "0" frequency for 50 milliseconds. Sync is denoted by a shift to the data "1" frequency for 350 milliseconds. In both cases, these transitions are followed by a 50-millisecond return to center frequency, which is to be considered as an integral part of all data bits and sync.

2. Functional Operation

a. GENERAL DECODING PROCESSES

Typically, when the spacecraft is not in the process of receiving commands, both decoder channels reside in the standby state. In this condition, the only power supplied by a channel is that required for its associated command receiver and portions of its tone detector circuitry. To activate one of the decoder channels, a CDA station transmits the correct tone pair, which permits that channel to verify the data format of subsequent addresses and commands. The sequence and timing requirements for valid input signals as well as the

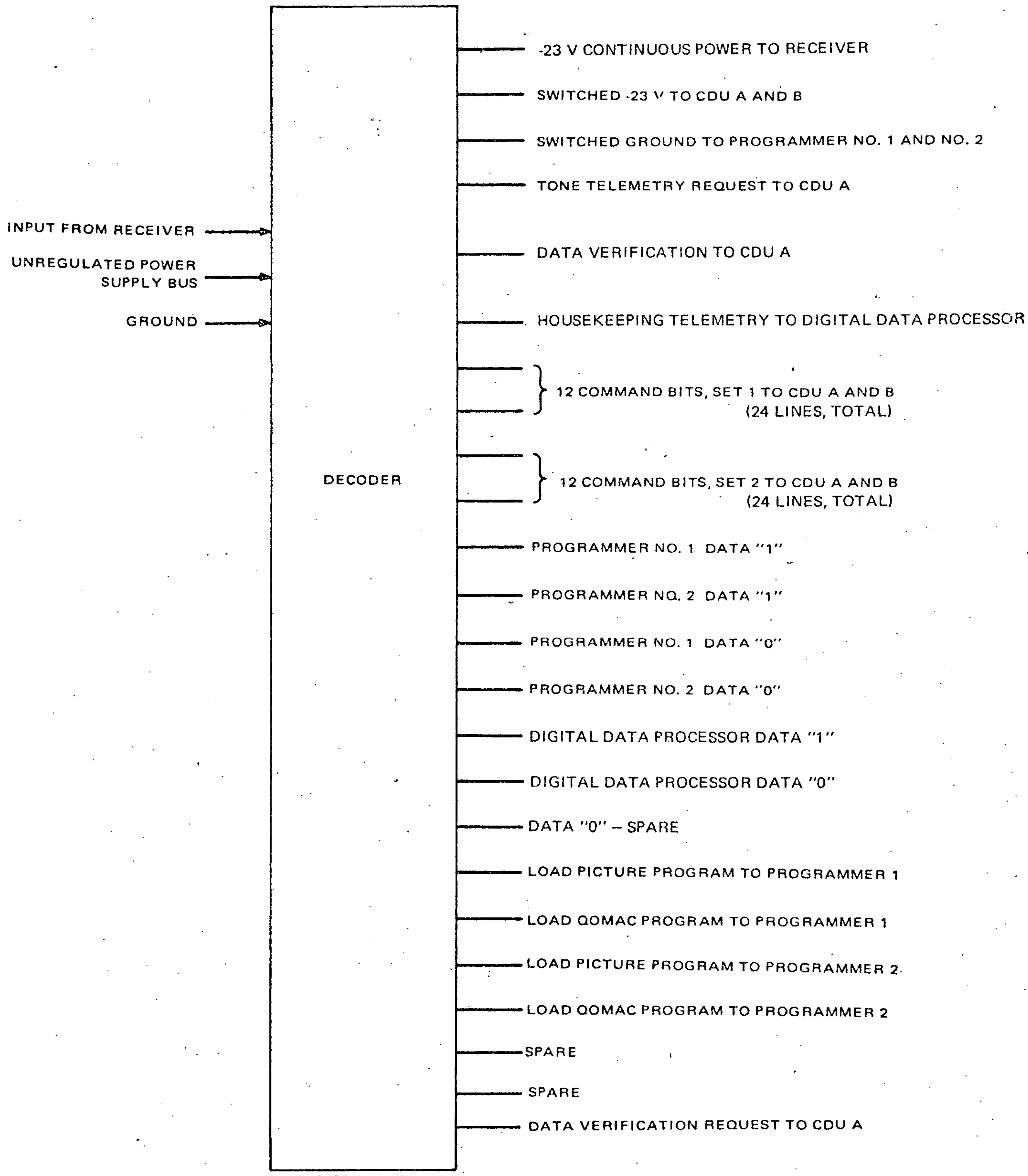


Figure VIII-2. Decoder Input and Output Interfaces

TABLE VIII-2. DECODER OUTPUT INTERFACE SIGNALS

Signals	Description
Continuous -23-Volt Power	Each decoder supplies -23-volt power continuously to portions of its analog circuitry and to the command receiver associated with the decoder.
Switched -23-Volt Power	When a decoder has been "enabled" and is in its operational state, -23-volt power is switched to both CDU's and the remainder of the decoder analog circuitry.
Switched Ground	The switched ground output consists of a hard ground made through a set of relay contacts. When the decoder is in the standby state, the output is at ground; when the decoder is enabled and is in the operational state, activation of the relay causes the ground to become an open circuit. This signal is supplied to the programmer and DDP where it inhibits acceptance by these units of spurious signals from the unpowered decoder.
Tone Telemetry Request	If the enable tone is received continuously for the appropriate length of time, this output is generated and sent to CDU A, where it initiates the readout of one or more frames of telemetry from the powered DDP.
Data Verification	All command and data bits are retransmitted to the ground station in real time. The decoder output is a three-level signal in which the different voltage levels represent the reception of data "1", data "0", or FSK center frequency. These levels, when coupled into the beacon telemetry channel of the spacecraft, are used to modulate an SCO.

TABLE VIII-2. DECODER OUTPUT INTERFACE SIGNALS (Continued)

Signals	Description
Data Verification Command	This signal is used to energize a nonlatching relay in CDU A while command transmission is taking place. The closure of this relay permits the decoder data verification signal to be coupled into the spacecraft telemetry link.
Power ON Telemetry	This output is held at -4.5 volts when the switched -23-volt power is activated. If this power is not switched on, this output is at ground potential.
Two Sets of 12-Command-Bit Outputs to Each CDU	Each validly received command causes two outputs belonging to one of these sets to become activated. The decoding of these outputs takes place in one of the CDU's, depending on which particular command has been received.
Digital Data Outputs to Programmers	Two separate data "1" output lines and two separate data "0" output lines from each decoder are used to supply digital data to both programmers.
Digital Data Outputs to the Digital Data Processor	A single data "1" output line and a separate data "0" output line from each decoder are used to supply digital data (specifying to commutator address in random access mode) to the digital data processor.
Load Picture Program Command	Two distinct command outputs of this type are provided by each decoder, one for each programmer. This signal must precede picture program data which is to be loaded into the programmer.
Load QOMAC Program Command	Two distinct command outputs of this type are provided by each decoder, one for each programmer. This signal must precede QOMAC program data which is to be loaded into the programmer.

TABLE VIII-2. DECODER OUTPUT INTERFACE SIGNALS (Continued)

Signals	Description
Enable Tone Detection Telemetry	This output is developed by the nominal 6-second OFF-DELAY circuit to indicate the recognition of an enable tone by the decoder.
Spare Outputs	1) A dual load data output, of the Load Picture for QOMAC program variety described earlier is provided for possible future use. 2) A single data "0" output used in TIROS M/ITOS to clock the telemetry commutator during its manual advance mode is not used for ITOS D and E.

TABLE VIII-3. DECODER DATA FORMAT

Function	Code
Address Sync	Data "1" frequency continuously for 350 milliseconds
Address Word	2 data "1" bits and 10 data "0" bits
Command Sync	Data "1" frequency continuously for 350 milliseconds
Command Word*	2 data "1" bits and 10 data "0" bits
Command Termination*	1 bit
Programmer or Data DDP	28 bits (follows load programmer and DDP random access commands only)

*For initial command entry into the spacecraft, a dummy command word consisting of 12 data "0" bits and a 13th "0" execute or dummy command termination bit immediately follows the first command sync pulse, in order to complete the format of the first command in a command sequence.

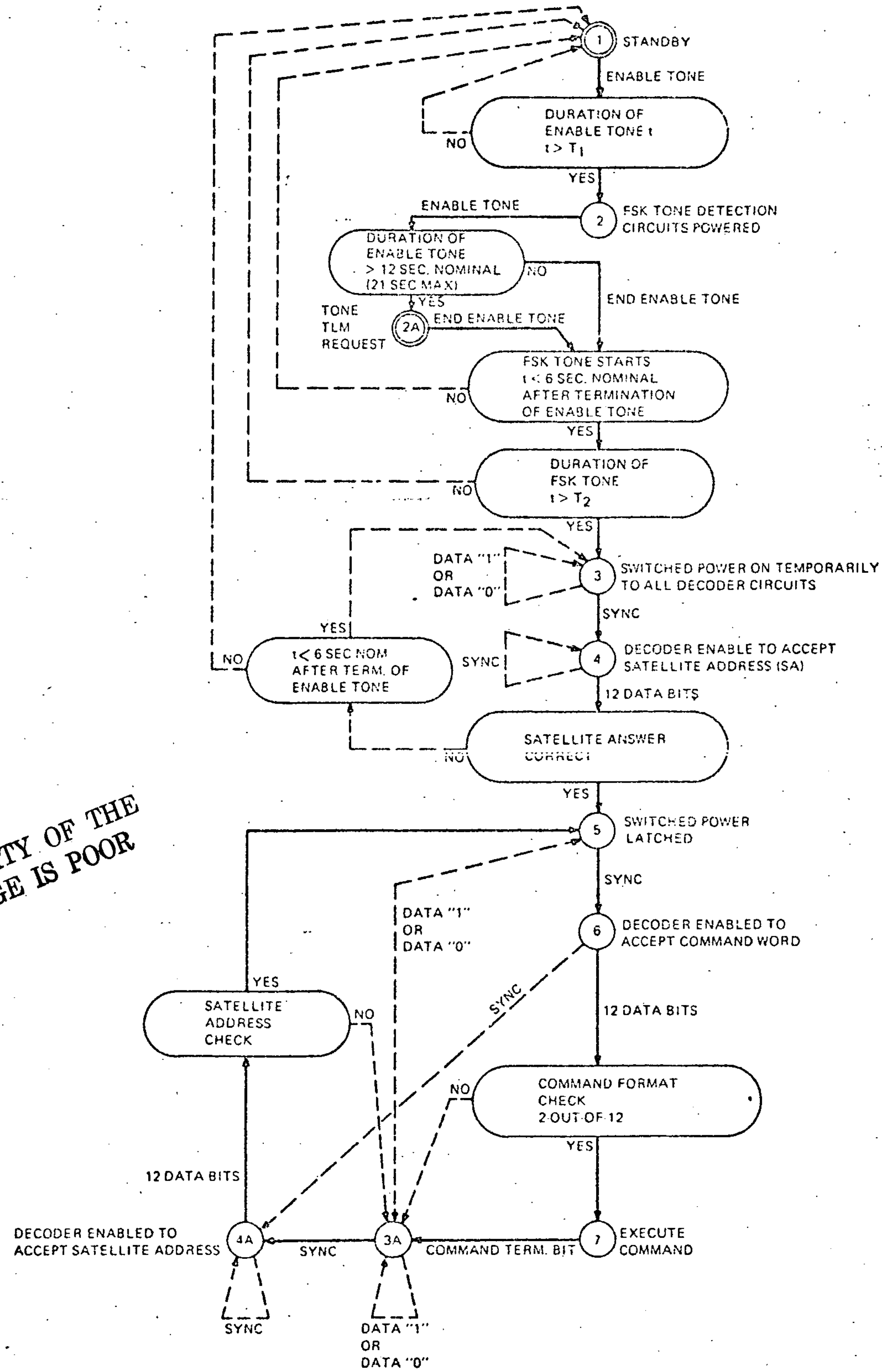
decoder's response to certain invalid command sequences are discussed below. A simplified logic flow diagram of the decoder is shown in Figure VIII-3.

Activation of a decoder residing in the standby state is accomplished by a latching sequence in the following way. That channel's enable tone is received for a minimum of T_1 seconds and is followed, within 3 seconds after the termination of the enable tone, by that channel's FSK center frequency tone which lasts for a minimum of T_2 second. The response of the decoder to this tone sequence is to supply power temporarily to the CDU's and all the decoder circuits, which permits FSK data to be processed. If a properly formatted spacecraft command address for the temporarily activated decoder is not received within a 3 to 12-second period (6 seconds nominal) following the termination of the enable tone, the switched power will drop out at the end of that time. In such a case, activation of the decoder channel can be achieved only by retransmitting the described sequence, starting again with the enable tone. However, if a valid address is received within the allowed time period, the temporarily switched power will become permanently latched, and it will not be necessary to utilize the enable tone to process further data unless the FSK tones are absent for a period greater than 250 milliseconds.

Incorrect sequences of enable and FSK center frequency tones, time durations which are too short, or frequencies and/or amplitudes which do not meet specification will result in the decoder remaining in the standby state. Only if a decoder has been successfully activated through the receipt of a valid tone pair, will it demodulate the FSK signal and thereby provide logical true levels to its then enabled digital circuitry. These levels are generated by the decoder on separate data "1", data "0", and f_c (center frequency) lines at times corresponding to the receipt of the appropriate tone at the audio input to the decoder.

An auxiliary function is performed by the decoder if the enable tone provided to it is present for a minimum period between 6 and 21 seconds (12 seconds nominal). Such an input, in addition to satisfying the requirements for the first step in activating the decoder, also causes it to generate a "tone telemetry request" signal which is used to initiate the readout of housekeeping telemetry data.

As shown in Table VIII-3, a valid address consists of a sync signal followed by 12 data bits, and only 2 of which must be data "1" bits. The decoder verifies that the address contains exactly 2 data "1" bits in a field totaling 12, and also checks that these 2 bits lie in the proper positions within the address word. Each decoder channel will accept as valid either of two such addresses; on any one spacecraft both decoder channels respond to the same two addresses, but the addresses for different spacecraft are unique. In a particular decoder channel, one address enables a set of gates used to decode a group of 66 command words; the other address enables a different set of gates which decode the same group of 66 command words. However, the outputs of all the gates are physically connected to perform separate functions. Thus, through the



NOTES: 1) FOR STATES 3 THROUGH 7, FSK TONE DROPOUT FOR A PERIOD GREATER THAN 250 MILLISECONDS WILL CAUSE RETURN TO STATE 1.
2) THE TRANSITIONS SHOWN IN SOLID LINES INDICATE THE LOGICAL FLOW FOR NORMAL, PROPERLY FORMATTED COMMANDING OF THE DECODER.

Figure VIII-3. Decoder Logic Flow Diagram use of two distinct addresses, 132 real-time spacecraft commands may be executed using only 66 command words.

When the spacecraft is being commanded initially, the first validated address is followed by a dummy command word, as indicated in Table VIII-3, which completes the latching sequence. The decoder is now set up to receive and decode the command sequence consisting of the spacecraft address followed by the command word.

A valid command word, as shown in Table VIII-3, has a format similar to a valid address: a sync signal followed by 12 data bits, 2 of which must be data "1" bits; however, in addition, proper format calls for a single command termination bit to follow the 12-bit command word. This 13th bit is a data "1" for command words in the command sequence (but a data "0" for the dummy command which occurs in the latching sequence). The decoder checks that a received command word contains only 2 data "1" bits in a field totaling 12 bits. If this is the case, two decoder outputs corresponding to the positions of the 2 data "1" bits in the command word are provided from among that set of 12 gates which has been enabled by the particular address word which preceded the command word. The activated outputs are presented to both CDU's, in one of which the actual command decoding and execution takes place, depending upon which particular command has been sent. Receipt of the 13th, or command termination bit, causes the deactivation of these decoder outputs.

If the received command word was a Load Picture Program, Load QOMAC Program command, or a telemetry random access address, 28 bits of digital data are then provided through the decoder to the programmers and DDP. These data bits are identified in character to those in the decoder address and command words, and are presented immediately following the command termination bit of Load Programmer commands.

All of the data in the received address and command, as recognized by the decoder, is transmitted back from the spacecraft to the CDA station via the data verification link, with the following two exceptions:

(1) The address sync is not transmitted on the verification link. During the period when address sync occurs, SPM data appears on the beacon link when the telemetry subsystem is in the operational mode; DSAS data will appear on the beacon link when the telemetry subsystem is in the acquisition mode.

(2) The data "1" command termination bit following the command word is not retransmitted as a data "1" if the decoder has verified a valid command word. Instead, when the decoder has verified a valid command word, it provides a marker on the data verification link in the form of a lengthened data "0". This marker indicates the reception of the frequency representing data "0" during the period corresponding to actual

reception of the center frequency portion of the 12th bit of the command word (in addition to the period corresponding to the frequency shifted portion of this data bit, but only if it is indeed a data "0") as well as during the entire period corresponding to the reception of the command termination bit, no matter which type of data bit is actually sent. However, if a received command is not a valid command, all address data (excluding address sync) and command data (including the command termination bit) will be returned via the data verification link exactly as interpreted by the decoder.

Once the decoder switched power has been latched on by an acceptable sequence of enable tone, FSK center frequency tone, and initial address as described above, it remains latched until all FSK signals drop out for a period greater than 250 milliseconds. At that time, the decoder enters the standby mode and the entire sequence of enable tone, FSK tone, address and dummy command must be repeated to regain access to the decoding circuits. This operation is analogous to a "push-to-talk system and has the advantage that, when the spacecraft is beyond communications range of a CDA station, the command decoding system is turned off and is thus inaccessible to spurious command. In addition, the decoder automatically reverts to standby power requirements for the greater part of the spacecraft orbit.

In the normal operation of the decoder, the initial address is followed by command sync and a command word as described above. Subsequent commands, even when properly formatted, can be verified by the decoder and decoded by a CDU only if each command word is preceded by a valid, properly formatted address. Therefore, the normal commanding sequence following the initial command word after acquisition is: valid address, valid command, valid address, valid command, etc. Once latched, the decoder switched power may be held on while the spacecraft is in range of a CDA station, without the necessity of continuously transmitting this address-command sequence. This can be done by simply transmitting a continuous FSK center frequency tone, which starts, typically, immediately after the transmission of a command termination bit. The result of receiving various incorrect data formats on the decoder operation may be deduced from an examination of Figure VIII-3, the simplified logic flow diagram of the decoder.

b. DETAILED CIRCUIT DESCRIPTION

A block diagram of each decoder channel is shown in Figure VIII-4, and a timing diagram in Figure VIII-5. The detailed logic diagram for the dual command decoder is RCA Dwg. No. 1976087, which may be found in a separate manual. *

*RCA Corporation, Astro-Electronics Division, TIROS M/ITOS Spacecraft Logic Diagrams, AED M-2175, Contract NAS5-10306, Princeton, N.J., June 15, 1969.

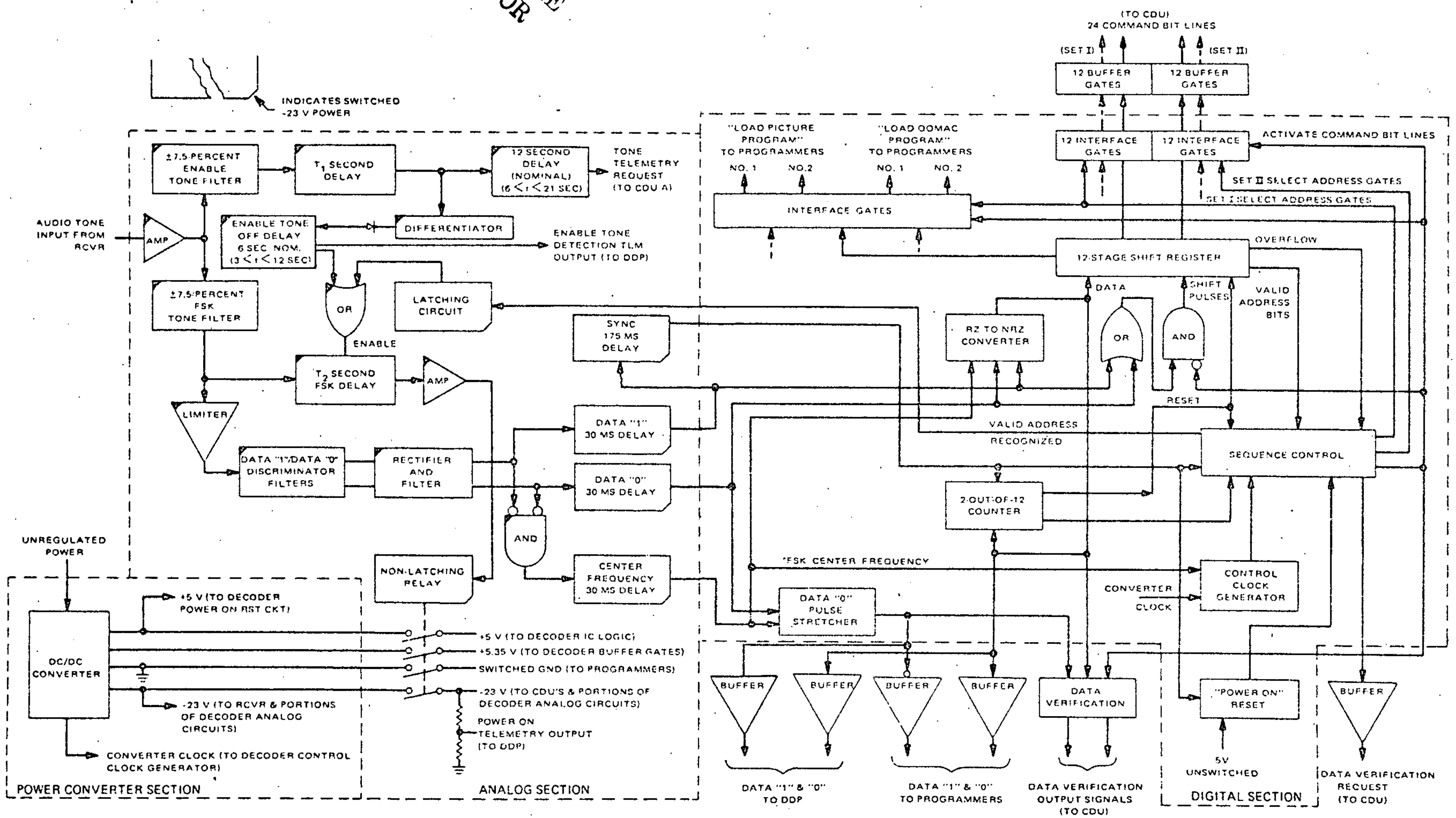


Figure VIII-4. ITOS D and E Decoder Block Diagram

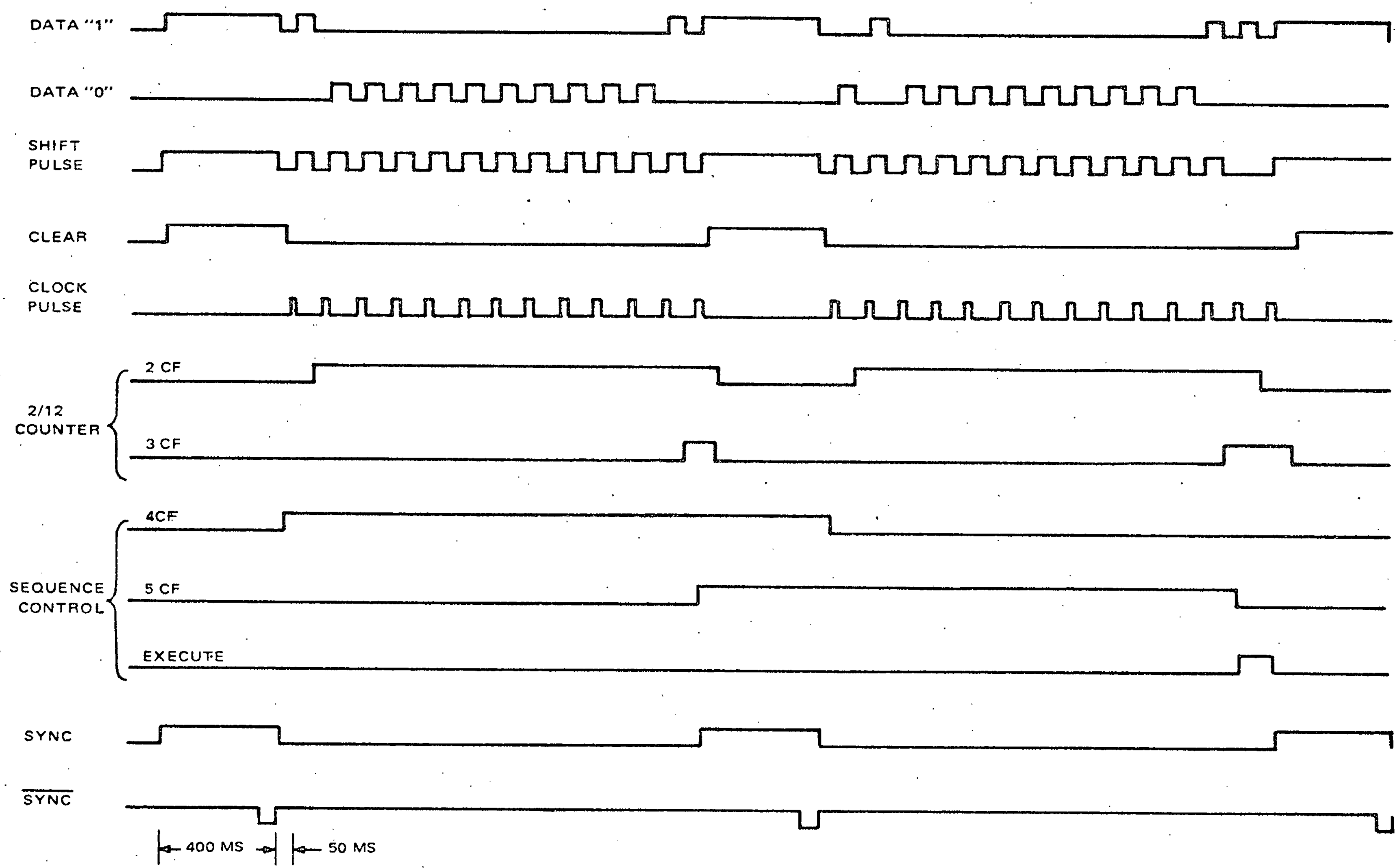


Figure VIII-5. Decoder Timing Diagram

(1) ANALOG CIRCUITS

The input buffer amplifier of the decoder provides a nominal gain of five to increase the voltage level of the audio tones from the receiver to a working level for the detection and demodulator circuits and to provide drive to the tone filters.

The enable tone is coupled through a ±7.5-percent bandpass filter to a detector circuit where it is converted to a DC level. This level is then integrated by an RC network to provide the T_1 timing. If the enable tone is present for 21 seconds, a second RC integrator causes the "enable tone telemetry request" signal to be generated.

When the enable tone terminates, a nominal 6-second "off delay" monostable multivibrator is triggered. The multivibrator enables the FSK tone detection circuitry for a 3 to 12-second period, during which the T_2 period of FSK tone and the spacecraft address must be received. If the correct address is not detected within this period, the enable signal is removed from the FSK tone detector. If the address is detected within the period, a level is generated which maintains the enabled condition of the FSK tone detection circuitry for as long as the FSK tone is received.

The FSK tone is coupled through a ±7.5-percent bandpass filter to a detector circuit and converted to a DC level. This level is passed through an RC integrator to obtain the T_2 timing. When the integrator threshold is exceeded, a relay becomes energized causing -23 volt power to be applied to the rest of the analog circuitry and to the CDU and causes +5-volt and +5.35-volt power to be applied to the digital integrated circuits and output buffers, respectively. The FSK tone output of the ±7.5-percent bandpass filter is also coupled to a limiter amplifier which drives a discriminator filter. The signal at the "1" output of the discriminator filter peaks with a shift from the FSK tone center frequency, f_c, to f_c +7.5 percent. The signal at the "0" output of the discriminator filter peaks at a frequency of f_c -7.5 percent. The signal levels at the "1" and "0" outputs are 10 db down from the peaks when the FSK tone is at center frequency. Each detected "1" or "0" data level is timed for 30 milliseconds by an RC integrator before a valid data pulse is generated. The detected data "1" and data "0" pulses are combined in an OR gate before integration to obtain an indication of a return to center frequency. The center frequency level obtained is integrated for 30 milliseconds before a center frequency pulse is generated. The data "1" pulse output is coupled to a sync pulse integrator which times this signal for an additional 175 ms (in addition to the previously timed 30 ms) before producing a sync pulse output. In this way, the 30-ms data "1's" are distinguished from the 205-ms sync pulses even though both are at the same data "1" level.

The four signals (data "1", data "0", f_c, and sync) are converted through buffer circuits to pulse levels compatible for use with the digital integrated circuits.

Output signals generated by the integrated circuits are converted through output buffer circuits to voltage levels appropriate for spacecraft distribution.

(2) DIGITAL (INTEGRATED) CIRCUITS

The digital section of the decoder consists of integrated circuits, which comprise the following:

- Data shaping circuits,
- 12-bit shift register,
- Control logic,
- Spacecraft address check circuit,
- 2-out-of-12 check circuit,
- Data verification circuit, and
- Programmer load command circuit.

The data, f_c, and sync pulses received from the analog section are pulses whose widths have been shortened by the timing integrators. Thus, a data "1" pulse having an original width of 50 ms has been reduced to a 20-ms pulse because of the 30-ms integration time. Following the trailing edge of this pulse, a 30-ms interval (the f_c integration time) elapses before a 20-ms f_c pulse is generated. The data "1" and data "0" pulses are OR'ed to obtain decoder shift pulses. The return-to-zero (RZ) format data is converted to a non-return-to-zero (NRZ) format at the input to the first stage in the decoder shift register. This conversion provides for shifting data into the register at a time when the first stage inputs are not changing.

When power is initially applied to the digital logic, a flip-flop locks the control logic in the reset state. The control logic consists of a four-state sequencer and bistable multivibrator. When a valid address is received, this circuit maintains the enabled condition of the FSK detector in the analog section. When a sync pulse is detected, the shift register and the data format checker are reset and the reset clamp to the control logic is released and enters state 1. After the trailing edge of the sync pulse, a data "1" (the sync pulse is actually a long data "1" pulse) is shifted into the first stage of the register and serves as a marker bit to detect register overflow. At the same time, the control logic enters state 2. While in this state, the decoder is prepared to accept 12 bits of data which contain two data "1's" occupying those bit positions that correspond to the spacecraft address wired into that particular unit.

The 2-out-of-12 format check is accomplished by a 4-state counter which advances state with each incoming data "1" pulse. A sync pulse always resets this counter and is not itself counted as a valid data "1" pulse. The counter is advanced by the same shift pulse as the register, and this allows checking of command and data "1" pulses as they are shifted into the register. The states of the counter are listed in Table VIII-4.

TABLE VIII-4. COUNTER STATES

State	Flip-Flop		Causative Event
	2 CF	3CF	
1	0	0	Sync pulse receipt (to reset counter)
2	1	0	First data "1" pulse receipt
3	1	0	Second data "1" pulse receipt
4	0	1	Third data "1" pulse receipt

Thus, only when the counter is in state 3 does data successfully pass the 2 out of 12 command word check.

When the 11th data bit of the spacecraft address has been stored in the shift register, the marker bit has reached the 12th register stage, and a gate is enabled which permits the 2 out of 12 command word check and the check for a correct spececraft address. The address is actually examined during the leading part of the 12th data bit. Thus the inputs to the AND gate that decodes the address bits have to be taken from the register 1 bit early. If the 12th data bit of the address is to be a data "1", the AND gate input must come from the input to the 1st stage of the register (which serves as an RZ-to-NRZ converter). If the decoded address is correct, and if the 2 out of 12 checker is in state 3, the shift pulse which stores the 12th data bit in the register also causes the control logic to enter state 3, and the spacecraft address multivibrator sets, thus providing the FSK tone detector latch. If the wrong address is received, the control logic reverts to state 1, the reset state. While in state 3, the decoder is ready to accept the sync pulse which precedes the command bits. When this pulse is detected, the register is reset, the 2 out of 12 counter is reset, and, following the trailing edge, a marker bit is again shifted into the register's 1st stage. At this time, the sequencing logic enters state 4. If the logic were in state 3, and if a shift pulse were detected without a sync pulse, the logic would reset to state 1. While the control logic is in state 4, the decoder is prepared to accept a command word consisting of 12 bits of data of which 2 are data "1's". As the bits are shifted into the register, the data "1's" are tallied, at their leading edges, in the 2 out of 12 counter. When the 12 bits are stored in the shift register, as indicated by the overflow of the marker bit, and if the 2 out of 12 counter is in its state 3, indicating that exactly two data "1's" were received, an "execute" bistable multivibrator is set. When the "execute" multivibrator becomes set, it enables 12 command bit output gates, and the two gates associated with the register stages containing data "1's" produce outputs. Each output gate is connected to an output buffer which converts a +5-volt pulse from the gate to a 5.35-volt pulse for use in the CDU where the decoding of the commands actually takes place. At the same time that a command is executed, the control logic is reset to state 1. When the command termination bit is received, the "execute" multivibrator is reset and the command bit outputs are de-energized. If a sync pulse is detected while the control logic is in state 4, prior to register overflow, the control logic reverts to state 2 until a correct spacecraft address is again received.

The data which is distributed to the programmers and DDP is taken from the outputs of the digital shaping circuits after passing through output buffers. Data from the same source is used to generate the data verification signals. The data "1" and data "0" pulses are summed together to form the three-level signal, which is sent to the CDU for further processing before being transmitted back to the ground as data verification.

In addition, during the execution of a command (when the "execute" multivibrator is set) the data verification output is forced to the data "0" level for the duration of the command. However, if the 12 received data bits are not acceptable to the 2 out of 12 check, the data verification of the transmitted execution bit will be at the data "1" level (except for the execution bit of the dummy word which immediately follows the initial address code; the 13th bit is verified as a "0"). None of the output lines to the CDU's will be activated when an invalid code has an execution bit verified as a data "1".

(3) BUFFER CIRCUITS

The decoder makes use of two standard buffer circuits to provide signal outputs. The first circuit, a transistor switch with emitter tied through a diode to the +5.35-volt supply, is used for all command data bit outputs and the data "0" output to CDU A. The output is delivered from the transistor collector through a series resistance of 30 ohms. The data verification request output is also provided by this type of circuit, but without the diode. The second standard output is through a simple RC integrator which is used for the Load Programmer commands as well as the data outputs which are supplied to the programmers and DDP. The spare outputs are also provided by this type of buffer.

The three-level data verification signal to CDU A is formatted and buffered in a resistor summing network. The switched power telemetry signal and tone telemetry request to CDU A are provided directly from the decoder analog section by a resistor divider and transistor switch (output from collector through 1 kilohm series resistance), respectively. Power and ground outputs from the decoder come from the self-contained DC-to-DC converter; switched outputs of this type are delivered through relay contacts.

D. DUAL TIME BASE UNIT

1. General

The dual time base unit (TBU) generates basic timing signals required by the various parts of the spacecraft for synchronization and timekeeping. Two identical time base generators and two identical time code generators are contained in the dual TBU, one time base generator and one time code generator forming TBU No. 1 and the other pair forming TBU No. 2. Two ground commands are provided which turn on one TBU while turning off the other.

The time base generator section of each TBU generates the timing signals for synchronizing and coordinating all timing functions aboard the spacecraft (refer to TBU interface diagram Figure VIII-6). All of the timing signals required by the various sensors, programmers, secondary equipment, and telemetry circuits originate within the time base generator section of the TBU. The general configuration is similar to that of the TIROS M/ITOS-1 time base generator. Each time base generator includes a high stability crystal oscillator and a digital dividing chain followed by interface circuits. The time code generator section of each TBU generates a time identification code that is supplied to the SR, VHRR and DDP subsystems for simultaneous recording with remote data in order to identify the times at which the various sensory data are acquired. The time code is also supplied to the beacon telemetry of the communications subsystem.

Power is supplied to each TBU independently by separate DC-to-DC converters which are turned on and off by the aforementioned ground commands.

Changes in functional requirements of the ITOS D and E spacecraft demand modifications to the timing signals that were used on the TIROS M/ITOS-1 spacecraft. These changes are due to the following:

- Elimination of APT and AVCS subsystems
- Addition of VHRR subsystem
- Addition of VTPR sensors
- Addition of Digital Data Processor (DDP) and
- Addition of a third SR Recorder

2. Response to Commands

Each TBU contains two time base generators and two time code generators. Selection of one set is accomplished by two real-time commands,

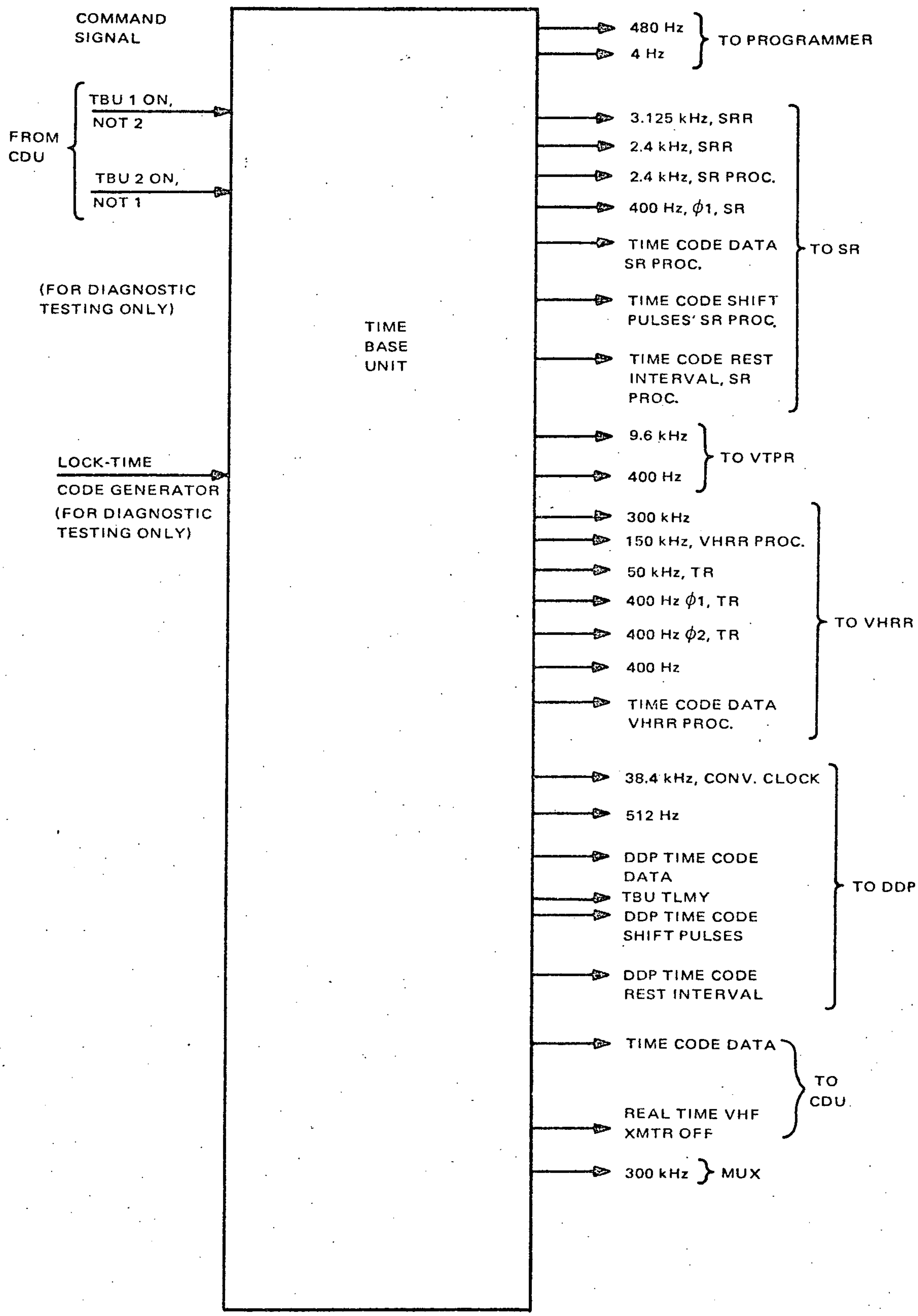


Figure VIII-6. Time Base Unit Interface Diagram which control the power input to the selected unit. The commands are as follows:

- TBU 1 ON, Not 2
- TBU 2 ON, Not 1

Inputs to the time base and code generators are as follows:

- -24.5 volts, regulated, which drives the DC-to-DC converter.
- Time Code Generator Lock. This input is used only during ground testing.

3. Time Base Generator Description (Refer to Figure VIII-7)

The time base generator (TBG) section of the TBU consists of a 2.4 MHz oscillator, a frequency doubler, and a digital countdown chain. A 4.8 MHz clock frequency is required to provide a 512 Hz signal to the DDP. The doubler circuit, which is new to the ITOS D and E system, provides a cost effective means for utilizing available 2.4 MHz oscillators. The 4.8 MHz output of the doubler is divided to provide the necessary frequencies to fulfill the various timing and synchronizing requirements of ITOS D and E. As implemented in TIROS M/ITOS-1 the outputs of the redundant time base generator circuits are combined in an "OR" gate to provide a single output of the circuit in operation to each user, whenever this configuration is feasible.

4. Time Code Generator Description

The ITOS D and E time code generator is the same as the one used on TIROS M/ITOS-1.

The time code generator generates a 24-bit serial digital readout to be used by the VHRR, SR, DDP and telemetry subsystems for time identification. The output consists of a binary count of the number of 1/4-second increments elapsed from the time unit power is turned on. The maximum cumulative capacity of the elapsed time function is 2^{24} quarter second intervals, or 48 days, 13 hours, 5 minutes, and 4 seconds.

A block diagram of the time code generator is shown in Figure VIII-8. Upon application of power (ON command), the shift register resets to a 0 count. After approximately 150 milliseconds, the register is released to count 120 Hz pulses. Binary counting is accomplished by applying a burst of 24 pulses to the register every quarter second. The register output is fed back, through an "add 1" circuit, to its input. At the completion of each counting cycle, the time code is updated by 1/4-second count.

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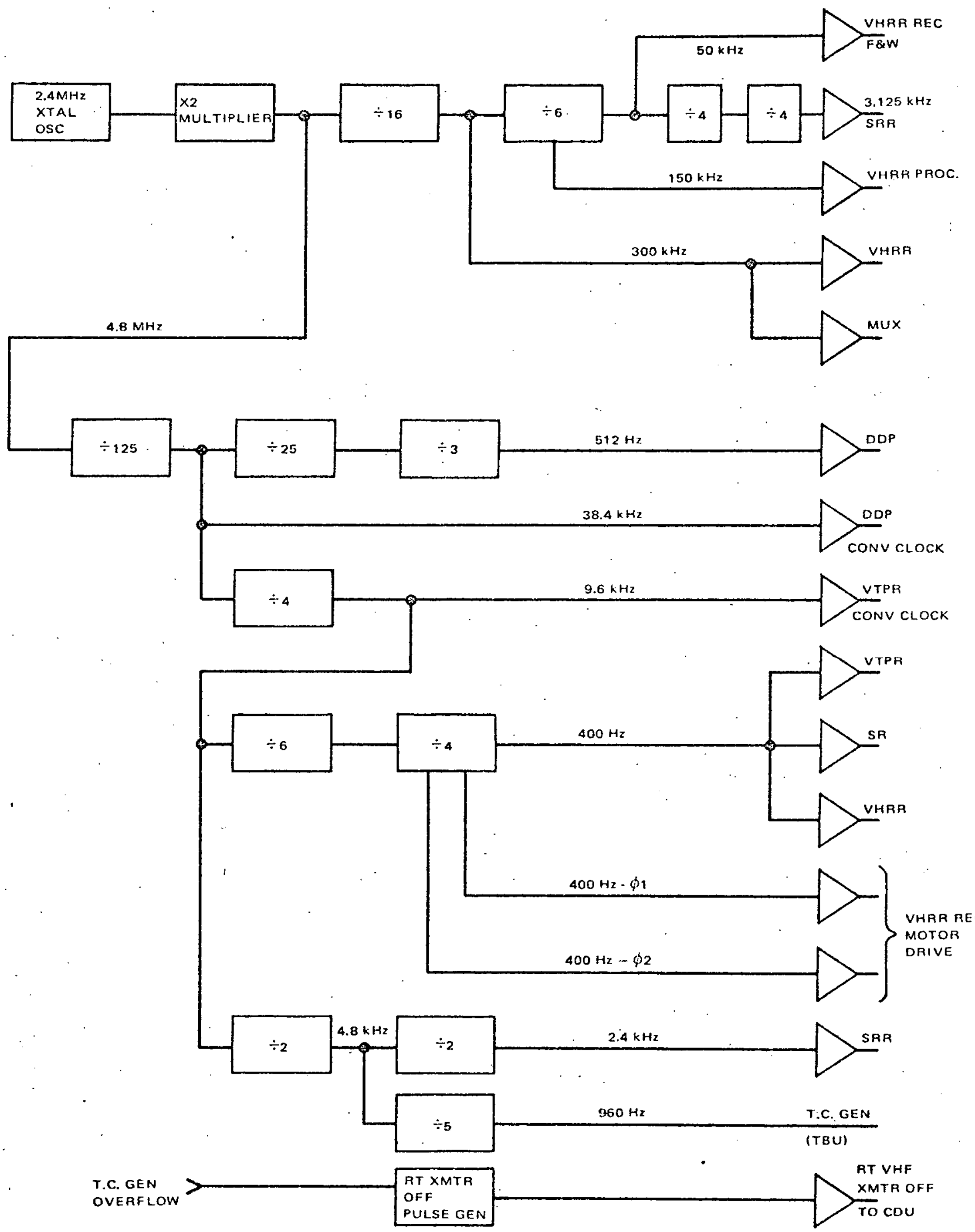

Figure VIII-7. Time Base Generator Logic Diagram

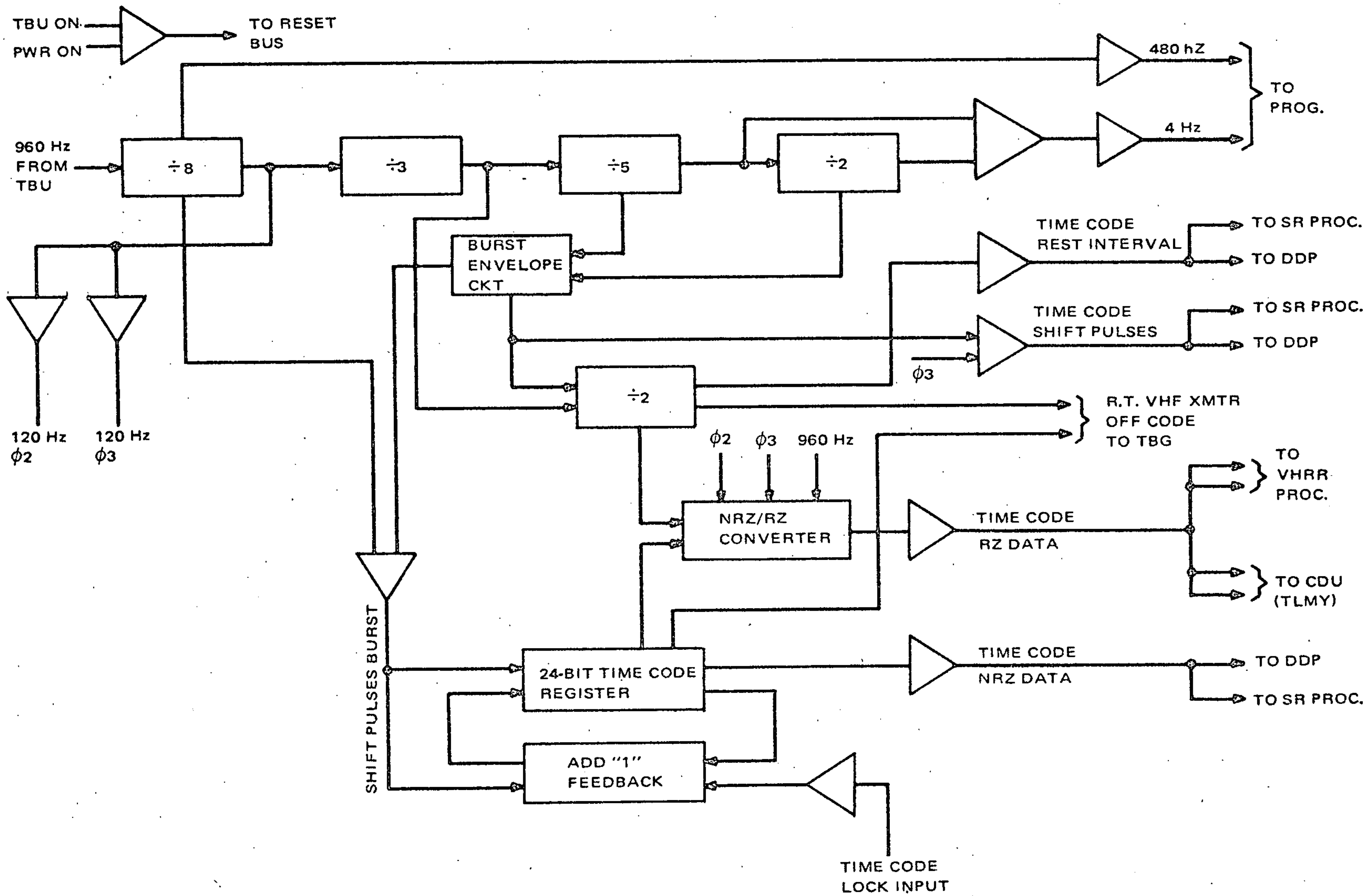

Figure VIII-8. Time Code Generator Block Diagram

The output of the register is available in NRZ (non-return-to-zero) form, for use by the DDP and SR subsystems, and in an RZ (return-to-zero) form, to supply a three-level time code signal to the VHRR and beacon telemetry subsystems. An NRZ-to-RZ converter provides the latter output. A timing diagram of the time code outputs is shown in Figure VIII-9.

The input signals to the time code generator are as follows:

- -24.5-volt power (common with the time base generator),
- +5.0 and +5.35 volts from a DC-to-DC converter, shared with the TBG,
- 960 Hz from TBG (same side),
- A TBU (No. 1 or No. 2) ON command pulse, which applies power to one TBU, removes power from the other TBU, and also resets the time code register, and
- A "time code lock" signal which inhibits operation of the 24-bit register, to simulate VHF transmitter turn-off prior to the completion of the 48.5 turn-off period, is only used for diagnostic and ground testing purposes.

The output signals from the time code generator are as follows:

- A 24-bit RZ three-level code (least significant bit first) to VHRR processor and beacon telemetry,
- A 24-bit NRZ code (least significant bit first) to DDP and SR processor.
- Time Code Shift Pulses to DDP and SR Processor
- A time-code rest interval signal to DDP and SR processor
- A 480-Hz signal to the programmers
- A 4-Hz signal to the programmers,
- Real-time VHF transmitter OFF pulse, representing a time count of 48.5 ±0.2 days, to the CDU via the time base generator section of the TBU.

5. Packaging

The dual TBU will use the same container as the one used for TIROS M/ITOS-1. One of the three logic boards associated with each TBU will be redesigned to accommodate the new signals required. A second logic board will require modifications involving the cutting of a few printed circuit traces, addition of several jumper wires and some module deletions which can be executed on an equivalent TIROS M/ITOS-1 board to enable its usage for ITOS D and E.

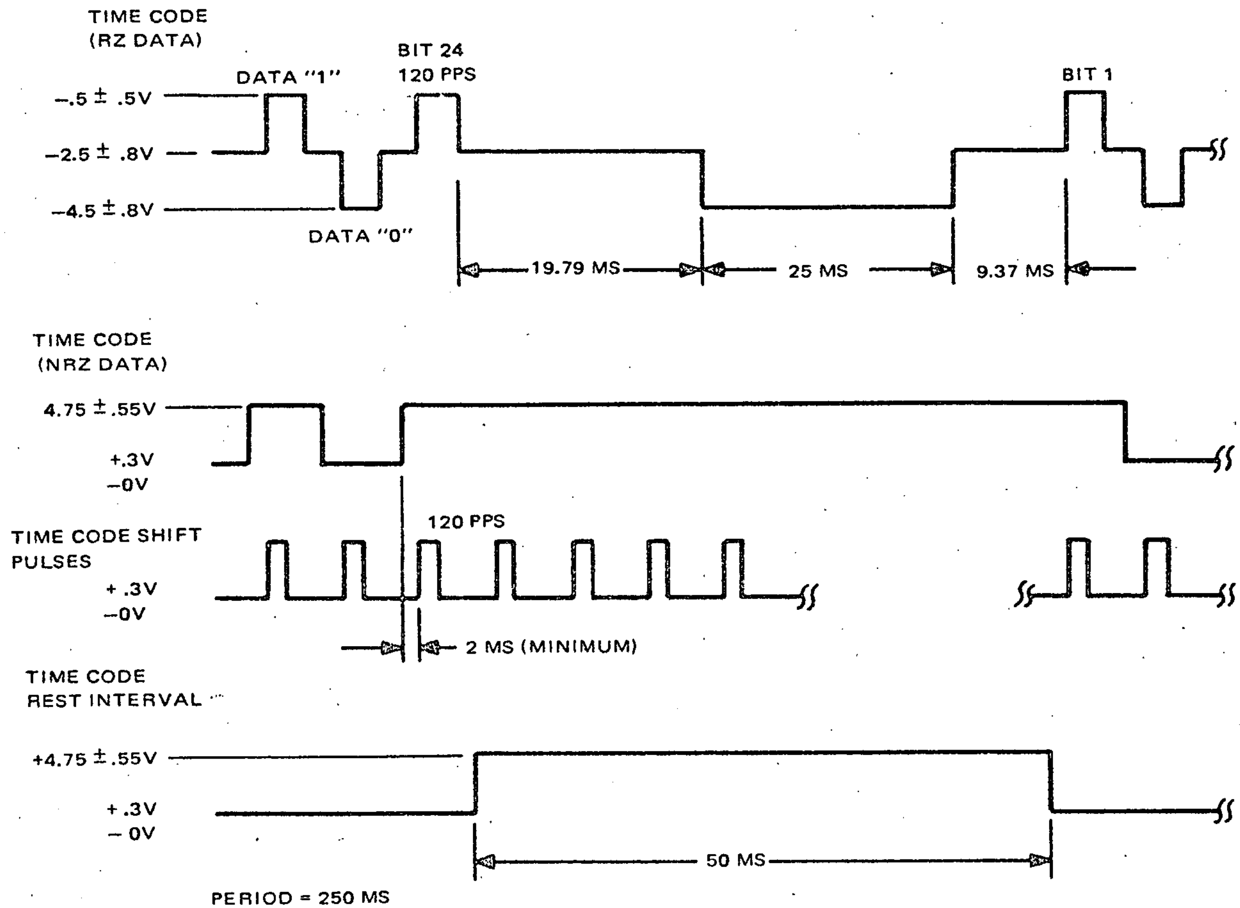

Figure VIII-9. Time Code Outputs - Timing Diagram

Harness board and buffer board modifications will also be necessary in order to route new signals to the TBU's interface connectors.

E. DUAL COMMAND PROGRAMMER

1. General

The dual command programmer DCP includes two completely redundant programmers, which are housed within a single unit. Each programmer receives real-time commands and data from either of the spacecraft's two redundant decoders. Timing signals for the synchronous operation of the DCP digital logic are received from the TBU. Either programmer, but not both, may be commanded ON at any time. The active programmer stores the decoder-supplied data, which contains the information necessary for the remote operation of the SR subsystem, the VHRR subsystem, and the QOMAC coil. The execution of the stored program may be modified by the real-time commands. Programmer outputs are distributed to appropriate spacecraft destinations either directly or via the command distribution units. A system block diagram for the programmer is shown in Figure VIII-10.

The basic technique of controlling event sequencing by counting the time elapsed from the start of an orbit (i.e., the crossing of the night-to-day transition) is retained from the TIROS M/ITOS units. However, ITOS D and E requirements demanded modification to the TIROS M/ITOS programmer with respect to the number of inputs and outputs provided, their destinations, and their timing. These changes have been necessitated mainly by:

- Deletion of APT and AVCS camera subsystems
- Addition of VHRR subsystem
- New requirement for global coverage of recorded SR data
- Addition of programmable segment deletion capability for real time VHRR and SR data.

The required programmer changes have been implemented by extending proven techniques used in the TIROS M/ITOS equipment. These changes involve mainly the addition of new logic circuitry and the modification of previously existing circuitry to meet the new requirements outlined above. The affected areas are listed below.

- Change of orbit counter front end from module 40 counter to straight binary counter
- N of 8 segment selection for real time VHRR and/or SR deletions
- Remote VHRR recorder control

- Record and playback control of two (out of three) SR Recorders time-sequenced to provide continuous SR coverage

2. Program Data Loading

When a Programmer No. 1 (or 2) ON command is received by the spacecraft, a latching relay becomes energized and power is applied to the DC-to-DC converter in the designated programmer which, in turn, supplies voltages to the integrated circuits and to the interface circuits. At power turn-on, the programmer becomes completely reset and then enters a standby mode. The programmer remains in the standby mode until a load command is received; this command may be a Load Picture Program or a Load QOMAC Program command. If the command is a Load Picture Program command, the 28 bits of digital data which follow contain instructions pertaining to remote operation of the SR subsystem and of the VHRR subsystem.

The 28 bits of data which follow a Load Picture Program command constitute either a "T_O word" or a "rephasing word". Word identification is given by the first 2 of the 28 bits. These 2 bits are decoded and an enabling signal is sent to either the T_O word control logic or to the rephasing word control logic to permit the loading of the remaining bits of the program data into the appropriate register. The T_O word data (see Table VIII-4) includes the T_O delay time (i.e., time from loading of the programmer until T_O, the night-to-day transition of the orbit) and the orbit correction factor, which establishes the exact duration of the orbit in the orbit counter. The rephasing word data (see Table VIII-5) includes the number of phasing correction counts, the polarity of the phasing correction, the VHRR recorder delay time, the deletion of real time SR operation, the deletion of real time VHRR operation, the enabling of VHRR record operation, and the orbit segment selection which allows real time SR and VHRR coverage to be enabled during programmed portions of an orbit.

At the trailing edge of a 100-millisecond Load Picture Program command pulse, the data verification level is generated and the three-stage picture program word identification counter and decoder are enabled. The first 2 bits of the word are decoded to determine if the remaining 26 bits contain a T_O word or a rephasing word. If the data is a T_O word, the T_O control logic enables the 12-stage orbit correction shift register, and 12 bits of data are shifted into the register. The first bit to enter the register is not used. The other 11 bits form the 2's complement of the T_O delay time. After loading, these bits are parallel-transferred to the 11-stage counter and the next 12 bits of the program (bits 15 through 26) are then shifted into the register. Of these, only bits 17 through 26 are used. These bits represent the true orbit time minus 1024 counts and are called the orbit correction factor. Bits 27 and 28 are not used by the programmer. The data verification signal is terminated 250 to 500 ms after the end of bit 26. After loading has been completed, the 11-stage counter commences counting the T_O delay time with counts occurring at 6.5-second

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TABLE VIII-5. T_O WORD FORMAT*

Bit No.	Function
1, 2	Bit 1 is a data "1", bit 2 is a data "0" in the T_O word.
3	Not used by programmer.
4 through 14	2's complement of the number of 6.5-second intervals from the end of loading the programmer until the first transition of the spacecraft from orbit night to orbit day (T_O), called "T_O delay time".
15, 16	Not used by programmer.
17 through 26	2's complement of the number of 6.5-second intervals in the true orbit time minus 1024 counts. Called "orbit correction factor".
27, 28	Not used by programmer.

*T_O word must be preceded by Load Picture Program command.

intervals. The orbit correction factor continues to be stored in the register until after the T_O delay has been counted out. At count T_O plus 1024, the factor is parallel-transferred, without destruction in the register, to the counter which continues to the next T_O (counter overflow) to establish the corrected orbit duration. The orbit correction factor remains stored in the register and corrects the duration of succeeding orbits until the programmer is turned off or the register is reloaded.

If the data following a Load Picture Program command is a rephasing word, the 2's complement of the number of phasing correction counts and the 2's complement of the VHRR delay/on time are shifted into the rephasing shift register and transferred to associated counters. Bits 15 through 26 are shifted into the register and stored to control the phasing correction polarity, remote VHRR operation, and SR and VHRR Real Time operation. Bits 27 and 28 are not used by the programmer.

The data verification signal is terminated 250 to 500 ms after the end of bit 26. During the first night portion of the orbit following loading of a rephasing word, the counter in which rephasing word bits 3 through 6 are stored commences counting (at T_O plus 1024) and causes the programmed number of counts to be added to or subtracted from (depending on the value of bit 15) the number of clock pulses generated in the clock control logic and supplied to the orbit

TABLE VIII-6. REPHASING WORD FORMAT

Bit No.	Function
1, 2	Bit 1 is a data "0", bit 2 is a data "1" in the rephasing word.
3 through 6	2's complement of the selected number of phasing correction counts; from 1 to 15 counts can be programmed.
7 through 14	2's complement of the VHRR Recorder Delay time. A delay up to 223 minutes in 52-second increments can be programmed.
15	Correction polarity. A data "1" causes an additional number of clock pulses (as determined by bits 3-6) to be injected into the orbit counter. A data "0" causes a number of clock pulses (as determined by bits 3-6) to be inhibited from the orbit counter.
16	Real time SR deletion. A data "1" enables inhibition of RT VHF transmitter dependent upon data bits 19-26. A data "0" enables continuous RT VHF transmitter operation.
17	Real time VHRR deletion. A data "1" enables inhibition of S-band transmitter and VHRR dependent upon data bits 19-26. A data "0" enables continuous S-band transmitter and VHRR operation.
18	VHRR recorder enable. A data "0" inhibits the VHRR record operation. A data "1" enables VHRR record operation. (Recording can take place during RT inhibit.)
19 through 26	Orbit segment selection. If bit N (N=19, 20, ----, 26) is a data "0"; VHRR and SR real time data transmission is enabled. If bit N is a data "1", the real time data selected by bits 16 and 17 is inhibited for the (N-18)th segment following the data load.
27, 28	Not used by programmer

counter. Thus time T_O may be shifted in either direction with respect to the actual night-to-day transition point in the orbit. Note that the correction is performed only once following any data load. If bits 3-6 are all data "0", no correction is performed. This enables data to be loaded for other functions without the necessity for making a phasing correction. Bits 16, 17, and 19 to 26 control the real time data coverage. The orbit is divided into 8 segments of 13.8 minutes duration. One segment is several minutes longer than the rest since the orbital period is not an integral multiple of the segment time. The segments are referenced to the orbit counter overflow which is established by the programmer T_O delay time. This point is usually picked at the night/day terminator. Segment No. 1 if the first 13.8 minute segment following this point, segment No. 2 is the next 13.8 minute segment, etc. Bits 19-26 indicate orbit segment selection with bit 19 being associated with the first segment after data load (not necessarily segment No. 1), bit 20 with the second segment after data load, etc. A data 1 stored will cause an inhibit function to be generated for the associated segment. Thus, if the Rephasing Word is loaded while the spacecraft is in segment No. 5, and bits 19 through 26 are 10011100 respectively, then the inhibit function will be generated during segments No. 5, 8, 1, and 2. The very first segment after load will be shorter than the full 13.8 minutes and its time is dependent upon the exact point of data load with respect to the fixed segment "division lines". The inhibit function will be gated to a particular output depending on the states of bits 16 and 17. Bits 16 will enable the inhibit function to delete real time SR data by generation of an OFF pulse at the start of any inhibited segment for turning off the real time transmitter. At the end of the inhibited segment, an ON pulse will be generated to turn the transmitter back on. Bit 17 will enable the inhibit function to delete real time VHRR data by generating an OFF pulse for turning off the S-band transmitter and the VHRR electronics at the start of an inhibited segment. At the end of an inhibited segment, an ON pulse will be generated to turn this equipment back on.

Recorded VHRR data coverage is controlled by bits 7-14 and bit 18. Bits 7-14 constitute the desired delay time, with respect to the data load, until VHRR recording is initiated. The data is the 2's complement of the delay time in 52 second increments. If recording is desired, bit 18 must also be a data 1. This allows the capability to load either rephasing data or deletion data without the necessity to record VHRR data. If recording is programmed, at the end of data load the delay time will be counted out in 52 second increments. At the end of delay time a VHRR Record Power ON pulse will be generated to apply record power to the recorder (refer to Figure VIII-11). After a 250 ms delay, a VHRR Record level will be presented to the recorder to start recording. The recorder requires 1.5 seconds to come up to speed. Therefore 1.5 seconds after the Record level is generated, a 1.0 second Time Code Gate signal will be generated for the VHRR processor which will enable 3 level RZ time code data to be recorded on the VHRR recorder. The gate width insures that at least three complete time code words will be recorded. The recorder will record for approximately 9 minutes with automatic stop being generated by virtue of an internal end-of-tape signal. At 624 seconds after the end of delay time, a VHRR

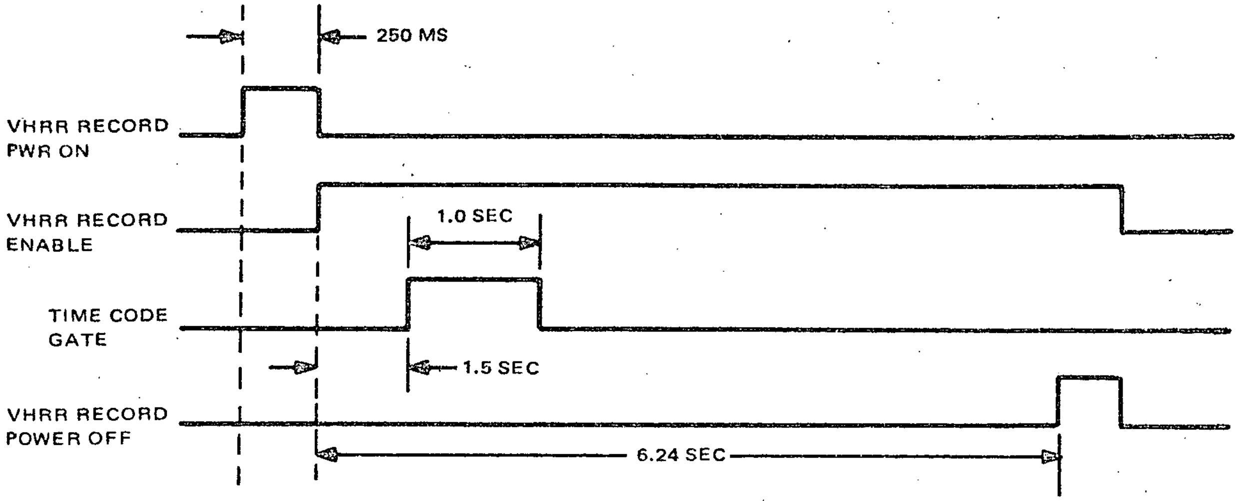


Figure VIII-11. VHRR Record Timing Diagram

Record Power OFF pulse will be generated to remove record power and the Record level will be terminated.

If the command is a Load QOMAC Program command, the following 28 bits of data contain instructions for remote operation of the QOMAC coil (Table VIII-7). The trailing edge of the 100-ms command pulse enables the 14-stage shift register, and the 28-bit digital data word begins to shift into the register. At the same time, the data verification hold-on level is generated. When the first 14 bits of data have been shifted into the register, an overflow signal causes the parallel transfer of these bits into the "count" registers. The first 3 bits, representing the number of QOMAC cycles to be performed, are transferred into a three-stage counter. If the program is a unipolar QOMAC program, these bits are not used. The 4th bit is the QOMAC mode bit, denoting whether normal QOMAC or unipolar QOMAC operation is to be performed.

The remaining 10 bits are transferred into a 10-stage counter which counts the delay until QT_O, the time at which remote QOMAC operation begins. When these bits have been transferred, the shift register resets and the remaining 14 bits of the program enter the shift register. These bits are used after QT_O to control the actual QOMAC operations. When this second group of 14 bits is stored, as indicated by an overflow signal, no further data bits can be accepted (without a new Load QOMAC Program command) and the QOMAC programmer enters a count mode. The data verification level is then terminated.

When the count mode is entered, clockpulses having a 4 second period drive the QOMAC quarter-orbit counter which initially contains data bits 5-14 of the program. The first clock pulse to be counted occurs from 4 to 4.3 seconds after

TABLE VIII-7. QOMAC PROGRAM WORD FORMAT*

Bit Number	QOMAC (Bit 4 must be a data "0")	Proportional QOMAC (Bit 4 must be a data "1")
**1 through 3	2's complement of the number of QOMAC cycles to be performed (from 1 to 8).	Not used.
**4	Data "0"	Data "1"
5 through 14	2's complement of the delay time until the first quarter-orbit timing begins. Delays of 1 to 1024 counts in 4-second increments may be programmed.	Same as for QOMAC.
15 through 21	Not used.	2's complement of the actual portion of each quarter orbit, in 16-second increments, during which the QOMAC coil will be energized when unipolar QOMAC operation is being used.
22 through 28	2's complement of the true quarter-orbit time minus 256 counts, in 4-second increments; corrects the quarter-orbit counter to the exact quarter-orbit time.	Same as for QOMAC.

*QOMAC program word must be preceded by a Load QOMAC Program command.

**If bits 1 through 4 are all data "1's", QOMAC operation stops and the QOMAC logic returns to the standby condition.

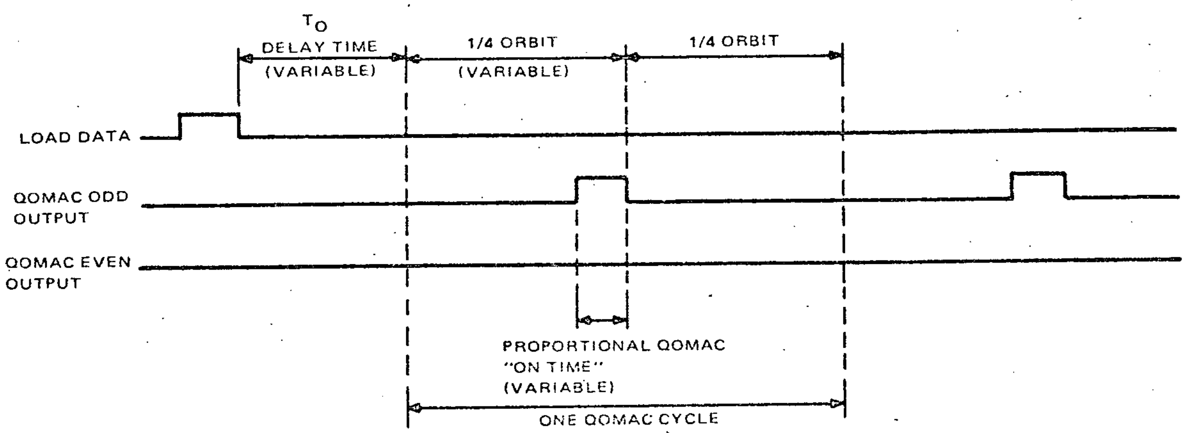
the trailing edge of the 28th data bit. When a number of clock pulses equivalent to the programmed delay time have occurred, the counter overflows. The time of overflow is referred to as QT_O. The delay time until QT_O can be from 1-1024 counts (in 4-second increments). At QT_O the counter resets and begins to count the quarter-orbit time in 4-second increments.

If data bit 4 in the program is a data "0", the program is a normal QOMAC program. At QT_O the QOMAC "odd" output is initiated. Counting then continues until count QT_O +256; at that time, data bits 22 through 28 are transferred from the storage register into the first seven stages of the counter. These bits represent a correction factor and cause the first nine stages of the counter to overflow after the programmed time interval of the corrected quarter orbit. Quarter-orbit times from 385 to 512 counts (in 4-second increments) may be programmed. When overflow occurs, the QOMAC "odd" signal is terminated and the QOMAC "even" signal is initiated. Counting continues until count 256 is again reached, at which time the correction factor is again transferred to the counter. When the next overflow of the first nine counter stages occurs, signifying completion of the second quarter orbit, stage 10 of the counter overflows again. At this time the QOMAC "even" signal is terminated, completing one QOMAC cycle. A three-stage counter, initially containing the programmed number of QOMAC cycles in 2's complement form, is advanced each time one cycle is completed. The QOMAC cycle is repeated, as described above, until the cycle counter overflows indicating the completion of the programmed number of cycles. At that time, the QOMAC sequencer enters a standby mode and no further QOMAC output signals are generated until another QOMAC program is received.

If data bit 4 in the load QOMAC program is a data "1", the program is a unipolar QOMAC program. Counting operations proceed as for a normal QOMAC program, except that no output signal is initiated until a programmed time after T_O +256. Immediately after the QT_O +256 transfer of data bits 22 through 28 into the first seven stages of the quarter-orbit counter, the contents of stages 3 through 9 of the counter are compared with bits 15 through 21, which are stored in a separate register. When these numbers are equal, the QOMAC "odd" output is initiated. Counting and quarter-orbit correction continues as in a normal program until a quarter orbit is completed. At that time, the QOMAC "odd" output is terminated, counting continues until a second quarter orbit is completed but no further QOMAC outputs are generated during this interval. A unipolar QOMAC cycle is defined as complete at the occurrence of this inactive quarter orbit overflow.

The same sequence of events as described above, is reinitiated at each quarter-orbit overflow of the counter.

The QOMAC cycle counter is inhibited in the unipolar QOMAC mode of operation, functioning only as a storage register for bits 1, 2, and 3. If bits 1, 2, and 3 are all data "1's", the QOMAC sequencer assumes a standby mode and does not generate QOMAC output signals. In the unipolar QOMAC mode, the "on" time for the "odd" QOMAC output is programmable in 16-second increments, but is limited to a maximum time which is equal to the true quarter orbit time minus 1024 seconds. The unipolar QOMAC cycle is illustrated in Figure VIII-12.



OPERATIONAL LIMITS

VARIABLE	TIME DURATION	COUNTS	TIME INCREMENT (SEC)
T_O DELAY	4 SEC TO 68 MIN 16 SEC	1 TO 1024	4
1/4 ORBIT TIME	25 MIN 40 SEC TO 34 MIN 8 SEC	385 TO 512	4
QOMAC "ON TIME"	16 SEC TO (1/4 ORBIT TIME −1024 SEC)	1 TO ~64	16

Figure VIII-12. Proportional QOMAC Cycle

3. SR Subsystem Control

a. SR RECORDER SEQUENCING

The addition of a third SR recorder in the ITOS D and E system requires new implementation in control of recording and playback of SR data. SR recorder selection is handled by the CDU via SRR1 SELECT, SRR 2 SELECT, and SRR3 SELECT, real time commands. Interlocks prevent more than two SR recorders from being selected. Selection in itself does not cause any action to occur other than the enabling of interface power to the selected recorder.

The CDU presents three signal lines to the programmer to indicate the status of its selection logic; SRR1 SELECTED, SRR2 SELECTED, and SRR3 SELECTED. The CDU also provides the programmer with the following decoded commands:

- Use SRR1
- Use SRR2
- Use SRR3
- Playback SRR1
- Playback SRR2
- Playback SRR3

The programmer processes the above signals with end-of-tape record and playback signals from each of the three recorders and controls the status of recording and playback for any combinations of one or two recorders. During two recorder operations, the major provisions provided for are as follows:

- Start of record sequence is initiated by the Use SRR-N (N = 1, 2, 3) command thus allowing option of first recorder to operate.
- If an SR recorder is filled, transfer of recording is made to the second recorder providing it is not filled.
- Command of playback to a particular SR recorder of a selected pair will cause the second selected recorder to start recording.
- Playback of both SR recorders is possible using two successive playback commands whereby the recorder which completes playback first will enter the record mode.

Provisions are also made for operating with only a single SR recorder selected. The programmer supplies record and playback levels for each of the three recorders. These signals are sent to the CDU which switches the actual power.

b. SR CONTROL

Since the SR subsystem is to be operated continuously, the programmer will not be required to turn power on and off to the radiometers as was the case for TIROS M/ITOS-1. The only control required is an indication of the day-portion of the orbit for use in a backup mode wherein the visible channel of the SR is transmitted on the real time link during the day while the IR channel is transmitted at night. The programmer will generate the Orbital Day signal which is a level which starts after the T_0 delay time (orbit counter overflow) and lasts until count 400 of the orbit counter during each orbit. The signal is supplied to the CDU which performs the appropriate switching based upon real time commands received.

4. Programmer Interfaces

Figure VIII-13 indicates the required interfaces. Table VIII-8 lists the input functions while Table VIII-9 lists the output signals.

5. Packaging

The DCP will use the same container as the one used for TIROS M/ITOS-1. Two of the six logic boards associated with each programmer will be redesigned to accommodate the new logic required. One of these boards (per programmer) will require a new external connector in order to enable the interfacing of commands and end-of-tape signals necessary for SRR sequencing. A third logic board will require a minor modification which can be executed on an equivalent TIROS M/ITOS board in order to convert the orbit counter to a normal binary counter thus eliminating the modulo 40 front-end feature used by the AVCS camera system on TIROS M/ITOS. Harness board and buffer board modifications will also be required in order to bring new signals to the programmer's interface connectors. Size, weight, footprint, and power will remain the same as the TIROS M/ITOS DCP.

F. COMMAND DISTRIBUTION UNIT (CDU)

1. General Characteristics

Two CDU's, designated CDU A and CDU B, perform the decoding and command distribution functions for the ITOS D and E real-time commands. The CDU's are located on opposite sides of the baseplate to minimize harness runs and for packaging considerations. Hereafter, both boxes will be referred to as "the CDU" unless one or the other is specifically designated.

The two boxes are not redundant; that is, CDU A could not be replaced by CDU B or vice-versa. Each CDU box controls a different set of functions, and, correspondingly, each decodes a unique group of commands. The CDU internal circuitry is duplicated so that redundancy is provided internally rather than between identical units.

The physical dimensions of the CDU boxes are identical to those for TIROS M/ITOS. CDU A contains eight component boards and a harness board; CDU B contains seven component boards and a harness board. Approximately 2/3 of these boards will require either minor rework or complete redesign to provide for the new ITOS D and E control functions. However, wherever possible, existing designs and hardware will be utilized.

TABLE VIII-8. DUAL COMMAND PROGRAMMER INPUTS

Signal	Source	Type of Signal	Function
SRR 1 SEL SRR 2 SEL SRR 3 SEL	CDU	Level Level Level	Informs programmer as to which recorders are to be used for recording SR data.
USE SRR 1 USE SRR 2 USE SRR 3		Pulse Pulse Pulse	Informs programmer as to which recorder is to be first for recording SR data.
PB SRR 1 PB SRR 2 PB SRR 3		Pulse Pulse Pulse	Informs programmer as to which recorder is to be played back.
PROG 1 ON PROG 1 OFF PROG 2 ON PROG 2 OFF		Pulse Pulse Pulse Pulse	Applies Power to PROG 1 Removes Power to PROG 1 Applies Power to PROG 2 Removes Power to PROG 2
EOTR 1 EOTR 2 EOTR 3	SR REC 1 SR REC 2 SR REC 3	Level Level Level	Informs the programmer that recording on the Associated SR recorder is completed.
EOTP 1 EOTP 2 EOTP 3	SR REC 1 SR REC 2 SR REC 3	Level Level Level	Informs the programmer that the Associated SR recorder has completed playback and is ready to record.
LOAD PIC PROG COMM LOAD QOMAC COMM SWITCHED GRD	DEC 1 and DEC 2	Pulse Pulse Level	Enables the PROG to accept a 28 bit T_0 word or rephasing word. Enables the PROG to accept 28 bits of QOMAC program digital data. Associated decoder has its PWR OFF; inhibits receipt of spurious data from that decoder.
DATA "1" INPUT DATA "0" INPUT		Pulse Pulse	Binary data in a 28 bit digital format from either decoder. This data may serve as a T_0 word, rephasing word or QOMAC word.
4-PPS CLOCK 480-PPS CLOCK	TBU	Pulse Pulse	From which is derived a 6.5 sec clock period for timing all SR and VHRR remote operations and a clock pulse with a 4-second period for timing QOMAC remote operations.
480-PPS CLOCK			Used throughout the programmer as a strobing pulse.
-24.5V	Regulated Power Supply	Level	Power

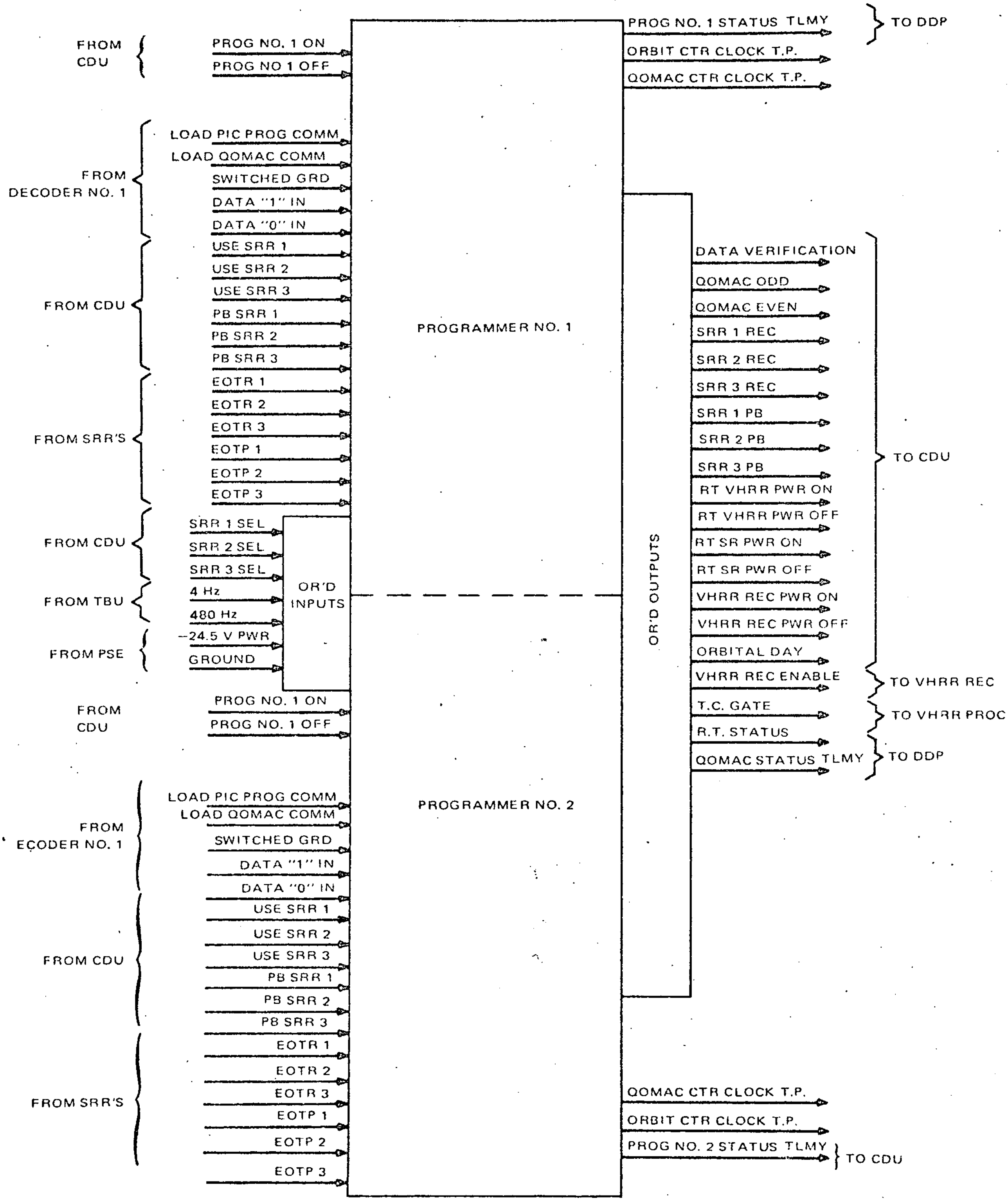


Figure VIII-13. Dual Command Programmer Interface Diagram

TABLE VIII-9. PROGRAMMER OUTPUTS

Signal	Destination	Type of Signal	Interface	No. of Outputs
SRR 1 REC	CDU	Level	Standard Output Buffer	1
SRR 2 REC		Level		1
SRR 3 REC		Level		1
SRR 1 PB		Level		1
SRR 2 PB		Level		1
SRR 3 PB		Level		1
RT VHRR PWR ON		Pulse		2
RT VHRR PWR OFF		Pulse		2
RT VHF XMTR PWR ON		Pulse		2
RT VHF XMTR PWR OFF		Pulse		2
VHRR REC PWR ON		Pulse		1
VHRR REC PWR OFF		Pulse		1
Orbital Day		Level		1
QOMAC Odd Output		Level		2
QOMAC Even Output		Level		2
Data Verification		Level		2
R.T. Status Tlm	DDP	Level	Telemetry Output Buffer	1
Prog 1 Status Tlm		Level		1
Prog 2 Status Tlm		Level		1
QOMAC Status Tlm		Level		1
VHRR REC Enable	VHRR REC	Level	Standard Output Buffer	1
Time Code Gate	VHRR Processor	Pulse		1
QOMAC Orbit Ctr Clock T. P.	Test Point	Pulse	*IC Output	1
Orbit Ctr Clock T. P.	Test Point	Pulse		1

*Output taken from I. C. gate through a IK ohm series resistor. This output will not be used to drive any loads internal to the programmer (for test purposes only).

The CDU is designed to meet all applicable requirements of the reliability program plan and all parts will be selected, derated, and preconditioned in accordance with the standard parts list for TIROS M and ITOS D and E.

2. Functional Description

a. General

The CDU performs the following functions:

- Transforms command bits received from either command decoder into command functions which are used to change the internal status of the CDU or are sent as control signals to other spacecraft subsystems;
- Acts as switching devices to connect power, as commanded, to redundant spacecraft subsystems;
- Controls the operation of various spacecraft subsystems and functions;
- Serves as a memory by storing commands;
- Interconnects and/or level-shifts spacecraft signals and routes them to appropriate subsystems;
- Performs automatic turn-off of various subsystems and functions whenever decoder voltage to the CDU is unlatched; and
- Provides test points and telemetry outputs to permit monitoring of internal status.

The CDU receives the following inputs:

- 24 command bit lines from each decoder (12 Set I lines and 12 Set II lines);
- Switched-23 volt power line from each decoder which is used to power the decode gates;
- Separate fused lines for each side of each subsystem whose power is switched by relays located in the CDU;
- Control or status indication signals. (These signals are used either to change the internal state of the CDU or they are level-shifted and routed to the appropriate subsystem.)

- Telemetry signals to be processed; and
- Ground.

The following outputs are provided by the CDU to accomplish functional tasks:

- Decoded commands used to drive relays or other circuitry located within the subsystem concerned;
- Power switched through relay contacts located in the CDU;
- Transistorized buffer driver outputs where level-shifted control signals or power switching functions are accomplished with transistors;
- Telemetry signals which have been "processed" within the CDU;
- Housekeeping telemetry power; and
- Internal telemetry and test points.

b. Command Decoding

Commands received by the ITOS D and E spacecraft will be a 2 out-of-12 code, wherever two bits out of the 12 bits in a correct command word are data "1's".

As in TIROS M/ITOS, the same codes are repeated, forming two sets of commands for a total command capability of 132. Of these, the ITOS D and E spacecraft requires the 110 commands listed in Table VIII-1.

Code assignments corresponding to these command functions will be determined during the detailed unit design phase in order to optimize selection. In general, the command to choose side 1 of a redundant subsystem will be in Set I and the corresponding command to choose side 2 in Set II, with the same bits assigned. Thus a command transmitted in the wrong set will not affect another subsystem.

In addition, certain commands must be enabled by either a key or a toggle switch in the CDA station before they can be transmitted to the spacecraft. These are as follows:

COMMAND ENABLING

Command	Enabled By
Scanning Radiometer Motor 1 OFF	Key
Scanning Radiometer Motor 2 OFF	Key
VHRR Motor 1 OFF	Key
VHRR Motor 2 OFF	Key
Deploy Solar Panels	Key
Charge Control, Trickle Charge	Toggle Switch
Shunt Control Amplifier 1 ON	Toggle Switch
Shunt Control Amplifier 2 ON	Toggle Switch
Shunt Control Amplifier Mode 1	Toggle Switch
Shunt Control Amplifier Mode 2	Toggle Switch
Pitch Loop Open Loop Mode	Toggle Switch
Dual Motor Mode ON	Toggle Switch
Disable Dual Motor Mode	Toggle Switch

Within the CDU, commands are decoded in series transistor AND gates, as shown in Figure VIII-14. Bit lines originate from the collectors of PNP output buffer transistors located in the decoder. Bit lines corresponding to received bits are activated by pulses at approximately +4 volts for 100 milliseconds. The decoded output is used internally in the CDU to drive relays; also as an input to other buffer circuits; or is sent out from the CDU as a control signal to a spacecraft subsystem.

Each decoder supplies 12 Set I bit lines, 12 Set II bit lines and a -23 volt (switched) line to each CDU as shown in Figure VIII-15. The -23 volt line is switched on to power the decoding gates in the CDU whenever the decoder is enabled to receive commands. Redundancy is maintained internally in the CDU in that any command can be actuated from either decoder.

c. Commands and Their Functional Operation

(1) *GENERAL*

All but two commands are decoded by the CDU. The Load QOMAC and Load Picture Program commands are processed within the decoder for direct transfer to the programmer. The remaining 108 commands are presented

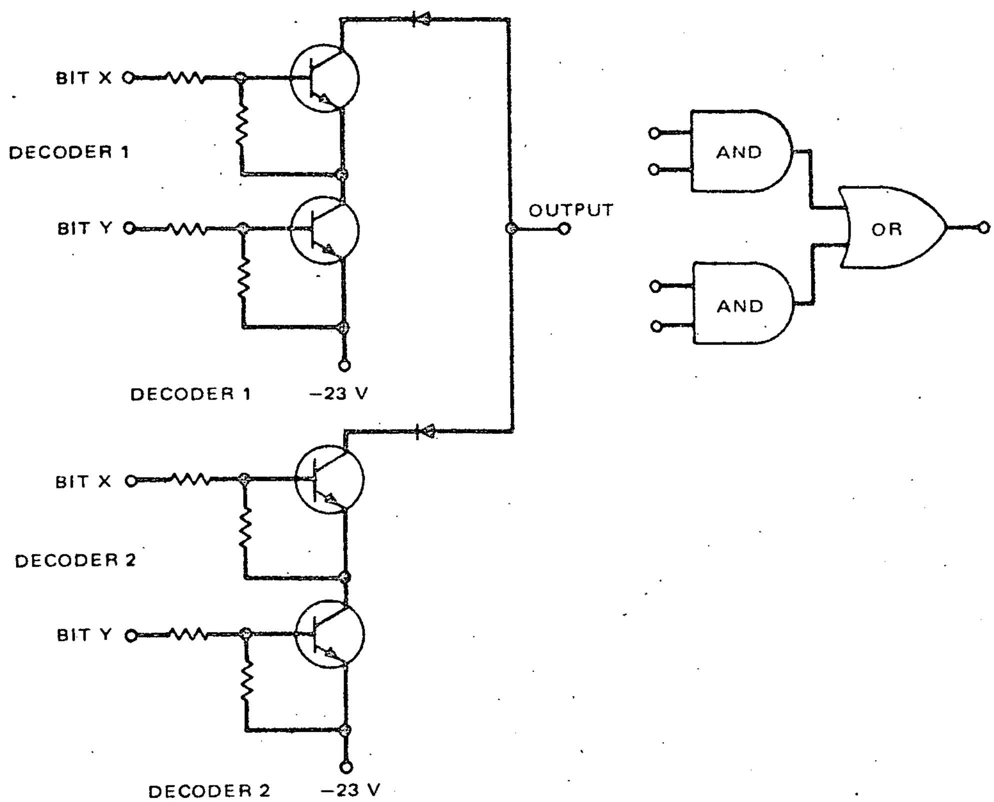


Figure VIII-14. Typical CDU Decoding Gate, Schematic Diagram

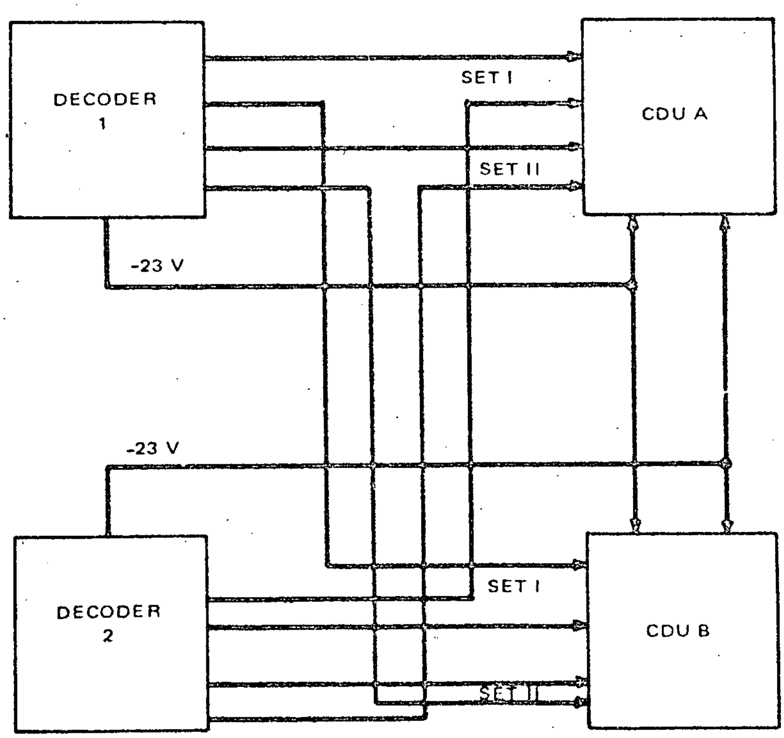


Figure VIII-15. Decoder and CDU Interconnections in this section, grouped according to controlled subsystem, and are accompanied by brief descriptions of their functional operations.

(2) POWER SUBSYSTEM

- Commands for Power Supply Electronics (PSE) Control

  Use -24.5 Volt Regulator 1, Not 2

  Use -24.5 Volt Regulator 2, Not 1

  Shunt Control Amplifier Mode 1

  Shunt Control Amplifier Mode 2

  Shunt Control Amplifier 1 ON

  Shunt Control Amplifier 2 ON

  Charge Control, Trickle Charge

  Charge Control, Normal Charge

These commands are decoded using the typical decoder gate configuration shown in Figure VIII-14, and set to the PSE where they are used to perform switching functions as indicated by the command names.

(3) TIME BASE UNIT (TBU)

- Commands for Time Base Unit

  Time Base Unit 1 ON, Not 2

  Time Base Unit 2 ON, Not 1

These commands are decoded and sent as command pulses to the TBU. There are interlocking arrangements within the TBU which assure that one side of the redundant TBU will always be powered, but that both will never be powered simultaneously. These commands also reset the time code generators (see Figure VII-16).

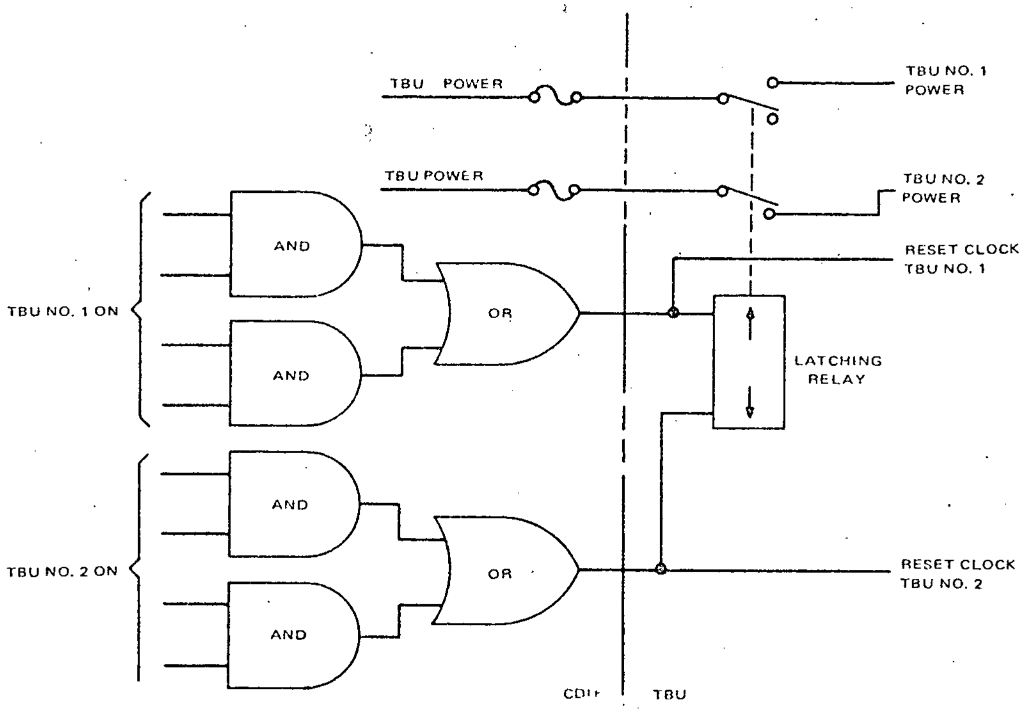


Figure VIII-16. Dual Time Base Unit Selection

(4) PROGRAMMER (DCP)

- Commands for DCP

Select Programmer 1, Not 2

Select Programmer 2, Not 1

Select Neither Programmer

These commands are decoded and set as command pulses to operate latching relays in the DCP where an interlocking function ensures that both programmers will not be on at the same time, (see Figure VIII-17).

(5) SCANNING RADIOMETER (SR) SUBSYSTEM

- Commands for SR Motors

SR Motors 1 and 2 ON

SR Motor 1 OFF

SR Motor 2 OFF

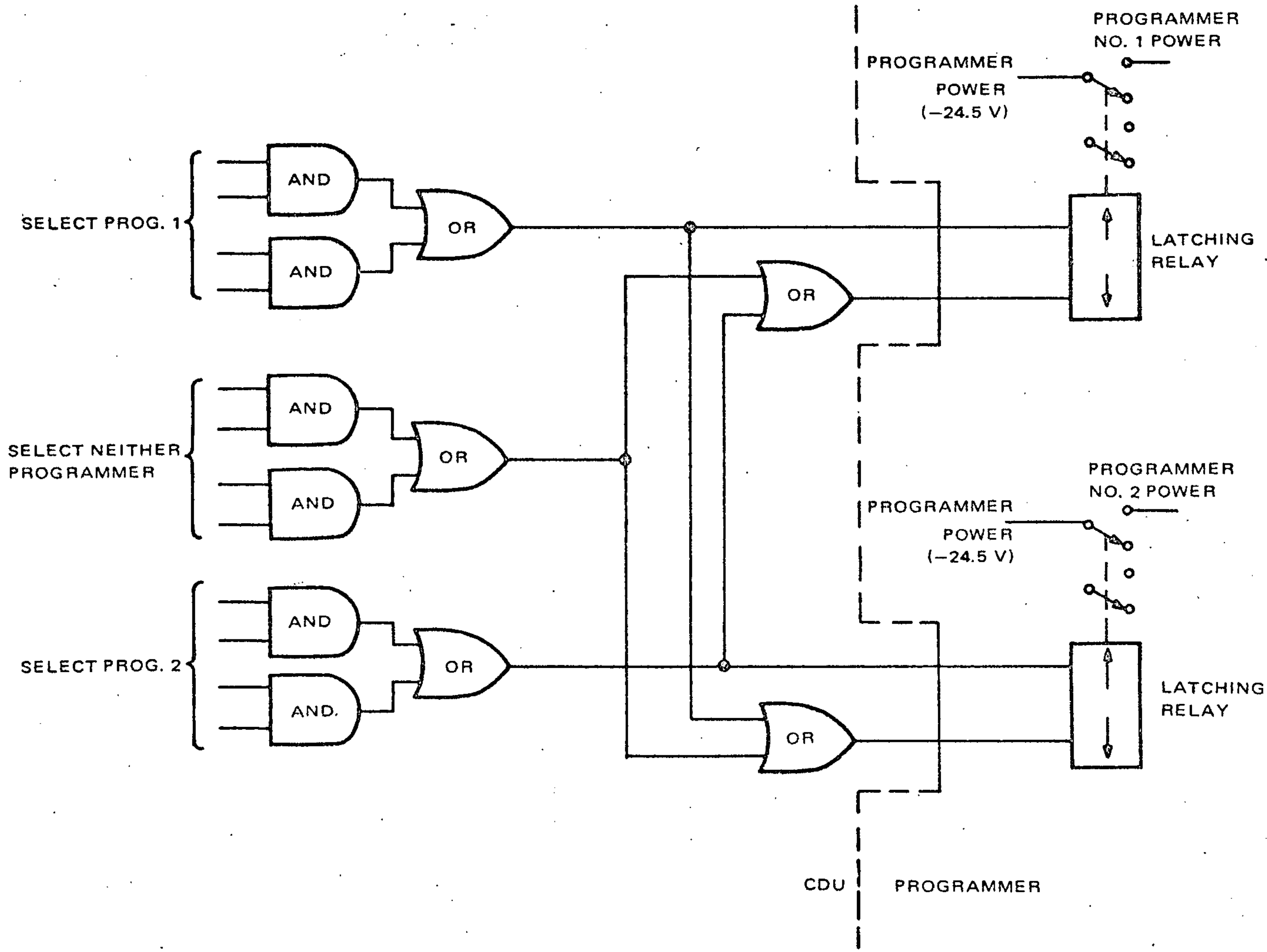


Figure VIII-17. Programmer Selection

These commands are decoded and sent as command pulses to the SR subsystem where power is switched to the SR motors as indicated.

- Commands for SR Electronics

  Use SR 1, not 2

  Use SR 2, not 1

  Use Neither SR

These commands simultaneously select the power bus and send command pulses to the appropriate scanning radiometer units to set up the required conditions. (See Figure VIII-18). Unlike TIROS M/ITOS, turn-on and turn-off of scanning radiometers is independent of programmer operation or status.

(6) SRR PROCESSOR CONTROL LOGIC

- Commands for the SR Processor

  Select Multiplexed Real Time SR Modulation

  Select IR Day Real Time SR Modulation

  Select VIS Day Real Time SR Modulation

These commands establish the scanning radiometer real time mode of operation. Relays are latched in the CDU which store the last command sent. Resultant relay states are processed with programmer orbit day status to provide three mutually exclusive real time control instructions to the SR Processor (see Figure VIII-19). Multiplexed modulation is the normal data mode whereby both IR and visible SR video signals are time-multiplexed onto a single channel by means of SRR staggered head recording techniques.

The Select IR Day, Real Time SR Modulation command is a backup mode eliminating the recorder path whereby only the IR channel of the two SR sensor outputs is transmitted in real time. The Select Vis Day Real Time SR Modulation command is another backup mode whereby the VIS channel is transmitted during the day portion of the orbit, and the IR channel during the night portion. The programmer provides definition of the day/night portion of the orbit, to the CDU. If the programmer is inactive while in this mode, the CDU will return to the night (IR) modulation logic.

(7) SCANNING RADIOMETER RECORDERS (SRR)

- Commands Associated with SR Recorder Control

  SELECT SR Recorder 1

  SELECT SR Recorder 2

  SELECT SR Recorder 3

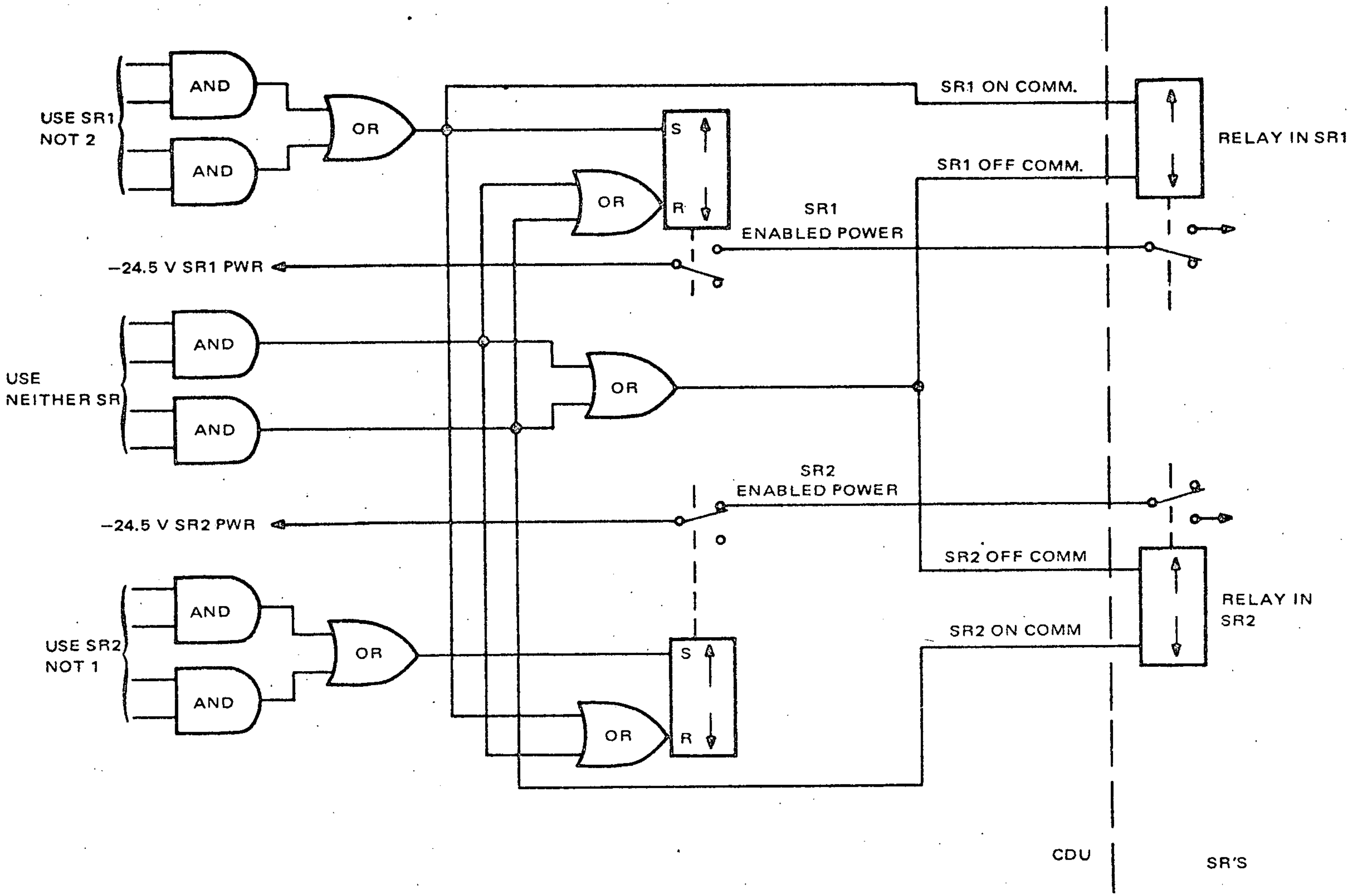


Figure VIII-18. SR Control Logic

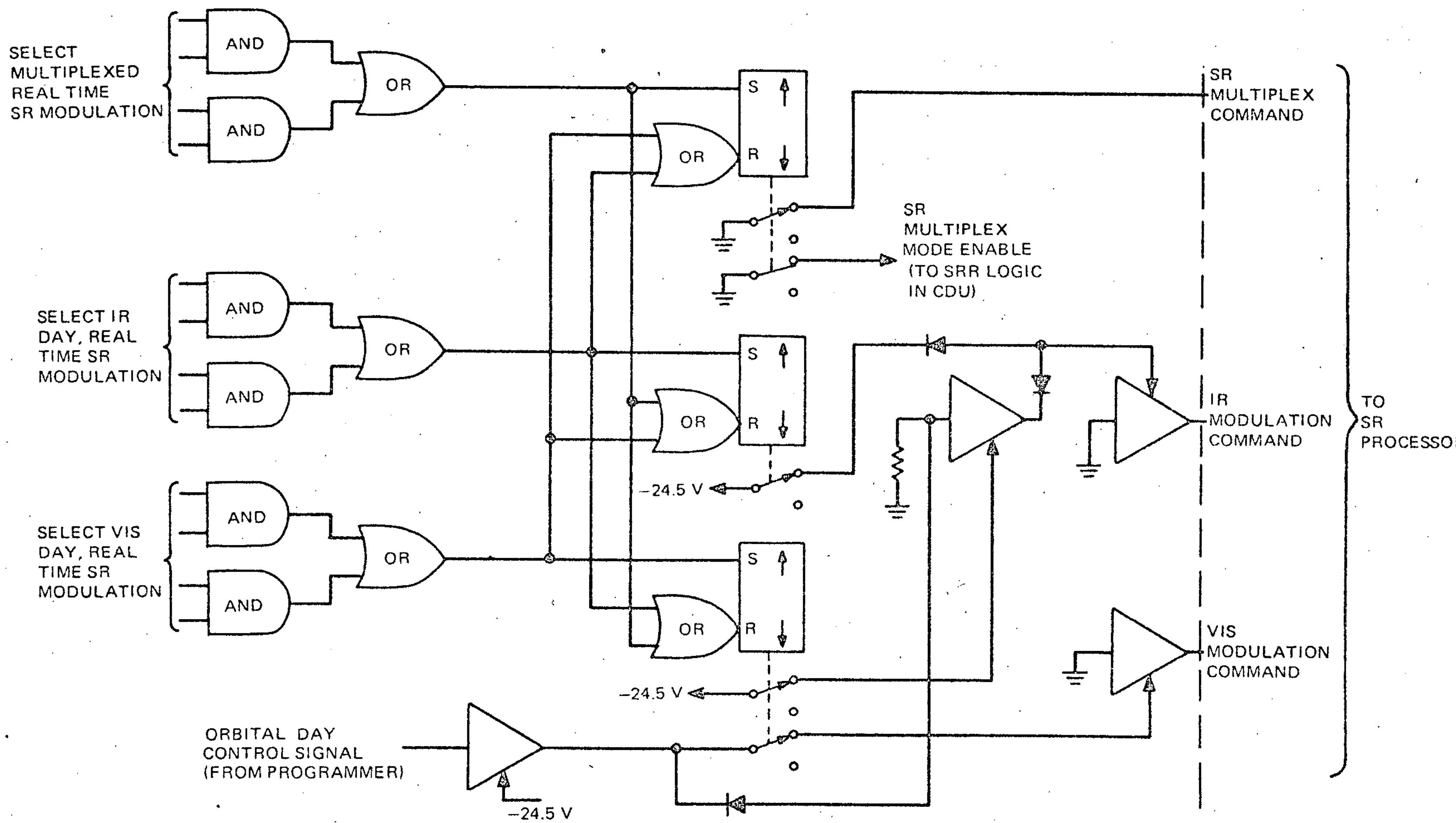


Figure VIII-19. SR Processor Control

SELECT NO SR Recorder

USE SR Recorder 1

USE SR Recorder 2

USE SR Recorder 3

PLAYBACK SR Recorder 1

PLAYBACK SR Recorder 2

PLAYBACK SR Recorder 3

The SR subsystem contains three SR recorders. During normal operation any two of the three recorders are used in a sequential manner while the third recorder provides redundancy in the form of a spare to be used in case of a recorder failure. Only one SRR can record at any time. If the recorder becomes filled or is requested to play back, the second selected recorder assumes the recording function. Playback of either a single or both recorders may be commanded. The option of selecting the first SRR to record and a means for transferring record mode to the second SRR by command are also provided. In addition, single recorder operation is also possible.

The CDU, in conjunction with the DCP, provides the signals necessary to control the three SR recorders. The programmer uses integrated circuit logic to process the selection status and decoded real-time commands from the CDU and the status of the end-of-tape indicators from the SR recorders. It then provides the CDU with the following signals which indicate which SRR should be in either the record or the playback mode:

SRR 1 Record

SRR 2 Record

SRR 3 Record

SRR 1 Playback

SRR 2 Playback

SRR 3 Playback

The CDU provides the SRR selection logic and the power switching, based on programmer inputs, to control the record mode and playback mode of the selected recorders. Refer to Figure VIII-20 for the SRR control logic in the CDU.

Upon receipt of a Select SRR command, motor and electronics power are enabled for switching to the associated SRR, EOT sense power is supplied to the selected SRR and an SRR selected indicator signal is supplied to the programmer. Upon receipt of a second selection command, the same events as above are activated for the second recorder. Any command to select the third recorder will be ignored by the CDU logic which is interlocked such that only one or two of the three SRR's may be selected. In order to change selection, it is necessary to first send the Select No SRR command which resets the selection logic.

After SRR selection has been made, entry into the record mode is made by sending the appropriate USE SRR command which establishes (via the programmer) the priority of which SRR is to be used first for recording.

An SR recorder will begin recording if motor power and electronics power are both applied and playback is not commanded. Whenever a programmer generated SRR record signal is received and the associated SRR has been selected for use, the CDU will cause the enabled motor power and electronics power to be switched to that recorder thus initiating a record mode.

If it is desired to transfer recording to the opposite SRR, the USE SRR command associated with that SRR will cause this to occur providing that the SRR had been properly selected.

An SR recorder will play back if both the motor and electronics power are applied and a playback command level is also present. Whenever a programmer generated SRR Playback signal is received and the associated SRR has been selected for use, the CDU will cause the enabled motor and electronics power to be switched to that recorder and a playback command level will be activated to that SRR. An additional constraint in the form of a playback inhibit is present during this mode. The playback inhibit is designed to allow playback only when the S-band transmitter is in the playback mode and the satellite is in ground station contact. Whenever this inhibit is present, the CDU will cause the motor and electronics power to be turned off to any SRR which is in a playback mode.

In addition, the CDU contains the decode gates for the USE SRR 1, USE SRR 2, USE SRR 3, PLAYBACK SRR 1, PLAYBACK SRR 2, and PLAYBACK SRR 3 real-time command pulses. Each of these commands is buffered to provide a resistively isolated output to each of the redundant programmers. Whenever a VHF transmitter has been selected and the SR real-time multiplex mode has been selected, the CDU will supply a real-time SR multiplex mode signal to any SR recorder whose electronics power is turned on. The SR recorder uses this signal to enable its playback head to read the visible and IR signals from the tape during the record mode. This time multiplexed signal is used for real-time SR transmission via the VHF transmitter. (See Figure VIII-21.)

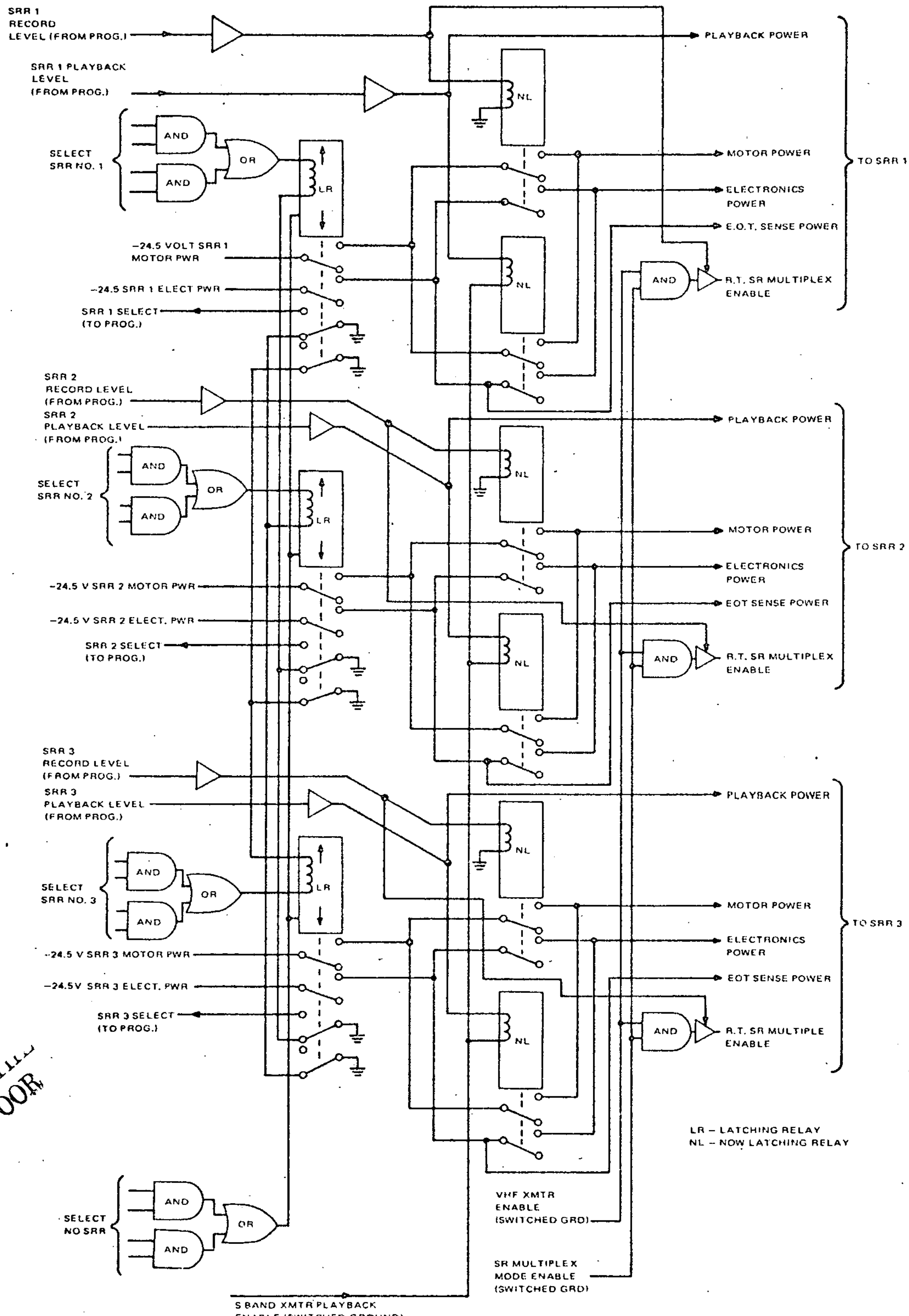


Figure VIII-20. SRR Selection Logic

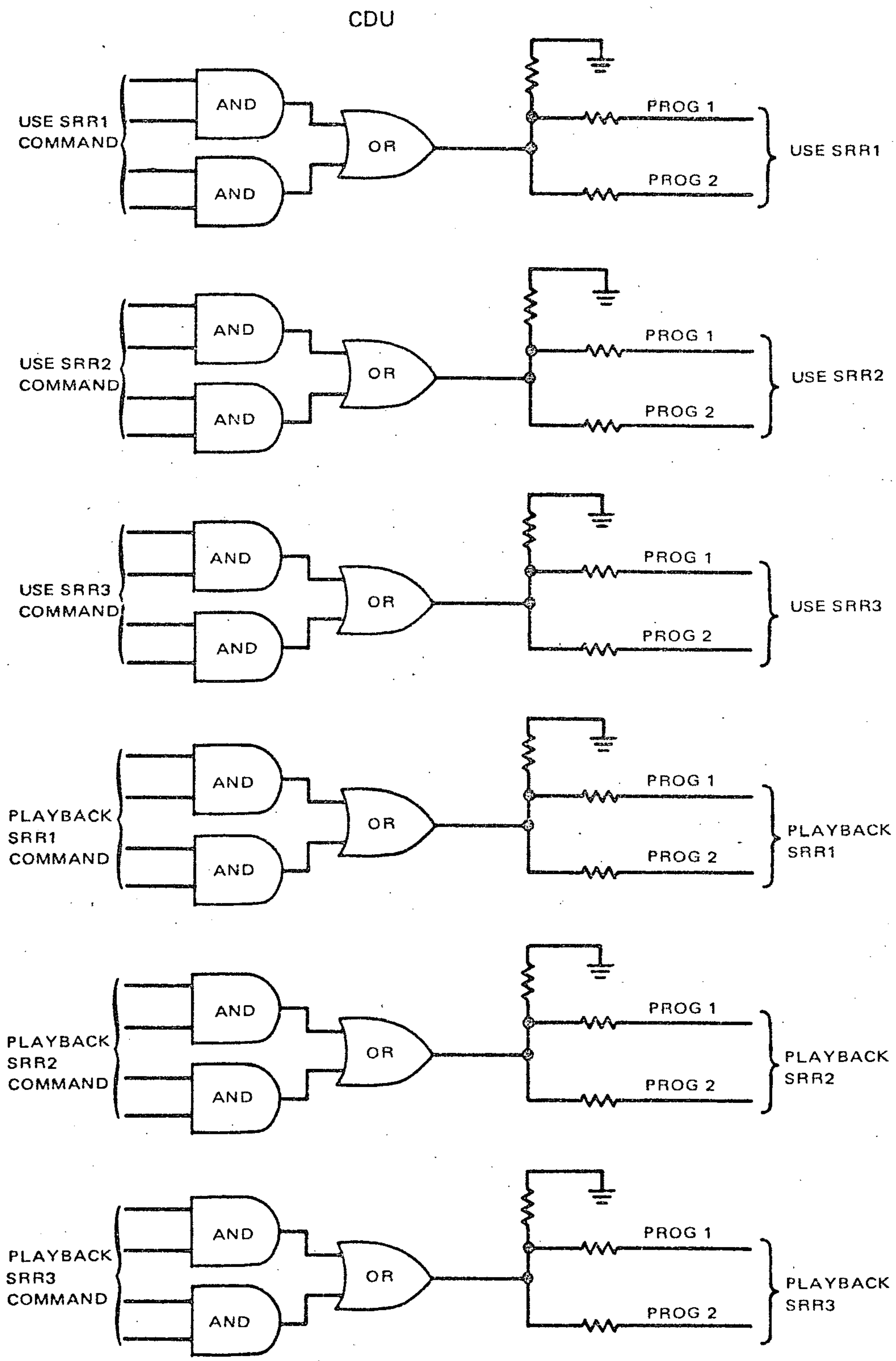


Figure VIII-21. SRR Command Decoding Logic

(8) VHF REAL-TIME TRANSMITTER

- Commands for VHF Transmitter Control

  Use VHF Transmitter 1, Not 2

  Use VHF Transmitter 2, Not 1

  Use Neither VHF Transmitter

Either VHF real-time transmitter, or neither, may be selected, but both cannot be selected at the same time. Selection of a transmitter causes its immediate power turn-on (see Figure VIII-22).

The transmitters are also under control of the DCP which can turn a powered transmitter OFF and then ON again in accordance with the orbit segment inhibit program for SR real-time data; by use of a VHF XMTR PWR OFF pulse, or a VHF XMTR PWR ON pulse, to toggle a relay in the CDU. This relay is also under real-time command control, so that the ground station can over-ride a mode established by the programmer.

Every 48.5 days, the time base unit will send a signal to the CDU which is used to turn off the operating VHF transmitter, provided that the time code generator in use had not been reset. One of the two VHF selection commands must then be sent to re-establish transmission. Special care is taken in developing the TBU turn-off logic in the CDU to assure that a single buffer gate short circuit failure will not, by itself, prevent VHF transmitter operation.

(9) VERTICAL TEMPERATURE PROFILE RADIOMETER

- Commands For VTPR Control

  VTPR Filter Motors 1 and 2 On

  USE VTPR 1, not 2

  USE VTPR 2, not 1

  Use Neither VTPR

  VTPR Patch Calibrate On

  VTPR Calibrate Disable

VTPR Patch Calibrate On

VTPR Calibrate Disable

The two redundant VTPR units are controlled by real-time commands processed in the CDU as shown in Figure VIII-23. Only one VTPR can be on at a time, and its selection applies power to the specified VTPR while simultaneously distributing a combination of decoded pulses to establish its normal operating mode. Thus, the command, USE VTPR 1, NOT 2, causes the CDU to generate control signals which

(a) remove power from VTPR 2 and turn off its filter wheel motor.

(b) apply a regulated power bus to VTPR 1 latch on its internal power relay, and turn on its filter wheel motor.

(c) disable the patch calibration mode.

(d) enable the normal calibration mode.

The USE VTPR 2, NOT 1 command performs the complementary set of functions with 1 and 2 interchanged.

The USE NEITHER VTPR command causes removal of power from the electronics and filter wheel motor for both VTPR 1 and VTPR 2.

During launch, both filter wheel motors will be on, but without VTPR electronics power, as set up by the VTPR FILTER MOTORS 1 AND 2 ON command. After normal mission operation is established, only the motor associated with the selected VTPR will be powered.

The VTPR Patch Calibrate ON command is intended primarily for ground testing purposes whereby the scanning mirror is set into a fixed position to constantly view the housing. This mode may be disabled either by a VTPR selection or CALIBRATE DISABLE command. The latter command also disables the normal calibration mode which is automatically entered each time a VTPR is selected for use.

(10) VERY HIGH RESOLUTION RADIOMETER (VHRR) SUBSYSTEM

- Commands for VHRR Motors

  VHRR Motors 1 and 2 ON

  VHRR Motor 1 OFF

  VHRR Motor 2 OFF

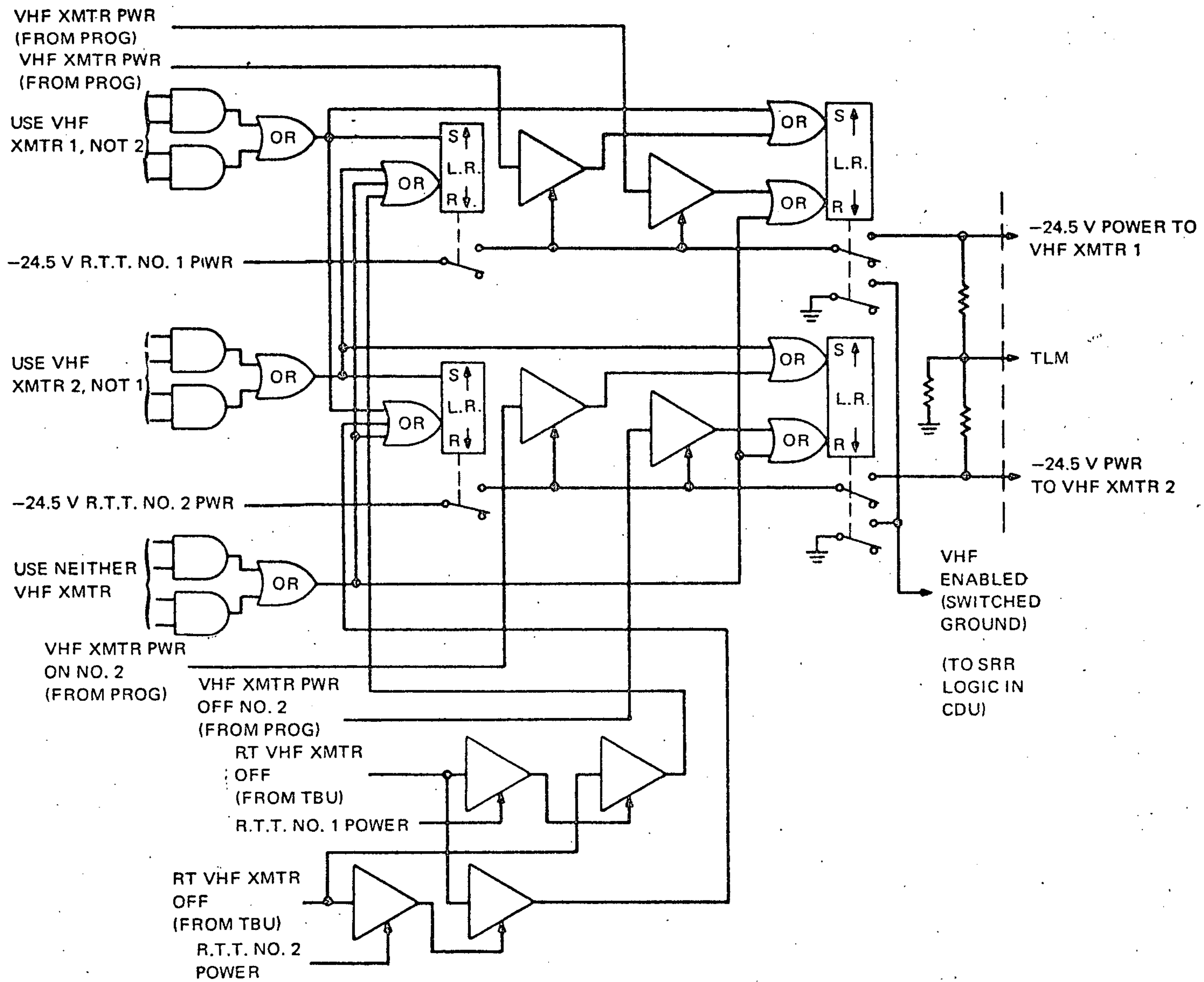


Figure VIII-22. VHF Real-Time Transmitter Control Logic

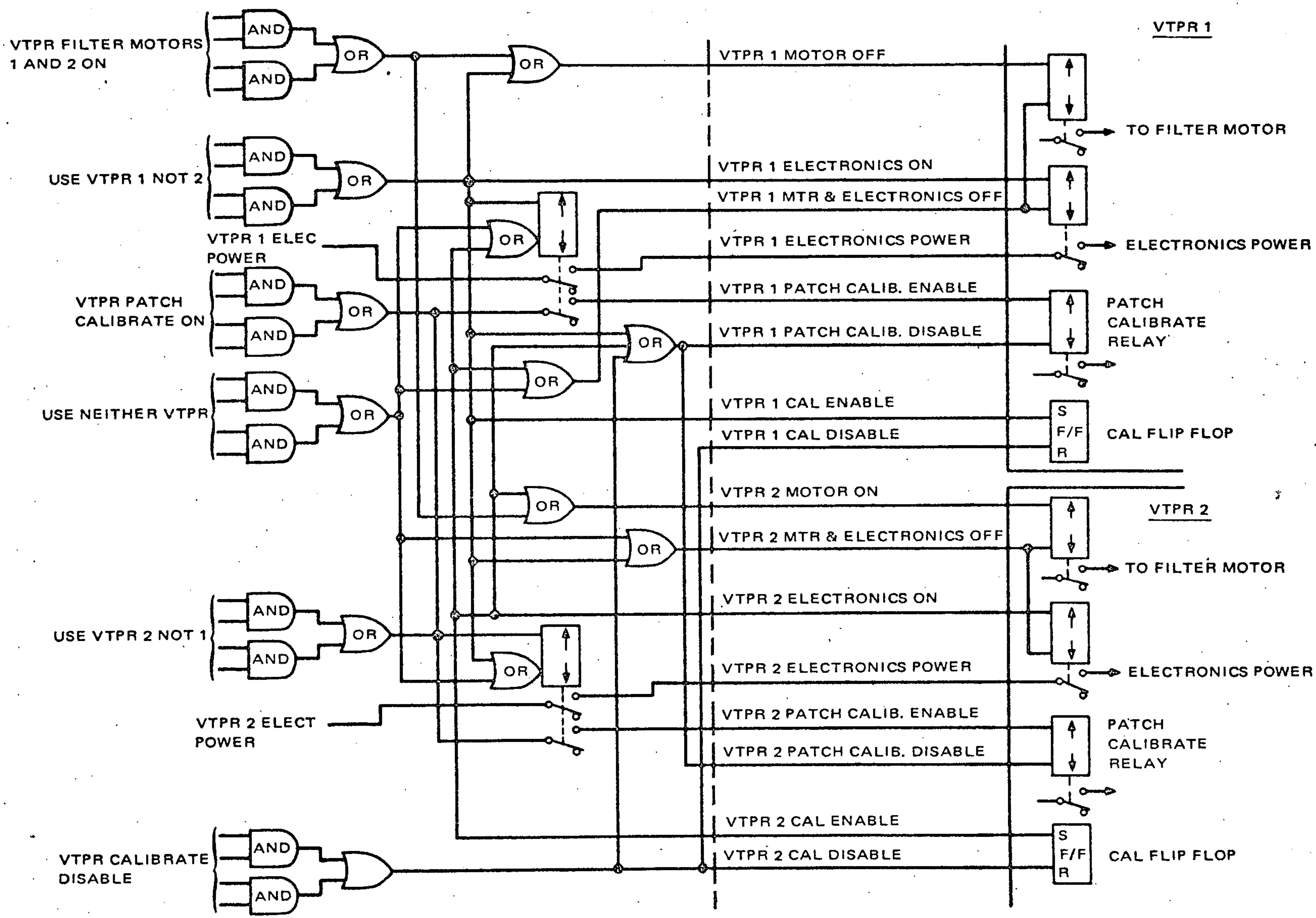


Figure VIII-23. VTPR Control Logic

These commands are decoded in the CDU and sent as pulses to operate relays in the VHRR electronics where power is switched to the motors. Scan mirror motors may be tuned on or off independently of VHRR power status to permit their continuous operation during launch and in orbit.

- Commands for VHRR Control

  Use VHRR IR 1, VIS 2

  Use VHRR IR 2, VIS 1

  Use VHRR 1

  Use VHRR 2

  Disable VHRR Electronics

Depending on the mode of operation, either one or both VHRR units may be active simultaneously. The two phased-mirror modes require both VHRR's on, each supplying one of the two complementary video channels to form an IR and visible composite signal through time division multiplex. In this case, the VHRR providing the visible signal will always have its mirror drive slaved in proper phase to that for the IR source such that one sensor scans space while the other scans earth.

In the backup mode of operation, the IR and visible signals are generated by one unit and are frequency multiplexed within the VHRR processor prior to modulating the S-band transmitter.

Each of the four independent mode commands is decoded within the CDU, and logically distributed to the two VHRR's and the VHRR processor to establish the corresponding operating conditions. Power is simultaneously switched by the CDU to the electronics of those VHRR's in the selected mode. Therefore, VHRR operation is enabled by any of the mode commands (see Figure VIII-24).

Upon receipt of the Disable VHRR Electronics command, power is removed from the electronics for both units.

Table VIII-10 summarizes the specific combinations of control functions which must be executed by the CDU to establish a given VHRR mode of operation.

Whenever the programmer inhibits real-time transmission of VHRR data for one or more orbit segments, it sends a R.T. VHRR PWR OFF pulse to the CDU which removes all VHRR power without altering the mode status retained within each VHRR and processor. Real-time S-band power is also disabled during this time, details of which are given in the section on S-band transmitter commands. At the conclusion of the inhibit period, the Programmer R.T. VHRR PWR ON pulse toggles the power relay in the CDU allowing return to the same mode established prior to turnoff.

TABLE VIII-10. VHRR CONTROL FUNCTION ACTIVATION CORRESPONDING TO S/C COMMANDS

		Spacecraft Commands				
		Use VHRR IR 1, VIS 2	Use VHRR IR 2, VIS 1	Use VHRR 1	Use VHRR 2	Disable VHRR Electronics
VHRR #1	Motor Sync	X		X		
	Motor Auto		X			
	Electronics on	X	X	X		
	Electronics off				X	X
	VIS off	X				
	IR off		X			
Relay in CDU	-24.5V switched power on	X	X	X		
	-24.5V switched power off				X	X
VHRR #2	Motor Sync		X		X	
	Motor Auto	X				
	Electronics on	X	X		X	
	Electronics off			X		X
	VIS off		X			
	IR off	X				
Relay in CDU	-24.5 switched power on	X	X			
	-24.5 switched power off			X		X
VHRR Processor						
	IR1, VIS 2 Mode	X				
	IR2, VIS 1 Mode		X			
	IR1, VIS 1 Mode			X		
	IR2, VIS 2 Mode				X	

The programmer also ensures that the electronics for the VHRR units are powered whenever it enters a VHRR Record sequence, provided VHRR power had not been disabled by a disabled by a direct command. A nonlatching relay in the CDU is actuated while VHRR recorder power is on to provide a temporaty by pass for the VHRR inhibited power bus.

(11) VHRR RECORDER SUBSYSTEM

- Commands for the VHRR Recorder
  Enable VHRR Recorder Power
  Disable VHRR Recorder Power
  Playback VHRR Recorder Data Channel 1
  Playback VHRR Recroder Data Channel 2

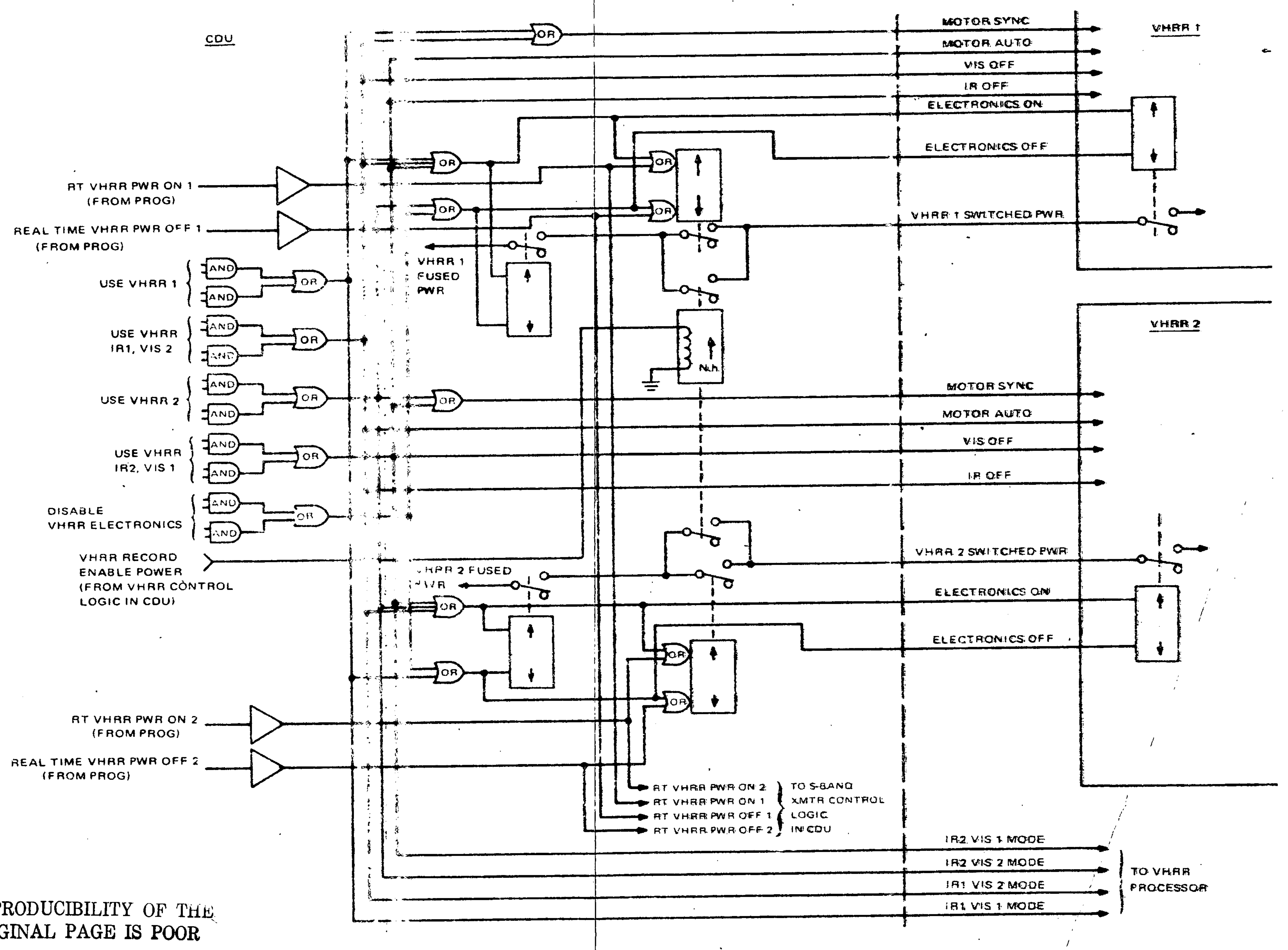


Figure VIII-24. VHRR Subsystem Control Logic

VHRR recording is remotely controlled through the programmer whereas playback is initiated by direct commands. Before either operation can be executed, both motor and electronics power must be switched on by a relay in the CDU which is toggled by the enable and disable commands (see Figure VIII-25).

For the record mode, the programmer latches a second relay in the CDU which applies power to the VHRR control logic in the CDU, the VHRR Recorder, and the time code gating circuits in the VHRR processor. After a 250 ms delay which allows for voltage stabilization, the programmer sends a command level directly to the recorder electronics to initiate recording. Power to the recorder remains until a Record Power OFF pulse, generated by the Programmer, after counting out a fixed time period, resets the relay in the CDU.

Playback of a VHRR Recorder can occur only if the recorder has been enabled and is not at its playback end of tape. With these conditions satisfied, the CDU will apply motor and electronics power to the Recorder whenever the S-band transmitter is powered in its playback mode. The interval between this event and VHRR Recorder commands provides the necessary delay for recorder electronics stabilization.

The data channel selected as part of the playback command determines the two particular tracks out of three which playback. Track 2 is represented by the flutter and wow clock. The VHRR signals on the other tracks are a function of the VHRR mode of operation at the actual time of recording as follows:

TABLE VIII-11. VHRR MODES

VHRR Mode	Data Channel 1 Track 1	Data Channel 2 Track 3
IR1 VIS 2	IR1, VIS 2	blank
IR2 VIS 1	blank	IR2, VIS 1
VHRR 1	IR1	VIS 1
VHRR 2	VIS 2	IR 2

Since all three tracks are erased by a single playback pass, the non-selected track is not recoverable.

Playback is terminated by the occurrence of one or more of the following events:

(a) Recorder arrives at end of tape.
(b) S-band transmitter playback mode is discontinued as result of a direct command or generation of a push-to-talk signal.
(c) A Disable VHRR Recorder Power command is received.

(12) S-BAND TRANSMITTER SUBSYSTEM

- Commands for S-Band Transmitter Control

  Select S-band Transmitter 1, not 2
  Select S-band Transmitter 2, not 1
  Select Multiplexer 1, not 2
  Select Multiplexer 2, not 1

  Real Time S-band Transmitter ON
  Playback S-band Transmitter ON
  S-band Transmitter OFF

The S-band and multiplexer selection commands perform functions similar to their counterparts TIROS M/ITOS by causing power to be enabled in the CDU for the selected units without turning them on. Unlike TIROS M/ITOS the ITOS D and E S-band subsystem has two modes of operation: the real time mode for continuous global transmission of VHRR data and the playback mode for recovery of SR and VHRR recorder stored data. Only one mode can be active at a given time as determined by the last Transmitter ON command received.

The Real Time S-band Transmitter ON command is decoded in the CDU where relays are latched to supply unregulated power to the selected S-band transmitter and to the summing amplifier in the VHRR processor; and -24.5v power to the processor real time circuits which include VCO's and frequency translators. Distribution of power to the appropriate combination of these VCO's and translators is performed within the processor itself in agreement with the VHRR mode.

For the Playback S-band Transmitter ON command, unregulated power is provided to the same units as before, but the selected multiplexer is powered (-24.5V) instead of the processor real time circuits. When this command is received, an S-band enable, in the form of a switched ground, is generated and maintained only as long as the S-band transmitter remains in the playback mode. This enable signal must be present for the operation of any of the spacecraft recorders in playback (see Figure VIII-26).

Power to all associated S-band units, whether used for real time or playback operation, is disabled by the S-band Transmitter OFF command.

Programmer inhibit of VHRR real time transmission will turn off all real time units, if powered in the real time mode, but will not affect playback operation. Subsequent receipt of the Real Time S-band Transmitter ON command will override this inhibit condition.

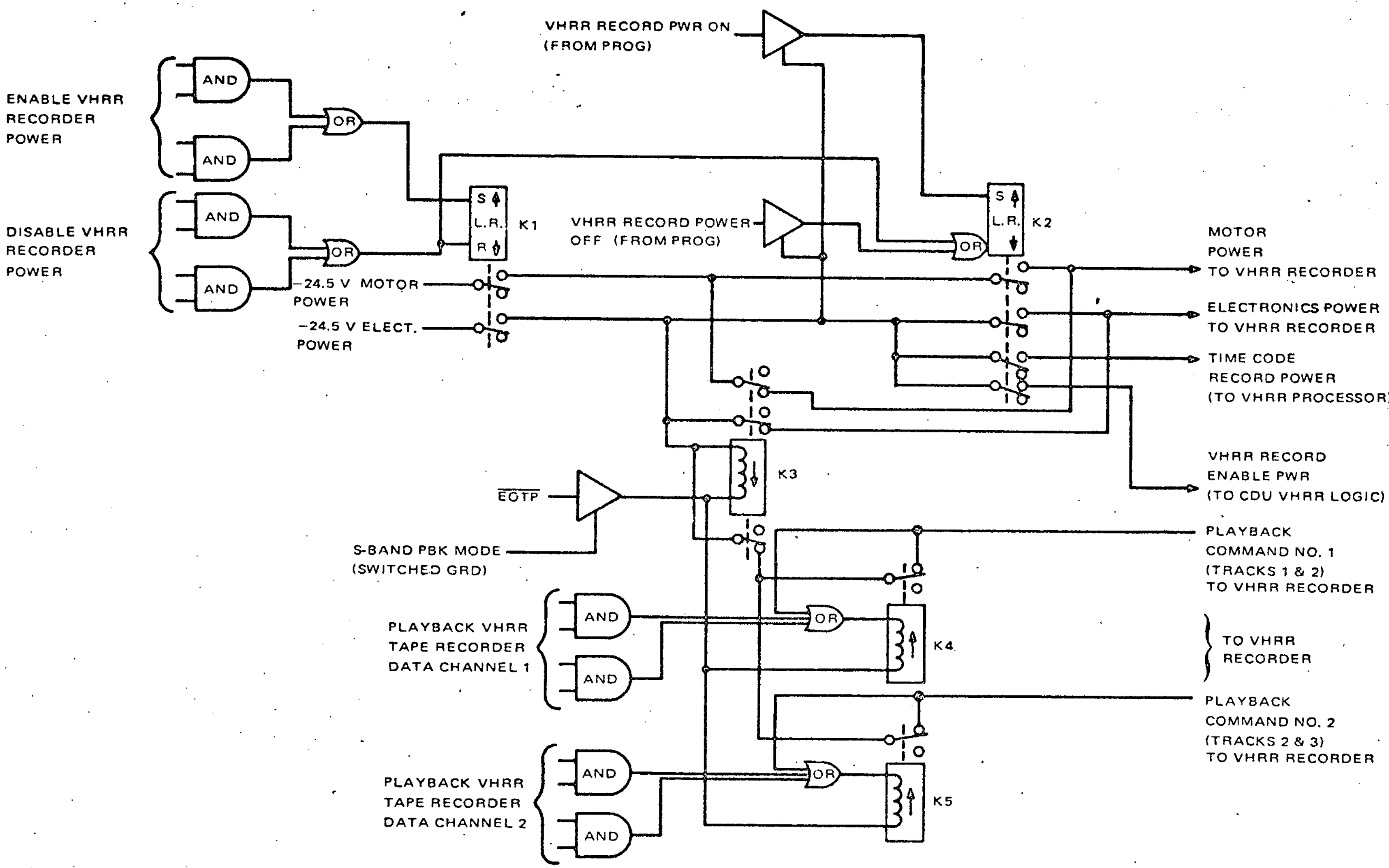


Figure VIII-25. VHRR Recorder Control Logic

The appearance of a push-to-talk signal is recognized only when the transmitter is in the Playback mode. The PTT pulse will then cause the S-band operation to revert to the status present prior to playback, either the real time mode (picking up the RT VHRR inhibit status of the programmer at time of return), or Transmitter OFF.

(13) PITCH CONTROL SUBSYSTEM

- Commands for Pitch Control

  Use Pitch Loop 1, not 2
  Use Pitch Loop 2, not 1
  Pitch Loop Open Loop Mode
  Pitch Loop Closed Loop Mode
  Pitch Sensors Crossed
  Pitch Sensors Normal
  Pitch Loop Gain Coarse
  Pitch Loop Gain Normal
  Enable Dual Motor Mode
  Disable Dual Motor Mode
  Dual Motor Mode ON

These commands are decoded and sent to the pitch control electronics as command pulses. The commands to choose either pitch loop No. 1 or pitch loop No. 2 also result in a command pulse to turn off the dual motor mode.

(14) ATTITUDE CONTROL COILS

- Commands for QOMAC and Magnetic Bias Control

  Enable QOMAC power
  Disable QOMAC power
  Magnetic Bias System Positive
  Magnetic Bias System Negative
  Disable Magnetic Bias System
  Step Magnetic Bias Switch

Magnetic bias and QOMAC operations are controlled by direct commands and by programmer signals (see Figure VIII-27). The magnetic bias coil current is controlled by a stepping switch, advanced by command; however, QOMAC coil current is a fixed value. Magnetic bias polarity is controlled by command but QOMAC polarity and duty cycle are determined by the programmer. Selecting a polarity for the magnetic bias current enables power to be applied to the magnetic bias coil through the stepping switch and enables the switch to be stepped. When the stepping switch is in position 11 (high torque mode), the magnetic bias coil is operated by the same programmer signal as the QOMAC coil. However, power may be enabled or disabled independently to the QOMAC

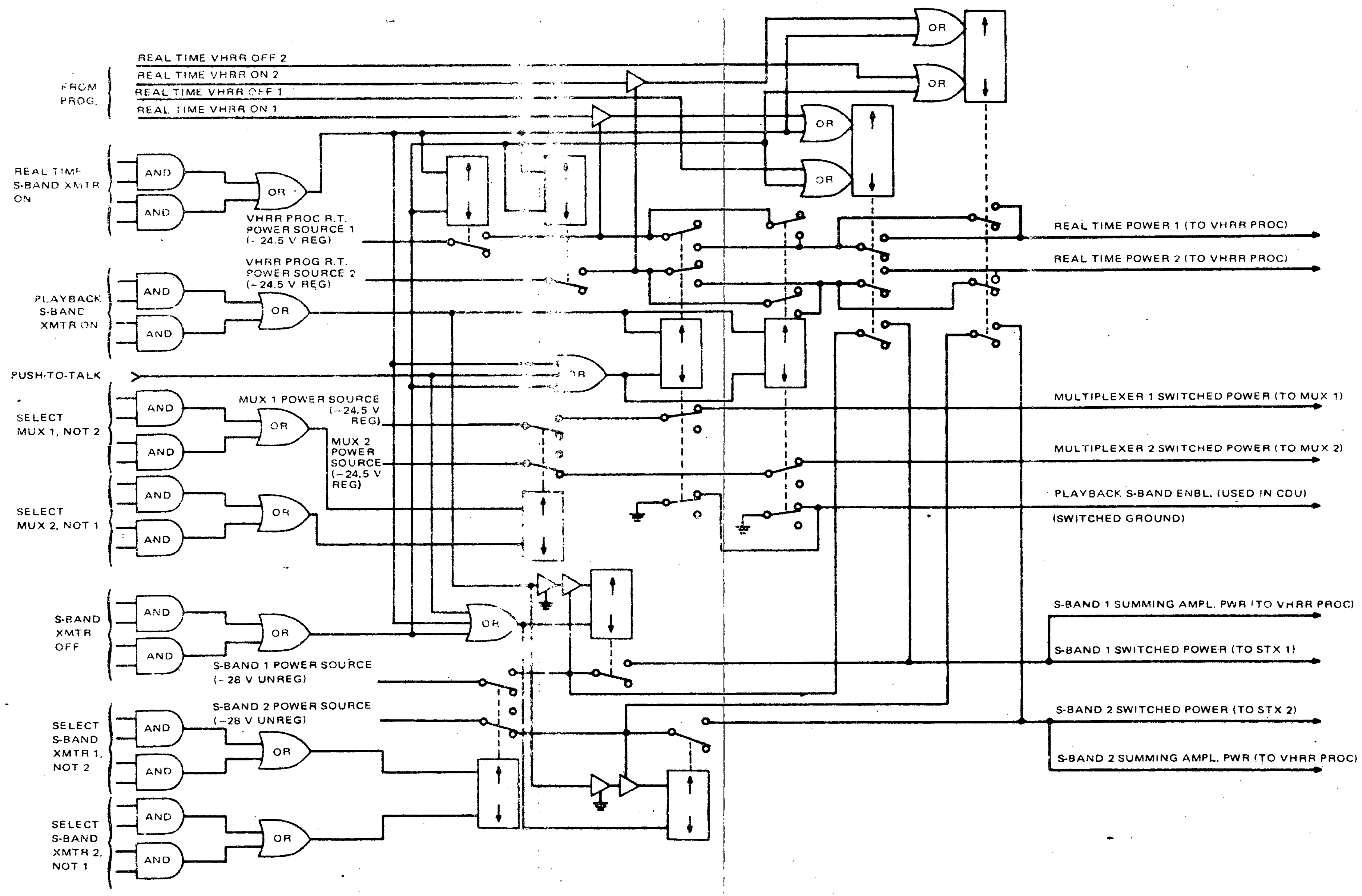


Figure VIII-26. S-band Transmitter Subsystem Control

FOLDOUT FRAME 1

FOLDOUT FRAME 2

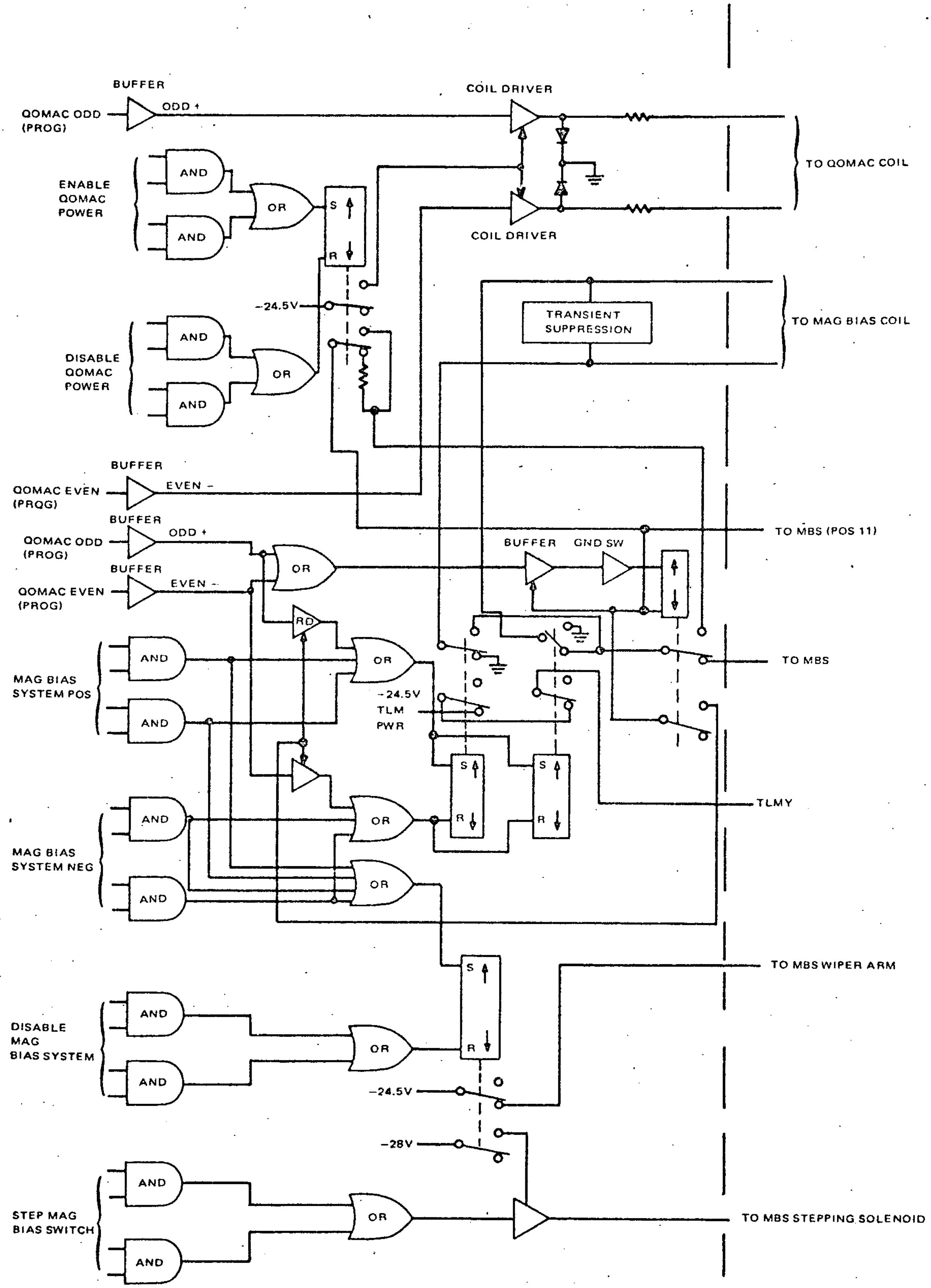


Figure VIII-27. QOMAC and Magnetic Bias Coil Control Logic and magnetic bias coils by the enable or disable QOMAC Power commands, respectively. In the high torque mode, the output of position 11 of the magnetic bias stepping switch is applied directly to the magnetic bias coil when the QOMAC even or QOMAC odd programmer signals are present, unless the QOMAC coil has been disabled. In that case, an 821-ohm resistor is connected in series with the output of position 11 of the stepping switch, and this limited current is applied to the magnetic bias coil. In all other positions of the stepping switch, the output of the switch is applied directly to the magnetic bias coil independent of any QOMAC coil function.

In the high torque mode, a "QOMAC Even" signal from the programmer sets the magnetic bias polarity relays to the negative torque position and a "QOMAC Odd" signal sets them to the positive torque position.

- Commands for Momentum Control

  Momentum Coil 1 ON
  Momentum Coil 2 ON
  Disable Momentum Coil System
  Momentum Coil System Positive
  Momentum Coil System Negative

Power to the momentum coils is switched through enable/disable and polarity relays in the CDU. Either, neither or both coils may be selected for operation at the same time. The momentum coils are controlled by command only and not by programmer signals as are the QOMAC coils. A polarity command operates on both coils so that they will always operate in parallel. A "PTT" signal turns off both coils but does not change the polarity selection (see Figure VIII-28).

(15) SQUIB FIRING

There is a pyrotechnic system on the ITOS D and E spacecraft which controls the deployment of the solar panels. Power to fire all squibs, which is obtained directly from the spacecraft batteries, is inhibited through the separation switch until the separation of the second stage.

- Commands for Solar Panel Squibs, (see Figure VIII-29).

  Deploy Solar Panels

This command from either of the two decoders results in the operation of one of two redundant nonlatching relays for the duration of the command period, connecting squib bus No. 1, if decoder No. 1 is used, or squib bus No. 2, if decoder No. 2 is used, to the solar panel squibs.

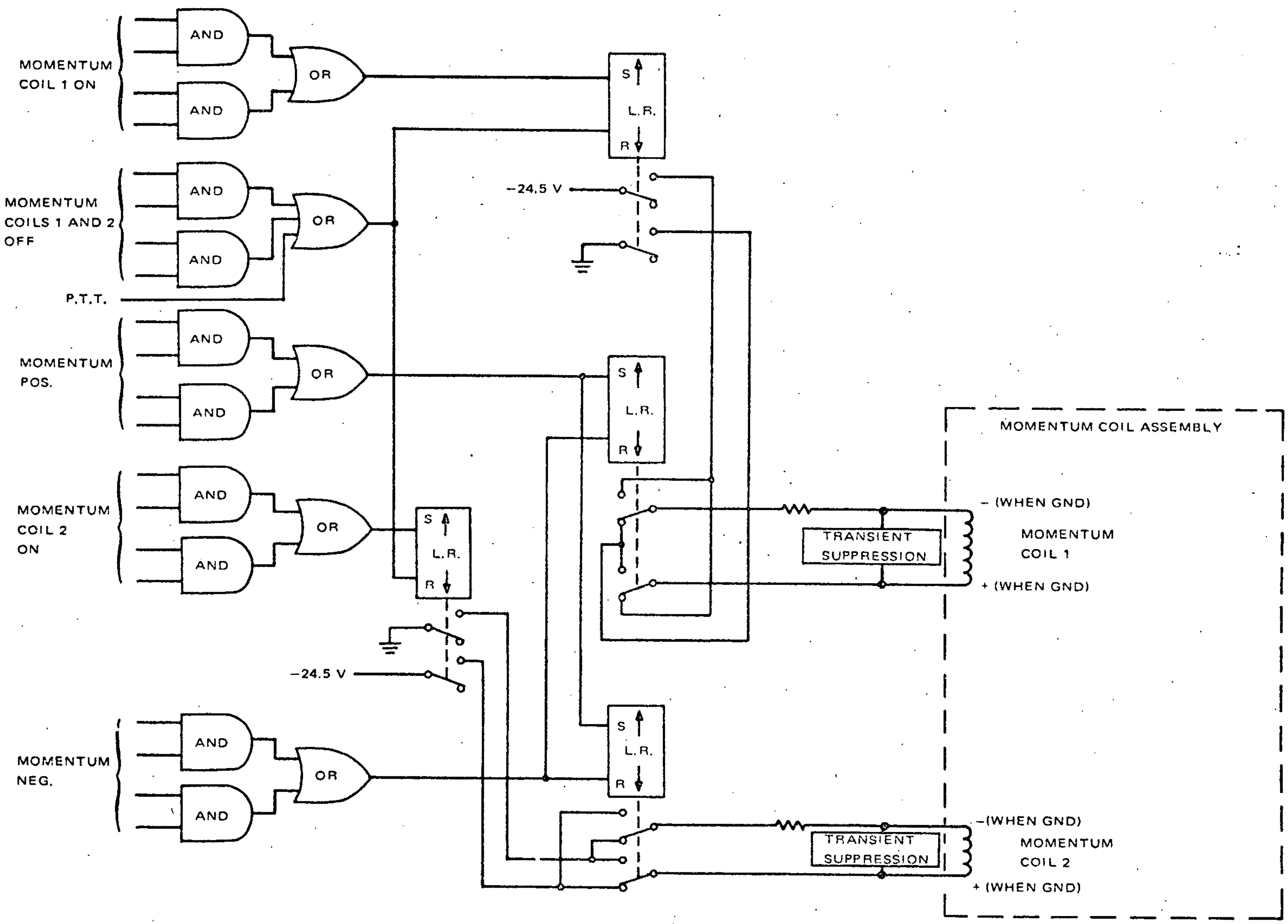


Figure VIII-28. Momentum Coil Control Logic

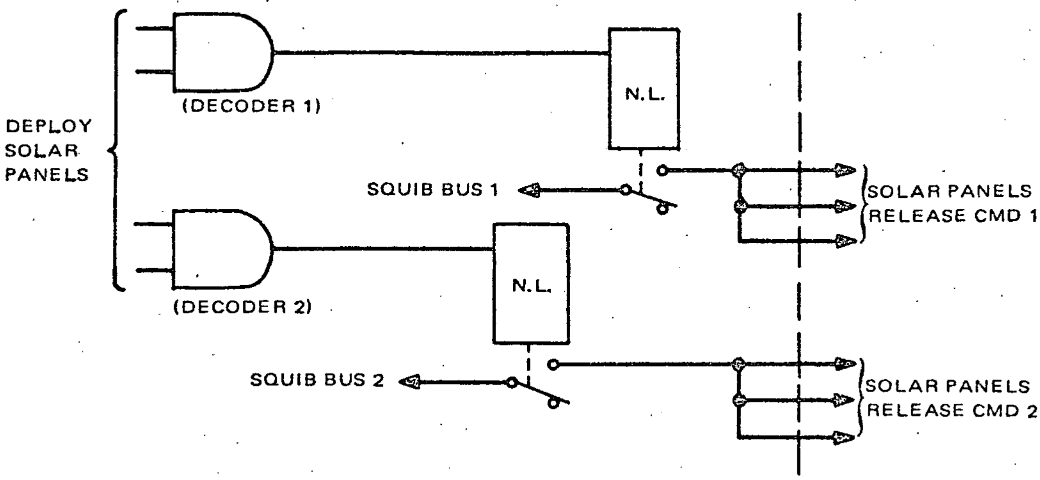


Figure VIII-29. Squib Firing Control Logic

(16) SOLAR PROTON MONITOR

- Commands for the Solar Proton Monitor

  Solar Proton Monitor ON
  Solar Proton Monitor OFF

The SPM ON command causes a relay driving pulse to be sent to the SPM electronics, which results in the application of power to the unit. For the SPM to operate, it must receive a 16-Hz clock from a powered DDP. Outputs are then generated for real time transmission by the beacon transmitter and also for assembly into the digital data message for recording.

Power is removed from the SPM upon receipt of the Solar Proton Monitor OFF command.

(17) BEACON TRANSMITTER

- Commands for Beacon Transmitter Control

  Use Beacon Transmitter 1, Not 2
  Use Beacon Transmitter 2, Not 1
  Use Neither Beacon Transmitter

Power is switched to the beacon transmitter through relays in the CDU. Either or neither beacon may be selected. Each beacon transmitter is modulated by SCO's designated as SCO 1-1 or 2-1 (2300 Hz), and SCO 1-2 or 2-2 (3900 Hz). The first number in the SCO identification denotes the beacon transmitter with which the SCO is associated; the second number indicates its frequency. There is no cross-strapping between SCO's and beacon transmitters. When a beacon transmitter is selected, power is also supplied to both of the associated SCO's and to the corresponding coils of the beacon output switching relays.

(18) *DIGITAL DATA PROCESSOR*

- Commands for DDP Control

  Use Digital Data Processor 1, not 2
  Use Digital Data Processor 2, not 1
  Use Neither Digital Data Processor

  Disable Digital Telemetry Power
  DDP Commutator Random Access Mode
  DDP Commutator Automatic Advance Mode

The Use DDP commands latch relays in the CDU to apply -24.5v regulated power directly to the DDP specified, thereby turning it ON. Only one DDP can be powered at a time. Power is removed from both DDP units upon receipt of the Use Neither DDP command (see Figure VIII-30).

Selecting either DDP also latches on a telemetry power relay in the CDU causing the Housekeeping Telemetry Power bus to become active. This separately fused bus distributes -24.5 Volt regulated power to the majority of status telemetry circuits located in other units throughout the spacecraft, and whose outputs are commutated in the DDP. Deactivation of this bus occurs either when both DDP units are commanded OFF, or by a separate command, Disable Digital Telemetry Power, which allows the DDP to remain ON while conserving the power normally dissipated for telemetry. In this latter condition, the telemetry bus is automatically reactivated whenever required to supply the real time beacon link.

Either one of two telemetry mode commands is decoded in the CDU and directly routed to the powered DDP for execution. When initially powered, the DDP resets to the automatic advance mode whereby its commutator continuously sequences through all telemetry input channels. Subsequently sending the command, DDP Commutator in Random Access Mode causes the commutator to select and dwell on the position specified by the 28-bit address and that follows the real time command, DDP Commutator Automatic Advance Command returns the DDP to its original normal mode.

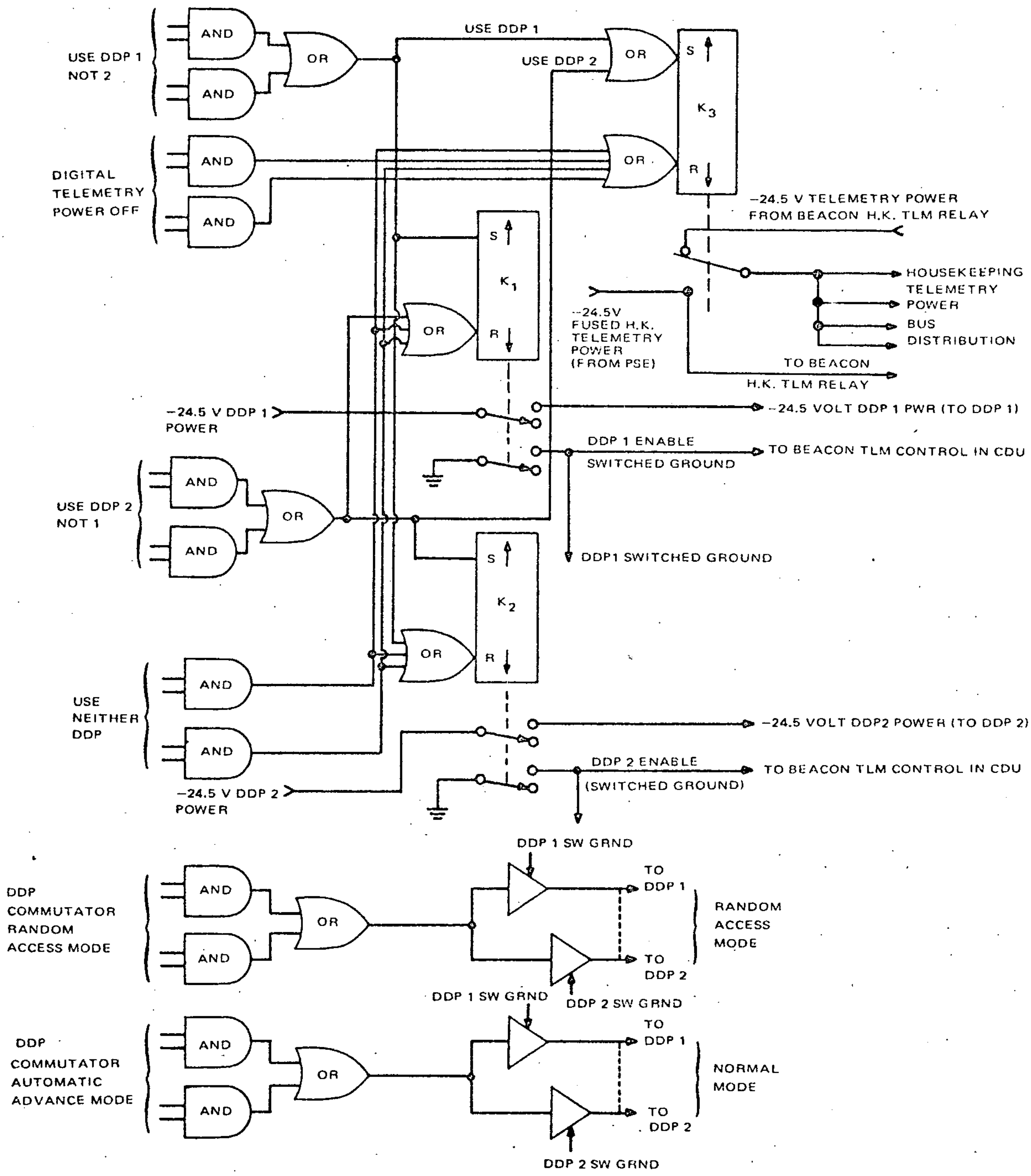


Figure VIII-30. Digital Data Processor Control Logic

(19) BEACON TELEMETRY SUBSYSTEM

- Telemetry Priorities

Relay switching within the CDU determines which of the available telemetry signals will be used to modulate the SCO. In the acquisition telemetry mode, the 3900-Hz SCO's receive either housekeeping data, command verification data or DSAS data; in the operational telemetry mode, SPM real-time data replaces DSAS data. The 2300-Hz SCO's receive either roll sensor data, summed roll sensor and pitch index pulse data, time code data, VTPR analog data, or pitch sensor data in both acquisition and operational modes.

Relay chains establish priorities for each telemetered function and couple the outputs from the appropriate telemetry devices to the modulation input of the Beacon SCO's. These priorities are shown in Table VIII-12.

During launch, prior to separation from the second stage, the modulation inputs to the Beacon 1 SCO's are interrupted external to the CDU (by the ACU), and accelerometer data is inserted in their place.

- Commands for the 3900 Hz Telemetry Subsystem

Beacon Housekeeping Telemetry ON
Beacon Housekeeping Telemetry OFF

Telemetry in Acquisition Mode
Telemetry in Operational Mode

The Beacon Housekeeping Telemetry On command is similar to the TIROS M Commutator 1 or 2 ON command. However, since the commutator in the DDP provides both the analog telemetry frame and end of frame pulses, either one of the two DDP's must be powered at the time of the telemetry request.

As shown in Figure VIII-31, the priority associated with beacon transmitter 1 is controlled by telemetry priority relay 1, and the priority associated with beacon transmitter 2 is controlled by telemetry priority relay 2. When telemetry priority relay 1 is reset, the beacon transmitter 1 SCO is connected to the beacon 1 lower priority telemetry. When the telemetry priority relay 1 is set, DDP 1 telemetry data is switched to the inputs of both beacon transmitter SCO's, so that DDP data will be sent to whichever transmitter is on. Similarly when telemetry priority relay 2 is set, lower priority data is removed from the beacon transmitter which was powered and DDP 2 telemetry data is placed on it. The routing scheme for the priority tree is shown in Figure VIII-32. Telemetry priority relay 1 is a self latching relay and will be "set," provided DDP 1

TABLE VIII-12. TELEMETRY PRIORITIES

	3900-Hz SCO's	
	SCO 1-2	SCO 2-2
Top Priority	Housekeeping Tlmy (DDP #1)	Housekeeping Tlmy (DDP #2)
	Housekeeping Tlmy (DDP #2)	Housekeeping Tlmy (DDP #1)
	Decoder No. 1 (data verification)	Decoder No. 2 (DV)
	Decoder No. 2 (data verification)	Decoder No. 1 (DV)
(Operational Mode)	SPM	SPM
(Acquisition Mode)	DSAS	DSAS
	2300-Hz SCO's	
	SCO 1-1	SCO 2-1
Top Priority	Roll Sensor No. 1	Roll Sensor No. 2
(Same for Operational and Acquisition Modes)	Roll Sensor No. 2	Roll Sensor No. 1
	Time Code	Time Code
	Roll Sensor No. 1 and Pitch Index	Roll Sensor No. 2 and Pitch Index
	Roll Sensor No. 2 and Pitch Index	Roll Sensor No. 1 and Pitch Index
	VTPR Analog Data	VTPR Analog Data
	Pitch Sensor No. 1 or 2*	Pitch Sensor No. 1 or 2*

*When pitch sensor data is selected, all other telemetry is removed from the 2300-Hz SCO's, thus giving pitch data a form of top priority. However, pitch sensor data may subsequently be interrupted on ground command by any of the other data on that priority tree.

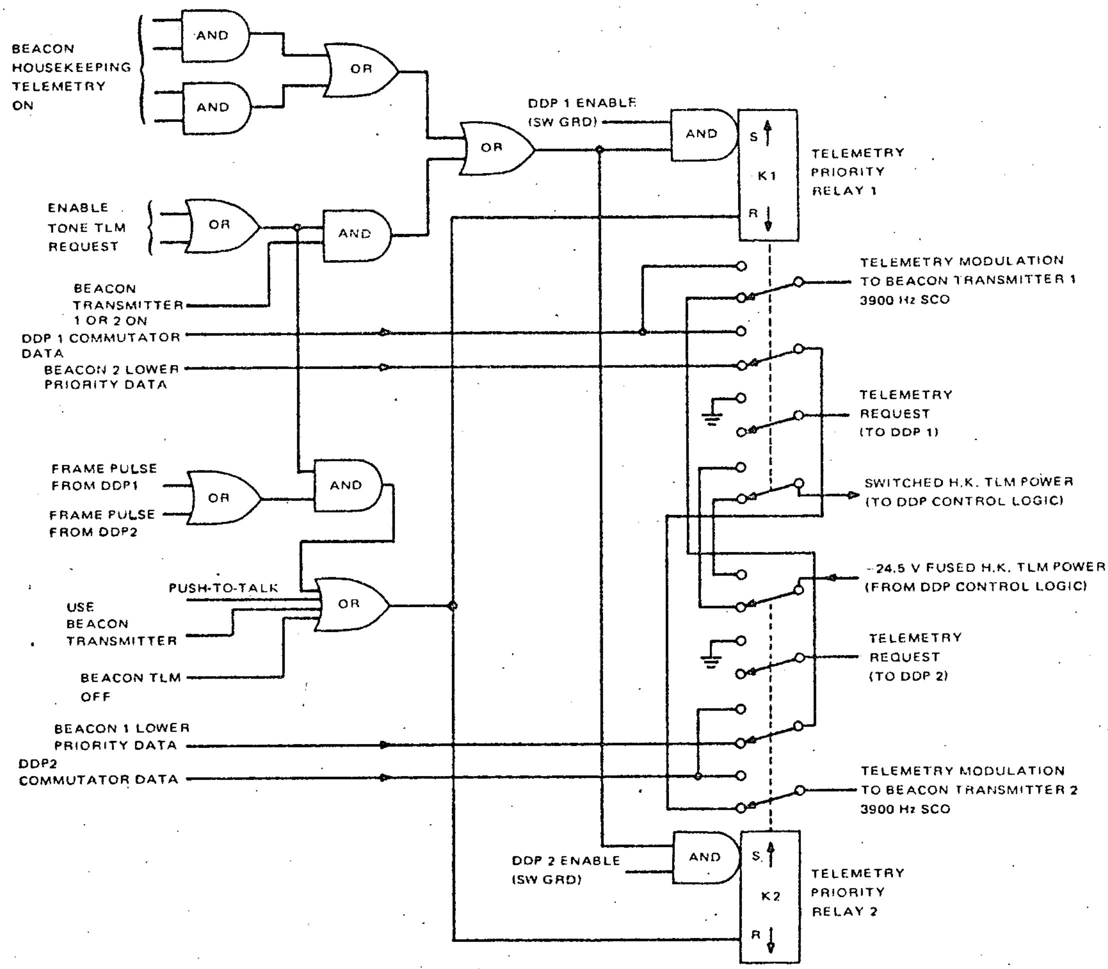


Figure VIII-31. 3900 Hz SCO Beacon Telemetry Control is on, with the Beacon Telemetry ON command, or the reception of either enable tone telemetry request if one of the beacon transmitters is on. Lower priority data is restored on the telemetry trees with the reception of a frame pulse from either DDP, the push-to-talk pulse, the Beacon Telemetry OFF command, or the Use Neither Beacon Transmitter command.

When either of the two telemetry priority relays is operated by a Beacon Telemetry ON command, the beacon housekeeping telemetry power bus is enabled and a telemetry request indication is sent to the associated DDP. The powered DDP supplies telemetry data to the priority tree in either the random access mode, or the automatic advance mode, depending on the mode set up by prior command. If it had been in the automatic advance mode, the second frame pulse after receipt of the request is sent to the CDU to reset the telemetry priority tree relays. This assures that at least one full frame is received at the ground. If the selected DDP had been in the random access mode, the DDP continues to transmit telemetry data from a single telemetry point, and the tree priority is maintained until the telemetry request is reset by either a PTT signal, a Beacon Telemetry Off command, or a Use Neither Beacon Transmitter command. The beacon housekeeping telemetry power bus is disabled whenever both priority relays are reset.

Command data verification is transmitted on the 3900 Hz SCO. A data verification signal may be received from a decoder, a programmer, or a digital data processor. When present, it causes the data bit stream, as received from the decoder, to be switched on to the telemetry tree according to its priority.

In the acquisition telemetry mode, power is switched to the DSAS. In the operational telemetry mode, this sensor is not powered.

- Commands for 2300-Hz Telemetry Subsystem

  Telemeter Pitch Sensor 1
  Telemeter Pitch Sensor 2
  Telemeter VTPR Analog Data
  Telemeter Roll Sensor 1 and Selected Pitch Index
  Telemeter Roll Sensor 2 and Selected Pitch Index
  Telemeter Time Code
  Telemeter Roll Sensor 1
  Telemeter Roll Sensor 2

These commands are used to switch telemetry to the SCO's in accordance with the priority flow given in Figure VIII-33. A passive summing network in the CDU adds the roll sensor inputs to the selected pitch index pulse input.

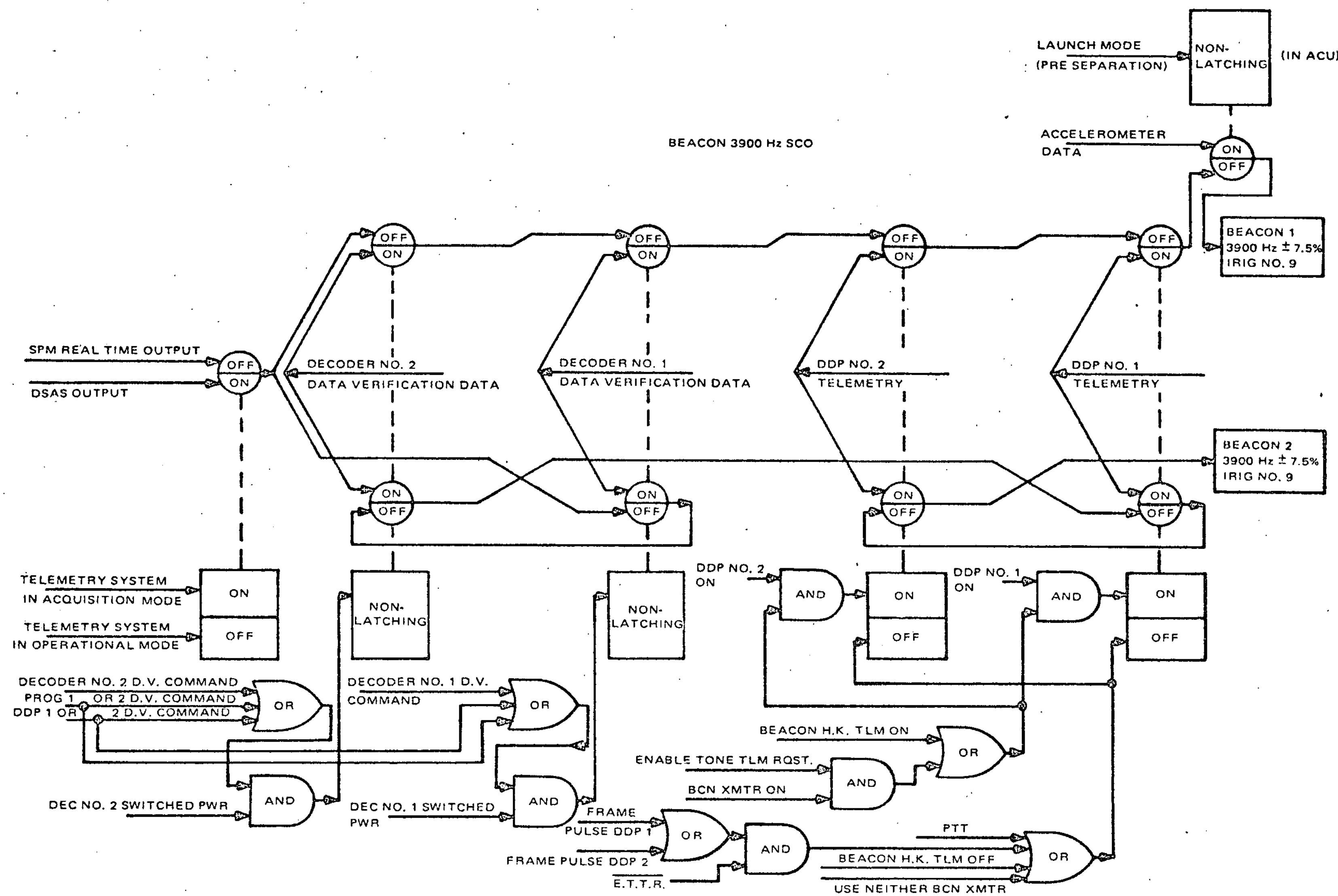


Figure VIII-32. Beacon 3900 Hz SCO Telemetry Operation

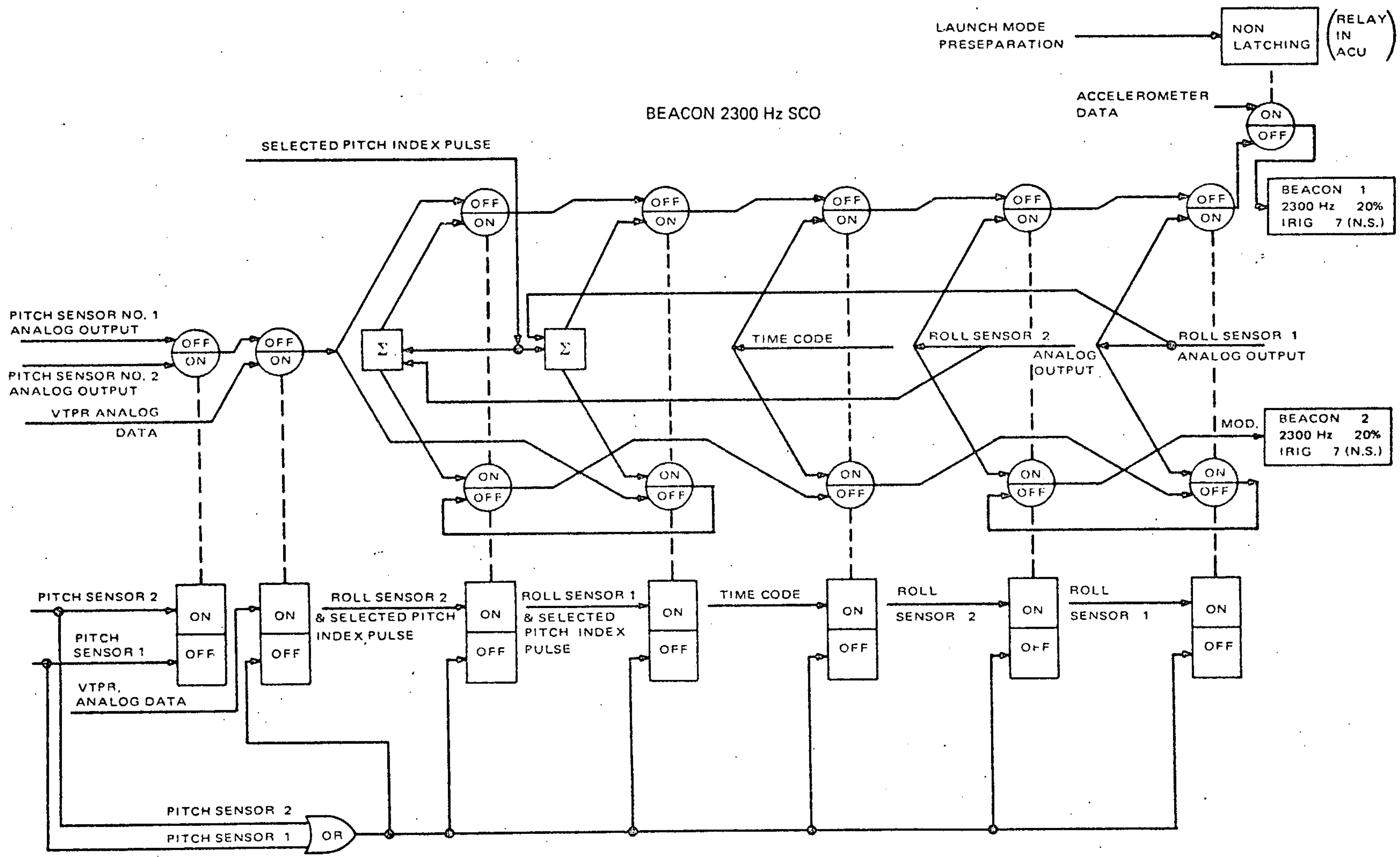


Figure VIII-33. Beacon 2300 Hz SCO Telemetry Operations

d. SPECIAL OPERATIONAL CONTROL FEATURES

The CDU performs various functions automatically, or in response to input signals other than commands. The following is a list of these functions and operations:

(1) PTT OPERATION

Whenever the -23 volt power from a decoder is unlatched from the CDU the PTT circuit generates a pulse which is used internally to terminate various functions and which is also sent as a command pulse to other subsystems. When a PTT pulse is generated, the following actions occur:

- VHRR and SR tape recorder playbacks are terminated.
- S-band transmitter is switched from the playback mode to either real time operation or to its OFF state.
- Momentum coils are turned off.
- Housekeeping telemetry commutators in the DDP are removed from the beacon transmitter SCO's but power is not removed from the housekeeping telemetry

(2) ENABLE TONE TELEMETRY REQUEST

When the FSK enable tone is maintained for approximately 12 seconds, the decoder sends a signal to CDU A to select housekeeping telemetry for transmission over the beacon link.

A DDP must be on at the time of request or no commutator output is available. The Enable Tone Telemetry Request will activate the automatic advance mode in the powered DDP and also apply power to the housekeeping telemetry bus. Either decoder will work with any combination of selected DDP and beacon transmitter for performing these functions.

One or more consecutive telemetry frames will read out, continuing until the tone is dropped, after which the frame in process is completed. The DDP then returns to its original telemetry mode prior to the Enable Tone request, resetting on the preselected commutator channel if it had been in random access mode.

SECTION IX

COMMUNICATIONS

A. INTRODUCTION

The communications subsystem provides five separate rf links for handling the communications traffic between the ITOS spacecraft and the ground stations. These five links are:

1. Command link for transmitting command messages from the CDA stations to the spacecraft.
2. Beacon telemetry link for transmitting tracking signals, real-time telemetry data, attitude data, analog vertical temperature profile radiometer (VTPR) data, real-time solar proton monitor (SPM) data, and command verification from the spacecraft to the CDA stations.
3. VHF real-time video link for transmitting scanning radiometer (SR) data from the spacecraft to worldwide local APT stations.
4. S-band real-time video link for transmitting very high resolution radiometer (VHRR) data to local stations.
5. S-Band playback video link for transmitting recorded SR data, VHRR data, VTPR data, SPM data and digital houskeeping telemetry to the CDA stations.

The total requirements and the essential characteristics of the five communications links are summarized in Table IX-1. The communications subsystem is designed to permit operation of the first four links concurrently and to be compatible with the CDA and APT ground stations. Operation of the Playback video link inhibits S-band real-time transmission of VHRR data. In this section, the five communications links are treated separately. For each link there is a discussion of bandwidth and modulation requirements. Appendix C contains analyses of all communication links.

B. COMMAND LINK

1. General Description

The command link for the ITOS D and E spacecraft is identical to that of TIROS-M/ITOS-1. A simplified block diagram of the command link is shown in Figure IX-1. A common single element antenna is used for command reception and beacon transmission. The command signal transmitted from the CDA stations is a circularly polarized electromagnetic wave. The spacecraft command

TABLE IX-1. SUMMARY OF ITOS D AND E COMMUNICATIONS LINKS

	Link	Carrier Frequency	Information Signal	Baseband Bandwidth	Modulation	Subcarrier Frequency	RF Spectrum Bandwidth*
1.	Command	148.56 MHz	Enable Tone	CW	CW/AM	F_1	22.6 kHz
			Digital Commands	10 bits/sec	FSK/AM	F_2	
2.	Beacon	136.77 MHz	Housekeeping Telemetry, Command Verification DSAS and SPM Data	59 Hz	FM/PM	3.9 kHz	8.5 kHz
			Attitude Data, Time Code and Analog VTPR Data	160 Hz	FM/PM	2.3 kHz	
3.	VHF Real-Time	137.50 MHz**	Scanning Radiometer Video Data	900 Hz Visible 450 Hz IR	AM/FM	2.4 kHz	27.2 kHz
4.	S-band Real-Time	1697.5 MHz	Very High Resolution Radiometer Data	35 kHz	FM/FM	80 kHz and 230 kHz***	1.0 MHz
5.	S-band Playback	1697.5 MHz	Recorded VHRR Data	35 kHz	FM/FM	88 kHz	2.9 MHz
			Recorded SR Data	18.75 kHz, Visible 9.38 kHz, IR	FM/FM	212 kHz and 388 kHz	
			Recorded Digital VTPR, SPM and Housekeeping Telemetry Data	10.67 kbits/sec	DSBSC/FM and VSB/FM	300.00 kHz and 460.67 kHz	
			Flutter Correction	500 Hz	FM/FM	12.5 kHz, 25 kHz and 500 kHz	
			Pilot Tones	CW	CW/FM	300 kHz and 450 kHz	

* Information bandwidth only.
** or 137.62 MHz alternate frequency.
*** Backup mode only.

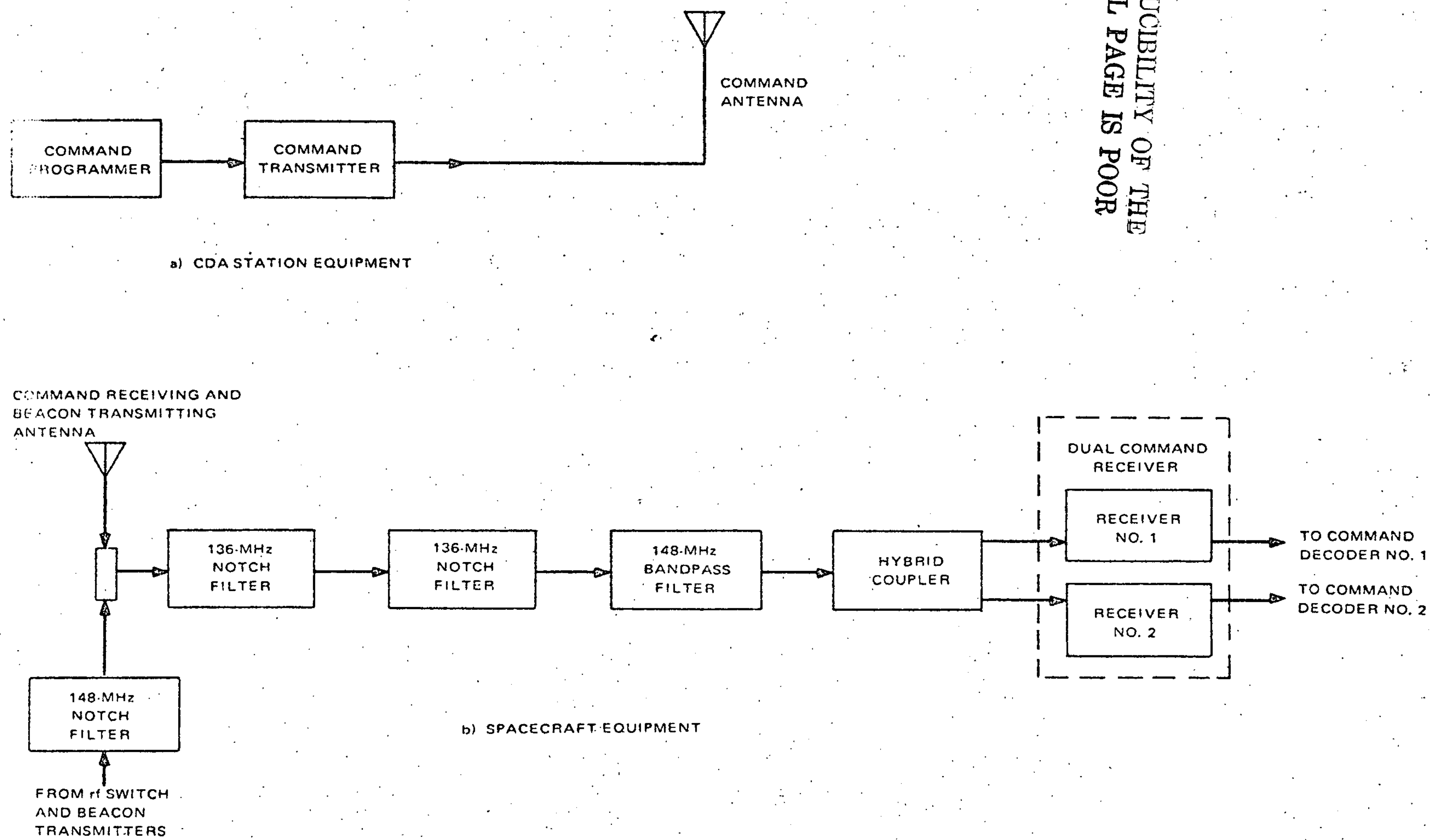


Figure IX-1. Command Link

and beacon antenna is linearly polarized. The fact that the antenna is linearly polarized while the transmitted electromagnetic wave is circularly polarized introduces a 3-dB polarization loss. Commands are transmitted to the spacecraft from the CDA ground stations as amplitude modulations of a 148-MHz carrier wave, and are received via the command and beacon antenna, the 136-MHz notch filters, the 148-MHz bandpass filter, the hybrid coupler, and the command receivers. The commands are in the form of two tone pairs, consisting of an enable tone and a frequency-shift keyed (FSK) subcarrier, both of which amplitude-modulate the 148-MHz rf carrier. Each pair of command tones is associated with one of the two sections of the dual spacecraft decoder. Command receiver channel No. 1 is connected to decoder channel No. 1, while channel No. 2 is connected to decoder channel No. 2. The outputs of the receiver channels are identical and consist of either the enable tone or the FSK subcarrier.

2. Signal Characteristics

The requirements of the rf command system are identical to those of the present TIROS-M/ITOS-1 system. The first signal of the command tone pair is an unmodulated sinusoidal enable tone. The second tone is FSK modulated with the 10-bits-per-second, return-to-zero, bipolar command data. Each tone amplitude-modulates the 148-MHz carrier with a modulation index of 90 percent. Two unique pairs of tones are used, one pair to address each of the redundant decoder channels. The frequencies of the tones are identical to those of TIROS-M/ITOS-1 and are specified in supplement 1 to the TIROS-M Programming and Control Handbook.* Each command decoder is tuned to accept only a given enable tone and a given FSK subcarrier. The 3-dB bandwidths of the decoder input filters are ± 7.5 percent of the center frequency for the enable tones, and ± 7.5 percent of the center frequency for the FSK subcarriers. The FSK subcarriers are modulated by a bipolar, return-to-zero waveform at a rate of 10 bits per second. A data "1" is represented by an upward +7.5 percent frequency shift of the FSK subcarrier. A data "0" is represented by a downward -7.5 percent frequency shift of the FSK subcarrier. A rest period, during which the center frequency is transmitted, always follows a "1" or a "0". The bit information is extracted by filtering the FSK subcarrier, using narrow bandpass filters centered at the maximum and the minimum subcarrier frequency shifts to separate the binary "1's" and "0's". The bandwidths of the filters are ± 2 percent of their center frequencies. The outputs of these filters are then envelope-detected. The detected command data is presented to the digital portion of the decoder, where the spacecraft address and the digital command are decoded. The remaining command decoding is performed in the command distribution unit.

*AED R-3365 F Supplement 1, RCA, Princeton, N. J., April 1970.

3. Antenna Subsystem

As in TIROS-M/ITOS-1, a single dipole serves as both the transmitting antenna for the beacon and telemetry signals and as the receiving antenna for the command receiver. In addition to the antenna, the command antenna group comprises a 148-MHz bandpass filter, two 136-MHz notch filters, matching stub lines, a hybrid coupler, a 148-MHz notch filter, and interconnecting cables. All these components are identical to those flown in TIROS-M/ITOS-1.

The dipole radiates a linearly polarized dipole pattern at the beacon frequency and receives a similar pattern at the command frequency. The 136-MHz notch filters isolate the command receiver from the real-time transmitters. The 148-MHz bandpass filter provides additional selectivity for receiving the command carrier frequency and rejecting the carrier frequencies of the spacecraft's transmitters. The hybrid coupler matches the antenna to each command receiver, divides the power equally to each, and also isolates the receivers from each other.

The 148-MHz notch filter on the beacon transmitter feed line suppresses any spurious signal from the beacon transmitters at the command frequency and isolates the beacon circuit from the command circuit. The interconnecting cables and connectors have been selected to provide the diplexing function and to provide a proper match between components.

The radiating element consists of a shaft and housing assembly, identical to that used in TIROS-M/ITOS-1, and mounted in the same position as on TIROS-M/ITOS-1.

4. Dual Command Receiver

The dual command receiver is the same as used on the TIROS-M/ITOS-1 spacecraft. Two identical command receivers in the same assembly are used for redundancy. The receiver is a solid-state unit which is fixed-tuned to the command frequency. The command receiver specifications are listed in Table IX-2.

A block diagram of one command receiver is shown in Figure IX-2. As shown on this diagram each channel is a complete single-conversion, crystal-controlled superheterodyne receiver. The incoming rf signal, on a 148.56-MHz carrier, is amplified and mixed with the output of a 128.56-MHz local oscillator to produce an intermediate frequency (if.) of 20 MHz. This if. signal is amplified and applied to a crystal bandpass filter that provides a high degree of selectivity.

TABLE IX-2. COMMAND RECEIVER SPECIFICATIONS

Characteristic	Value
Noise Figure	10 dB max
If. Band pass Characteristics	
Center Frequency	20.000 ±0.003 MHz
-6 dB Bandwidth	48 kHz (min)
-20 dB Bandwidth	60 kHz (max)
-70 dB Bandwidth	110 kHz (max)
Midband Response Variation	Less than ± 1 dB over a 40 kHz band (nominal) centered at 20.00 ± 0.003 MHz
Sensitivity	0.77 volt rms audio output for 1 microvolt input modulated 90% with a 5.4 kHz signal
Agc Control Range	
Input (rf)	2 microvolts to 10 millivolts (-101 to -27 dBm)
Output (audio)	0.9 to 1.6 volts rms
Noise Output with no input signal	<350 millivolts rms in 1 to 12 kHz band
Rf Input Source Impedance	50 ohms
Audio Output Load Impedance	5.6 kilohms ± 10 percent
Spurious Responses and Image Rejection	At least 45 dB down from 148 MHz; 50 dB minimum in 136-138 MHz band and at image frequency.
Audio Frequency Response (+1.5, -1.0 dB)	1.5 to 11.5 kHz referred to 5.4 kHz (0 dB)
Operating Temperature	-15 to +60°C
Power Supply	
Voltage	-23 volts dc ± 3 percent
Power Consumption	0.4 watt (max, each receiver)
Weight	2.5 pounds
Size (both receivers in one integral unit)	6.5 by 5.9 by 2.9 inches

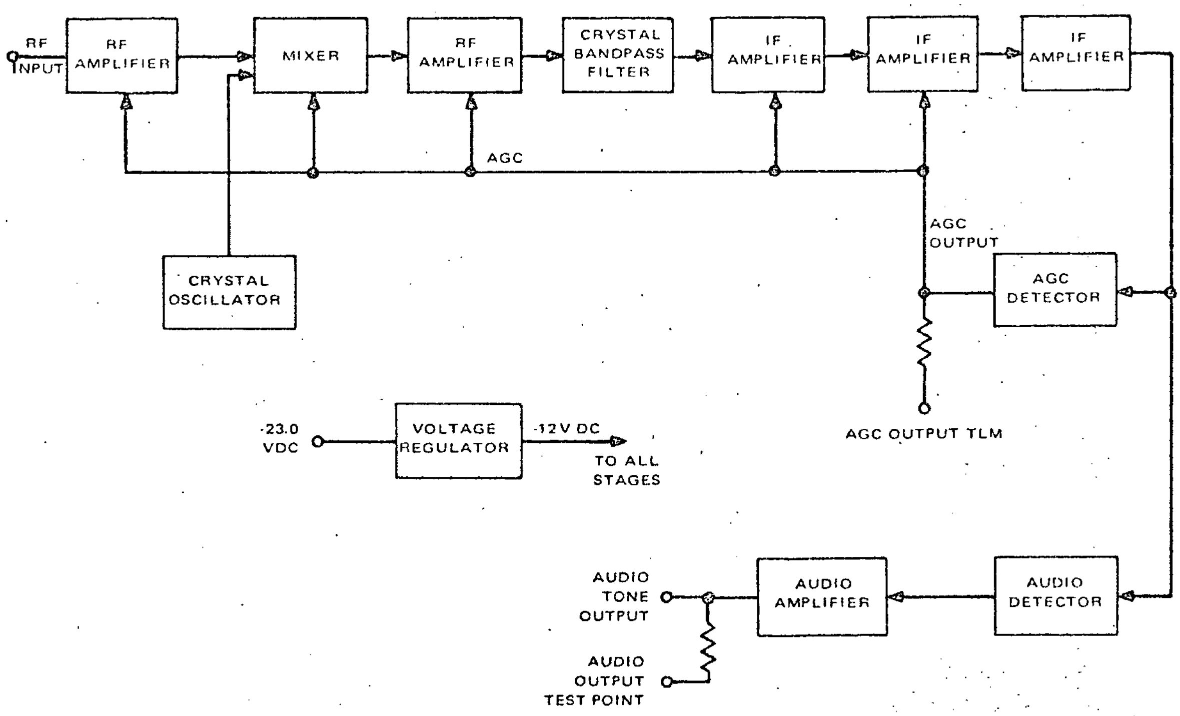


Figure IX-2. Command Receiver Block Diagram

After three more stages of if. amplification, the signal is applied to an agc detector and an audio tone detector. Agc is applied to the rf amplifier stage and mixer as well as the first three if. stages. The audio output is amplified and applied to the associated command decoder.

5. Subsystem Analysis

A complete treatment of the Command Subsystem Link Analysis is given in Appendix C. The results of that analysis are summarized below:

Rf Margin Above agc Threshold:

Panels Stowed, Unstabilized	=	+3.0 dB
Panels Deployed, Unstablized	=	+3.0 dB
Panels Deployed, Stabilized	=	+10.0 dB

Required Receiver Bandwidth (Worst Case) (+10°C to +30°C) = 40.0 kHz

Command Receiver if. Bandwidth at -6 dB = 48 kHz (min)

Demodulated Signal-to-Noise Ratio > 24.1 dB rms/rms

C. BEACON AND TELEMETRY LINK

1. General Description

The beacon and telemetry link of the ITOS D and E spacecraft is similar to that of TIROS-M/ITOS-1. It provides for the continuous transmission of the beacon signal and the telemetering and transmission of spacecraft operating parameters to the CDA stations. The telemetered operating parameters are housekeeping telemetry, attitude (roll and pitch data), Digital Solar Aspect Sensor (DSAS) data, accelerometer data, and command verification data. In addition, SPM data, and analog VTPR data can also be transmitted over this link. The data is used primarily for "quick look" analysis of the performance and status of the spacecraft; it is also used for troubleshooting operations. See Figure IX-3.

The beacon and telemetry subsystem is redundant, utilizing two subcarrier oscillators (SCO's) for each of two beacon transmitters. A single nonredundant antenna is shared with the command receiving link.

One SCO in each redundant set is a 3.9-kHz standard IRIG channel (± 7.5-percent deviation IRIG channel No. 9) and the other is a 2.3-kHz nonstandard IRIG channel (± 20-percent deviation). One beacon transmitter and its associated set of SCO's are in operation at a time; the selection is made by ground command.

The telemetry system has three modes of operation: launch, acquisition, and mission.

The launch mode data is only available over set No. 1 of the beacon system and terminates upon separation of the spacecraft from the launch vehicle. It provides a communication link for accelerometer data during the actual launch.

The acquisition and operational mode data is available over either beacon system. The same operating parameters may be telemetered in either mode, except that DSAS data is only available in the acquisition mode and SPM data is only available in the operational mode.

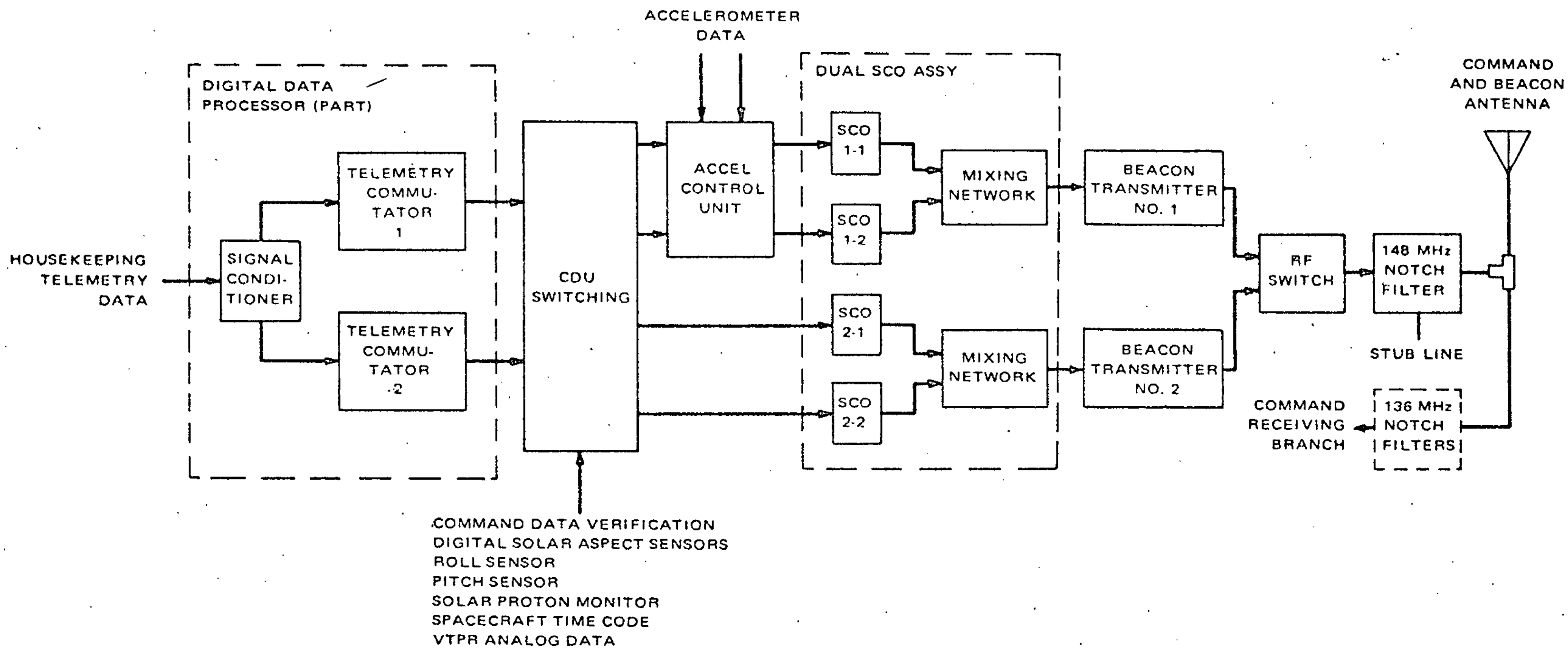


Figure IX-3. Beacon and Telemetry Link Block Diagram

a. 3.9-kHz CHANNEL

The 3.9-kHz SCO channel of the beacon and telemetry subsystem is allocated for the transmission of the types of telemetry data listed in Table IX-3. This listing indicates the types of telemetry available in the three telemetry modes and also indicates a chain of priority for the specific types of telemetry for the "Acquisition" and "Operational" modes. Priorities are established for each mode by relays in CDU A that supply power to the telemetry devices and couple the outputs of the telemetry devices to the modulation input of the SCO. For example, if housekeeping telemetry is requested in either the "Acquisition" or "Operational" mode, it will be transmitted in preference to data verification telemetry, even though a spacecraft decoder may be supplying data verification modulation for the SCO during the housekeeping telemetry frame time.

Only beacon No. 1 is normally operated during the launch mode, which terminates at spacecraft separation, and during this period the 3.9-kHz channel of beacon No. 1 is modulated by lateral axis accelerometer data only. Thereafter, the detailed priority for the 3.9-kHz SCO of beacon No. 1 is as follows:

- Housekeeping telemetry,
- Data verification from decoder No. 1,
- Data verification from decoder No. 2, and
- DSAS data in "Acquisition" mode, or SPM data in "Operational" mode.

TABLE IX-3. TYPES OF TELEMETRY ALLOCATED TO 3.9-kHz SCO

Beacon No. 1 Only	Either Beacon	
Launch Mode (Prior to Separation)	Acquisition Mode	Operational Mode
Lateral axis accelerometer data	Housekeeping telemetry Data verification telemetry DSAS data	Housekeeping telemetry Data verification telemetry Real-time SPM data

For the 3.9-kHz channel of beacon No. 2 (which is not normally operated during the launch mode), the detailed priority is as follows:

- Housekeeping telemetry,
- Data verification from decoder No. 2,
- Data verification from decoder No. 1, and
- DSAS data in "Acquisition" mode, or SPM data in "Operational" mode.

In the "Operational" mode, if data verification and housekeeping telemetry are not present, the 3.9-kHz SCO will be modulated with the real-time output of the SPM. If this device is in the OFF state, the SCO will be clamped to a 0-volt modulation level, equivalent to a data "1" level.

b. 2.3-kHz CHANNEL

The 2.3-kHz SCO channel of the beacons is allocated to the transmission of the types of telemetry data listed in Table IX-4.

TABLE IX-4. TYPES OF TELEMETRY ALLOCATED TO 2.3-kHz SCO

Beacon No. 1 Only	Either Beacon	
Launch Mode (Prior to Separation)	Acquisition Mode	Operational Mode
Thrust or lateral axis accelerometer data	Roll sensor data Time code data Roll sensor and selected pitch sensor index pulse data VTPR analog data Pitch sensor data	Roll sensor data Time code data Roll sensor and selected pitch sensor index pulse data VTPR analog data Pitch sensor data

The detailed priority for the 2.3-kHz SCO of beacon No. 1, in the "Acquisition" and "Operational" modes, is as follows:

- Roll sensor No. 1 data,
- Roll sensor No. 2 data,
- Time code data,
- Roll sensor No. 1 data and selected pitch index pulse,
- Roll sensor No. 2 data and selected pitch index pulse,
- VTPR analog data,
- Pitch sensor No. 1 data, and
- Pitch sensor No. 2 data.

For the 2.3-kHz SCO of beacon No. 2 (which is not normally operated in the launch mode), the priority is:

- Roll sensor No. 2 data,
- Roll sensor No. 1 data,
- Time code data,
- Roll sensor No. 2 data and selected pitch index pulse,
- Roll sensor No. 1 data and selected pitch index pulse,
- VTPR analog data,
- Pitch sensor No. 1 data, and
- Pitch sensor No. 2 data.

2. Signal Characteristics

a. HOUSEKEEPING TELEMETRY

The Digital Data Processor (DDP) continuously samples 172 channels at a rate of 16 channels per second. The beacon housekeeping telemetry signal is obtained from the output of the commutator prior to the a/d converter in the DDP. The channel assignments and format of the signal are described in detail in the Data Handling section of this report.

The commutator can be stopped at any desired point for continuous examination of data. Housekeeping telemetry may be requested by a standard digital command or by the transmission of a longer-than-normal enable tone. This added command capability is provided to permit the commanding of housekeeping telemetry from a facility that does not possess the equipment required to generate the normal digital commands. However, if the beacons or the DDP have been turned off, this emergency housekeeping telemetry command has no facility to turn a beacon or a DDP back on. The housekeeping telemetry data modulates the 3.9-kHz subcarrier on command.

b. COMMAND DATA VERIFICATION

If housekeeping telemetry is not requested, command data verification from a command decoder will be transmitted over the 3.9-kHz subcarrier when the associated data verification relay in the CDU is energized.

On beacon No. 1, decoder channel No. 1 data verification overrides decoder channel No. 2 data verification. On beacon system No. 2, the relative priorities of decoder channel No. 1 and decoder channel No. 2 data verification are reversed. The reason for interchanging priorities is to assure data verification from the selected decoder channel even if the other decoder generates an erroneous signal and energizes its data verification relay.

Each data verification relay is a nonlatching device that is energized by the associated decoder channel when the command word sync pulse is detected and remains energized for the duration of the command word. In addition, the data verification relay is energized by the spacecraft programmer when any of the "Load Programmer" commands is received. In this case, the verification relay remains energized until the programmer indicates that it has received a full complement of bits. Hence, should there be any spurious bits received, the register loads too quickly and the data verification relay is deenergized prematurely. Conversely, if a bit is lost or not transmitted, the programmer fails to deenergize the data verification relay, thereby indicating that erroneous data is stored in the programmer register.

The data verification relay is also energized by the digital data processor when the "Telemetry Random Access" command is received. As in the case of the programmer, the relay remains energized until the DDP indicates that it has received a full complement of bits, (9 bits for this case).

The transmitted verification signal is a 10-bit-per-second, return-to-bias (RB) digital data stream. The format and content are identical to the transmitted command data stream, except for the command termination bit (13th bit) of each direct command word. When a direct command word is accepted by the spacecraft as a valid command, the 13th bit is transmitted as a data "0". If the command word is not accepted by the decoder as a valid command, the 13th bit is returned in the same polarity as it was transmitted (see Figures IX-4 and IX-5).

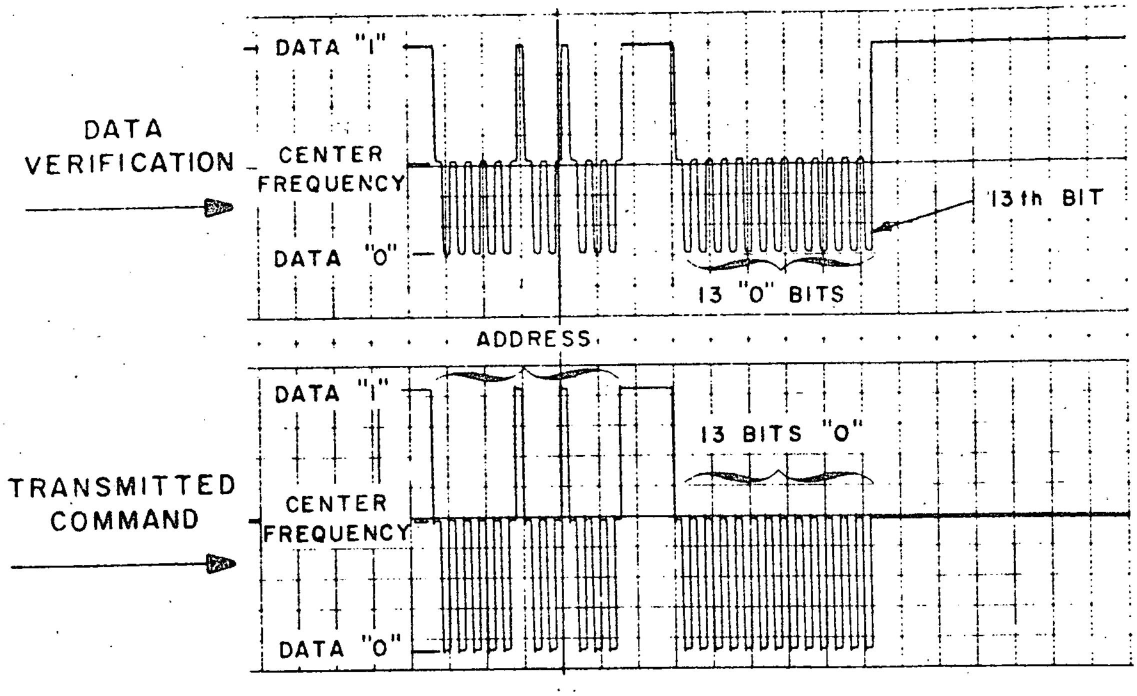


Figure IX-4. Data Verification of a Valid Command

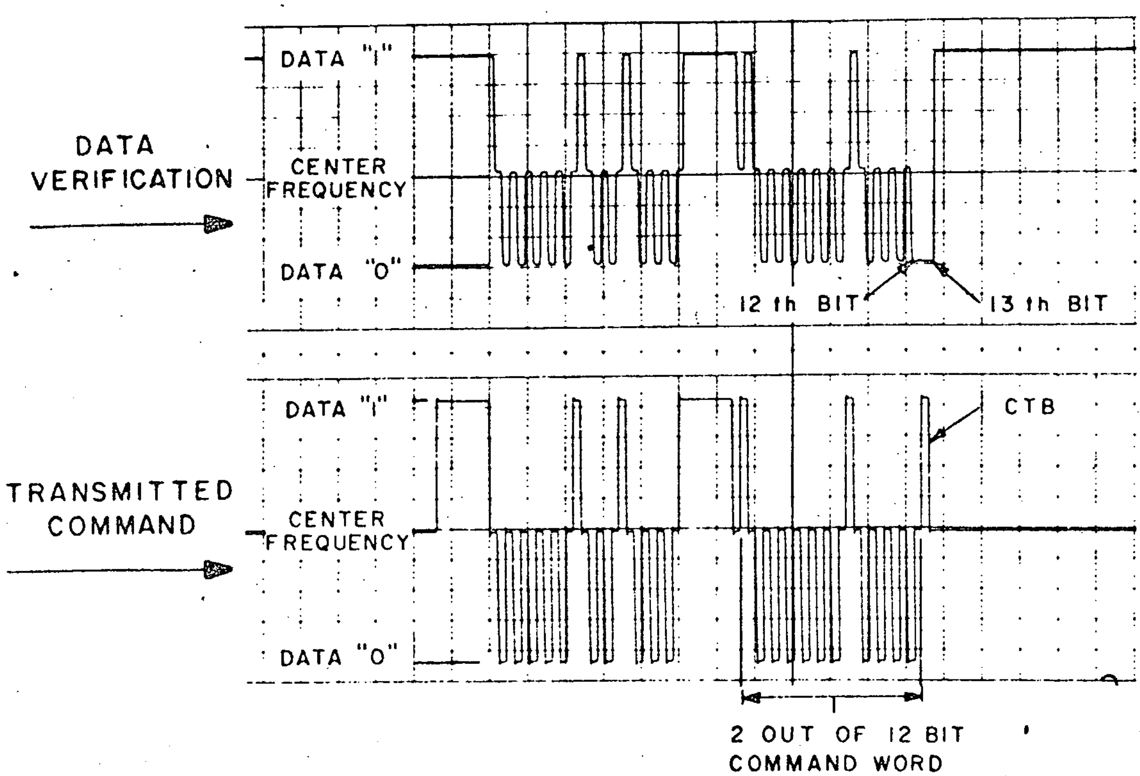


Figure IX-5. Data Verification Response to an Invalid Command

c. SOLAR PROTON MONITOR

The real-time transmission of SPM data over the beacon and telemetry link is a backup for the primary mode of transmission over the S-band playback link. In the real-time mode, the modulating signal is derived directly from the SPM electronics and not from the digital data processor, as in the playback mode.

The SPM output consists of a 16-pps, return-to-bias (RB) digital data stream (see Figure IX-6). Each data frame comprises 20 words, the first word of each frame being a synchronization word with a 111000101 pattern. A data word consists of 9 bits plus a one bit long rest period at bias level. The first 4 bits are the characteristic (exponent) and the next 5 are the mantissa with the most significant bits always transmitted first. This data modulates the 3.9-kHz subcarrier on command.

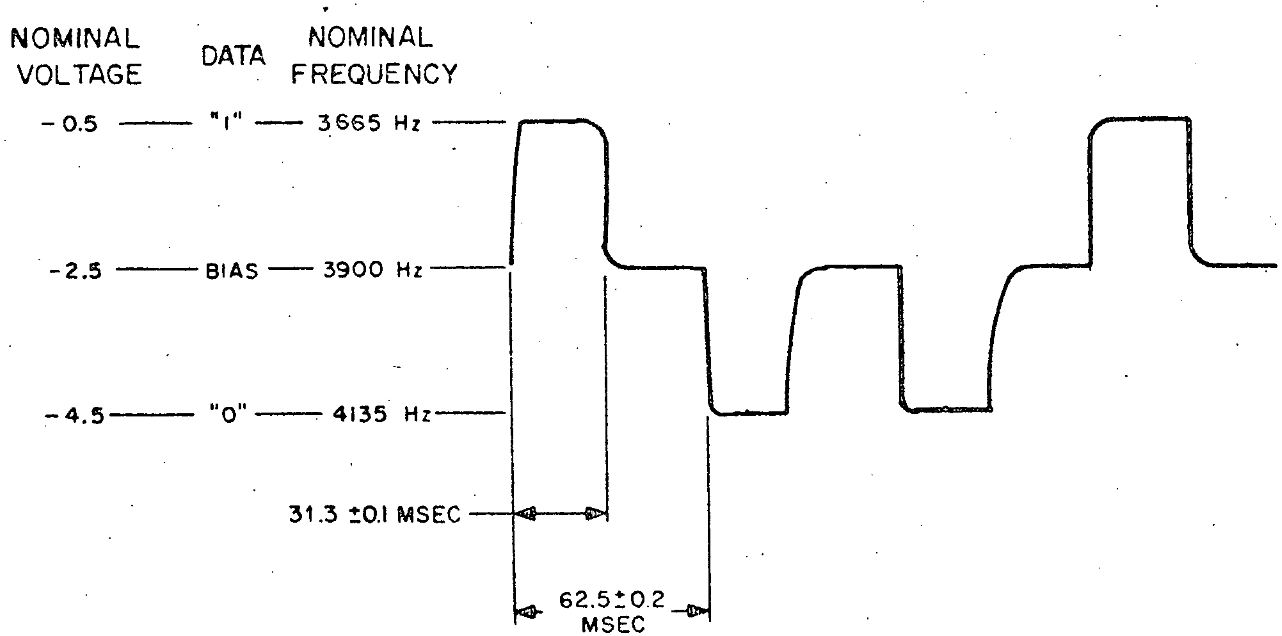
d. DIGITAL SOLAR ASPECT SENSOR (DSAS)

The DSAS is a device mounted on the earth-facing panel of the spacecraft to provide a readout that is a measure of the angle between the sun-spacecraft line and the positive pitch axis of the spacecraft. This angle is referred to as the "sun angle" or "gamma angle". Direct sunlight enters the device through a slit, casting a narrow band of illumination across a patterned light mask. Light passing through the pattern generates an 8-bit binary word, coded to indicate the angle of incidence of the light on the mask. The coding of the angle is actually contained in the first seven bits. The eighth bit is an end-of-word bit and is always coded as a binary "1". A gray code was chosen for this application to minimize the effect that any errors in synchronization of the data bits might have on the decoded value of the angle.

When commanded, this data modulates the 3.9-kHz subcarrier. The output is in a return-to-bias form in which, nominally, a data "0" is represented by a nominal 4135-kHz output, a data "1" is represented by a 3665-kHz output, and the bias value is 3900 kHz. The data bit rate is 2 to 4 bits per second. The actual engineering values for this data will be given in the Alignment and Calibration Data Book for each spacecraft.

e. PITCH AND ROLL SENSORS

The pitch and roll sensors are infrared detectors whose fields of view are scanned by a mirror mounted on the momentum wheel assembly. The pitch and roll sensors are identical except for their view angles and scanning geometries. The purpose of these sensors is to permit attitude determination by detecting the position of the earth's horizons with respect to a spacecraft reference.



REAL TIME SPM VOLTAGE AND FREQUENCY CHARACTERISTICS

	"1"			BIAS			"0"		
SPM OUTPUT VOLTAGE	-0.25	-0.5	-0.75	-2.25	-2.5	-2.75	-4.25	-4.5	-4.75
SCO FREQUENCY (Hz)	3620	3665	3715	3855	3900	3945	4090	4135	4180

NOTE: IF SPM IS OFF, THIS OUTPUT IS 0 VOLTS, CORRESPONDING TO AN SCO FREQUENCY OF 3607 Hz

Figure IX-6. Solar Proton Monitor Real-Time Data Characteristics

There are two operational purposes for telemetering pitch and roll sensor analog information and the roll sensor data and selected pitch index pulse. First, the roll sensor data is required for the determination of the roll attitude error of the spacecraft to provide information for the formulation of suitable QOMAC corrective programs. Second, the roll sensor and selected pitch index pulse telemetry is used to verify that spacecraft "earth-lock" is maintained by the pitch control system. Gross "hunting errors" and loss of earth lock by the pitch control system are immediately obvious from the time phasing of the index pulse with respect to the roll sensor signal. In addition, the telemetry information can also be used to evaluate the pointing accuracy performance of the pitch control system.

A typical waveform from the roll sensor is shown in Figure IX-7.

The required 3-dB bandwidth is 160 Hz. This is the largest bandwidth required for any of the attitude data signals.

f. TIME CODE DATA

The 24-bit spacecraft time code originates in the time base unit (TBU). The signal is transmitted, on command, as a 120-bit-per-second, return-to-bias digital data stream which modulates the 2.3-kHz subcarrier. The least significant bit is transmitted first.

g. VERTICAL TEMPERATURE PROFILE RADIOMETER ANALOG DATA

The real-time transmission of analog VTPR data is primarily for engineering evaluation purposes and is not intended for operational use.

The signal format has essentially the same characteristics as the digital output of the VTPR (described in Section VI of this report), except that the analog data is derived from a point in the sensor just prior to the analog-to-digital converter. The analog data rate is 16 data values per second.

h. ACCELEROMETER DATA

During the launch mode (prior to separation) beacon transmitter No. 1 is selected. In this mode, the subcarriers are modulated with analog data from accelerometer sensors. The sensor signals are filtered and conditioned to the proper dc bias level by the accelerometer control unit (ACU).

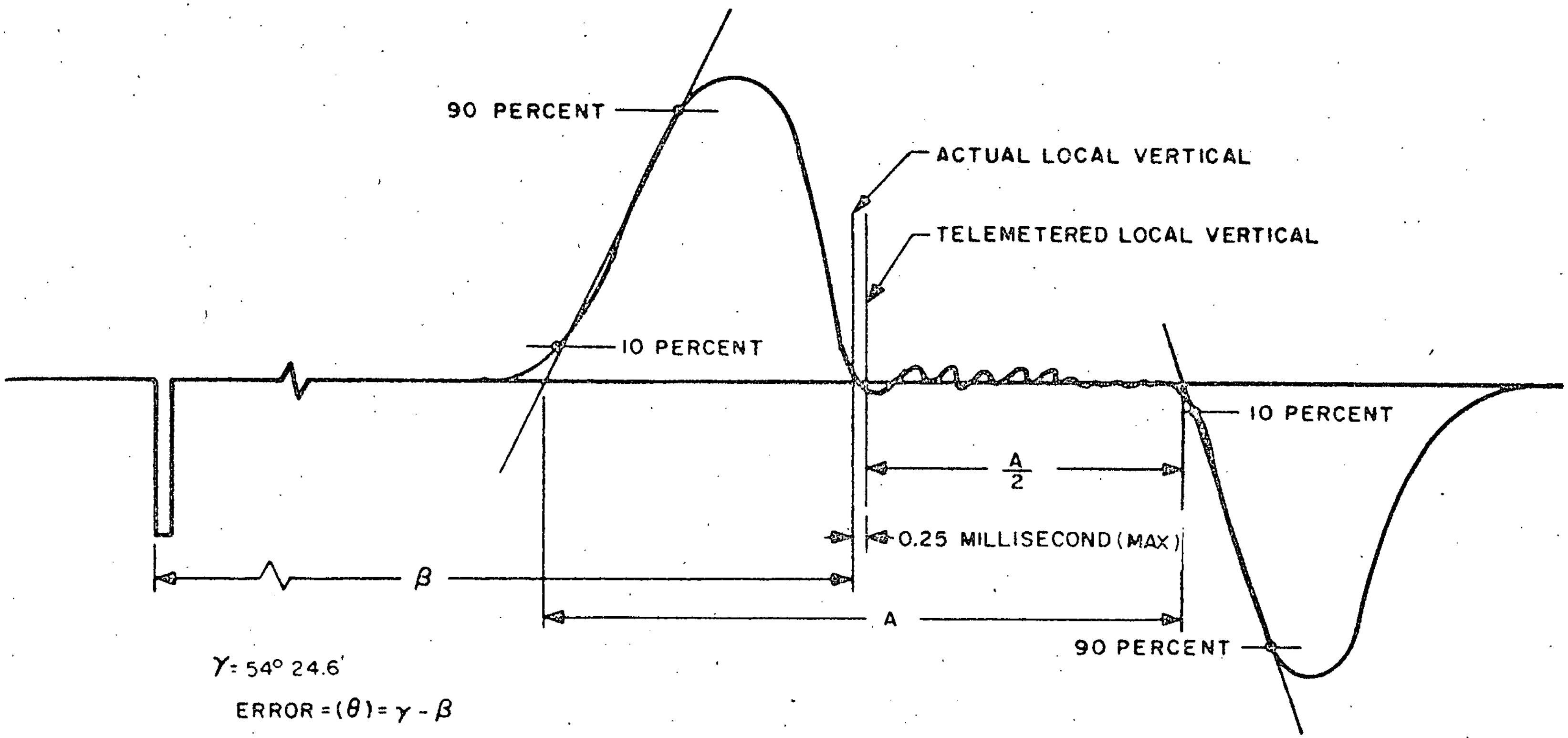


Figure IX-7. Typical Roll Sensor and Pitch Index Telemetry

The bias and filter circuits of the ACU are designed to provide the following volts per G accelerometer outputs.

- Lateral accelerometer output: bias is -2.5 volts; -5 volts for +4G and 0 volt for -4G along either the Y-Y axis or the X-X axis.
- Thrust accelerometer output: bias is -4.0 volts; 0 volt for +16G and -5 volts for -4G along the thrust axis.

Only two accelerometers are used, although there are three mounting positions on the accelerometer mount, because there are only two subcarrier oscillators (SCO) in the existing system for handling the incoming signals from the CDU. Once a particular mission is defined, the two accelerometers can be mounted in either two of three possible positions to provide the desired lateral-lateral or lateral-thrust acceleration information to the SCO's. By proper arrangement, any one of the following four possible combinations of lateral-lateral and lateral-thrust acceleration information for the SCO's can be effected.

- Lateral-Lateral (Y-Y axis and X-X axis). One of the two accelerometers provides Y-Y axis acceleration data to modulate the 3.9-kHz subcarrier which has a bandwidth of 59 Hz. The other accelerometer provides X-X axis acceleration data to modulate the 2.3-kHz subcarrier which has a bandwidth of 160 Hz.
- Lateral-Lateral (X-X axis and Y-Y axis). Same arrangement as above except the Y-Y axis acceleration data modulates the wide bandwidth 2.3-kHz subcarrier.
- Lateral-Thrust (Y-Y axis and Z-Z axis). One accelerometer provides Y-Y axis acceleration data to the 3.9-kHz subcarrier and thrust (Z-Z) axis information modulates the 2.3-kHz subcarrier.
- Lateral-Thrust (X-X axis and Z-Z axis). Same arrangement as above except X-X axis acceleration modulates the 3.9-kHz subcarrier.

After separation from the 2nd stage, the relay of the ACU is released, allowing the normal telemetry signals from the command distribution unit to go directly to their respective SCO's.

3. Dual Subcarrier Oscillator Assembly

The dual SCO is the same as used on TIROS-M/ITOS. It consists of four voltage-controlled oscillators forming redundant pairs. Two operate on a 2.3 kHz center frequency and two operate on a 3.9-kHz center frequency (IRIG channel No. 9). Their characteristics are given in Table IX-5.

TABLE IX-5. DUAL SCO ASSEMBLY CHARACTERISTICS

Parameter	SCO 1-1 and SCO 2-1	SCO 1-2 and SCO 2-2
Center Frequency (f_c)	2.3 kHz	3.9 kHz (IRIG standard)
Deviation (percent f_c)	± 20 percent	± 7.5 percent
Input Baseband	dc to 160 Hz	dc to 59 Hz
Subcarrier Information Bandwidth	1240 Hz	703 Hz
Input Sensitivity	0 to -5.0 volts dc with -2.5 volts dc producing f_c. Less negative input decreases frequency.	0 to -5.0 volts dc with -2.5 volts dc producing f_c. Less negative input decreases frequency.
Input Impedance	350 kohms min	350 kohms min
Load Impedance	33 kohms, +100 percent, -10 percent	33 kohms, +100 percent, -10 percent
Linearity (from best straight line: percent of p-p deviation)	± 1 percent	± 0.25 percent
Maximum Amplitude-Modulation on Output	± 10 percent	± 10 percent
Subcarrier Harmonic Distortion	less than 3 percent	less than 1 percent
Output Voltage	adjustable: 0.25 to 0.70 volt p-p into 33 kilohms load	adjustable 0.25 to 0.70 volt p-p into 33 kilohms load
Output Impedance	39 kohms ± 10 percent (ac coupled)	39 kohms ± 10 percent (ac coupled)
Supply Voltage	-24.5 ± 1.0 volts dc	-24.5 ± 1.0 volts dc
Current per SCO	12 mA	12 mA
Center Frequency Drift (long term)	less than ± 1 percent of deviation bw at 22° C	less than ± 1 percent of deviation bw at 22° C
Temperature Stability	less than ± 1.5 percent of deviation bw from -15 to +60°C	less than ± 1.5 percent of deviation bw from -15 to +60°C
Size	1.91 by 1.58 by 1.031 inches	1.91 by 1.58 by 1.031 inches

The 2.3-kHz SCO was selected (instead of a higher frequency) due to the requirement that it be suitable for long-line voice channel use. The high baseband bandwidth (160 Hz) required adoption of a ± 20-percent bandwidth which is not an IRIG standard.

The 3.9-kHz SCO has a ± 7.5-percent deviation (IRIG channel 9), with a baseband bandwidth of 59 Hz.

The outputs of SCO 1-1 and SCO 1-2 are resistively combined, and the composite signal modulates beacon transmitter 1. Similarly, the outputs of SCO 2-1 and SCO 2-2 are resistively combined to form a modulating signal for the input of beacon transmitter 2. Selection of one of these systems is accomplished by applying power to only one beacon transmitter and one SCO pair at a given time.

Amplitudes of the SCO outputs are set so that the nominal deviation indices of the beacon transmitters are 0.7 radian for the 2.3-kHz SCO and 0.5 radian for the 3.9-kHz SCO. Adjustments are made after the units are assembled into the dual beacon transmitter and SCO assembly configuration.

Input telemetry signals are in the range of 0 to -5 volts. At 0 volt, the SCO oscillates at the lower edge of its band; at -5 volts, it oscillates at the upper edge.

Figure IX-8 is a block diagram showing the two redundant pairs of SCO's in the dual SCO assembly. Only one SCO (1-1) is shown in detail since the others have the same basic configuration.

4. Beacon Transmitter

The ITOS D and E beacon transmitter is identical with the TIROS-M/ITOS-1 beacon transmitter. The two redundant beacon transmitters have the same carrier frequency of 136.770 MHz, but only one is operated at a given time (by command selection). The "on" beacon transmitter is continuously modulated by the two frequency-modulated subcarriers with center frequencies of 2.3 and 3.9 kHz; the nominal carrier phase modulation indices for these two signals are 0.7 and 0.5 radian, respectively.

As shown in Figure IX-9, the crystal oscillator provides a stable carrier frequency at 34.1925 MHz. The dual SCO assembly output feeds the phase modulators two variable-capacitance diodes. These two "vari-cap" diodes are connected back-to-back to give greater dynamic range and less distortion than a single unit. The phase modulator is followed by a buffer amplifier, another amplifier, a varactor multiplier, and a power amplifier. A bandpass filter between the power amplifier and the antenna reduces all spurious and harmonic outputs to 60 dB, or more, below the carrier level; the minimum power output is 250 mW.

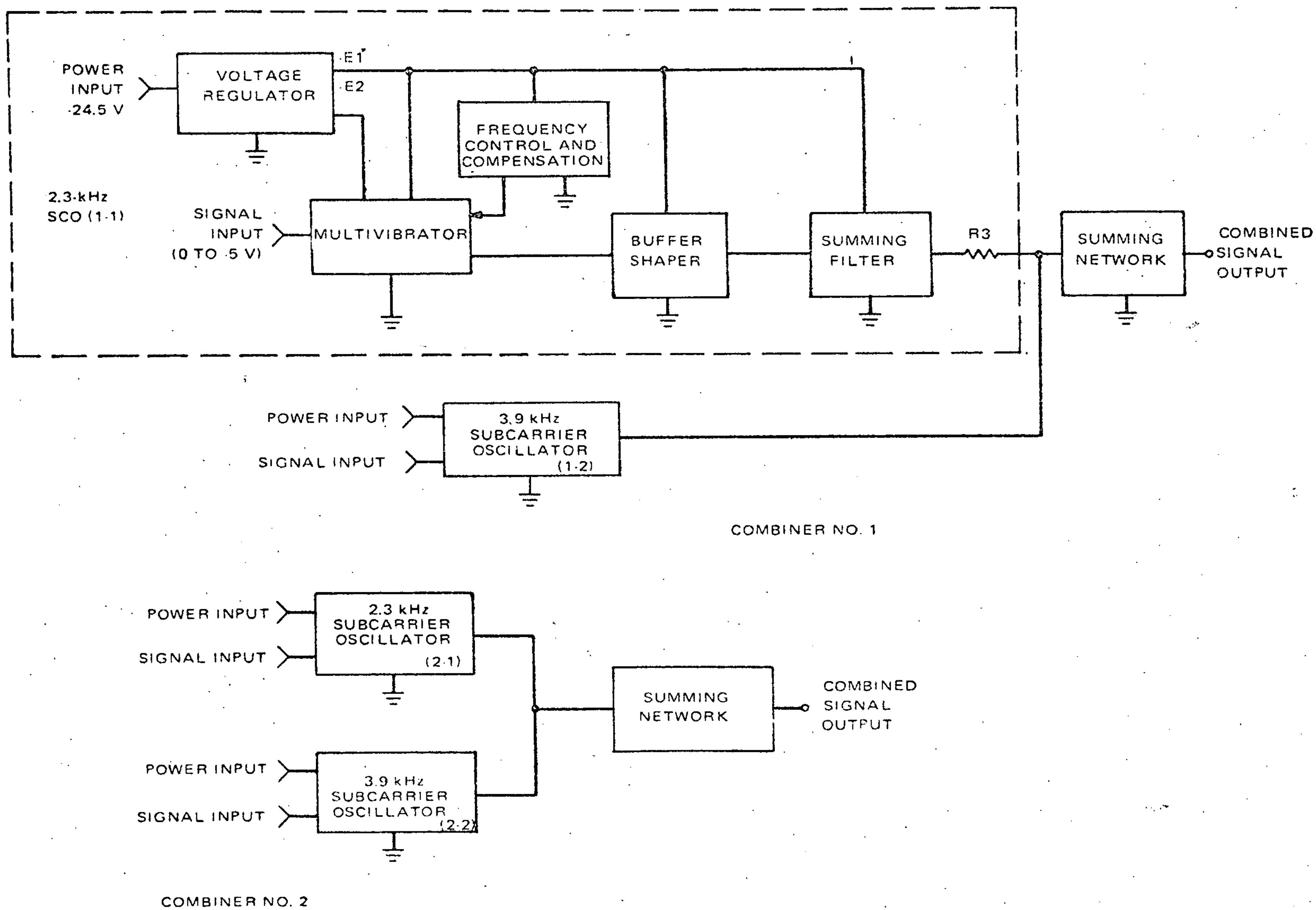


Figure IX-8. Dual Subcarrier Oscillator

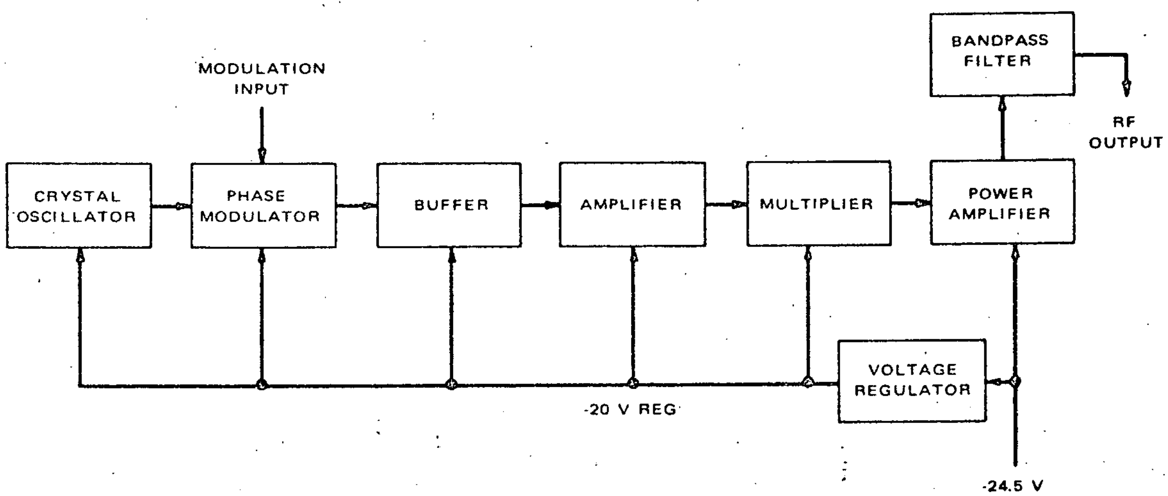


Figure IX-9. Beacon Transmitter

The voltage regulator regulates the -24.5 volt supply input to -20 volts and protects the unit against input voltages up to -36 volts.

Each beacon transmitter is housed in a milled aluminum case, 4 by 4 by 1.25 inches, with flush top and bottom covers. Mounting holes in the four corners allow the two transmitters to be stacked with the dual SCO assembly.

The main specifications of the transmitter are given in Table IX-6.

The modulation linearity of the beacon transmitter is such that with the two subcarriers present and with the 2.3 and 3.9 kHz subcarriers modulating the carrier with a phase index of 0.70 and 0.50 radian, respectively, all intermodulation products from 700 Hz to 10.1 kHz are at least 30 dB down from the 3.9-kHz tone. Intermodulation terms are measured at the output of a true fm detector.

The transmitter design minimizes the spurious output (both radiated and conducted) in the 146- to 151-MHz range and in the subharmonics of this frequency band. When operating in a 1.5:1 VSWR or less, the level of any discrete frequency or broadband noise in a 40-kHz noise bandwidth is specified as follows: (1) less than -80 dBm for bands centered from 146 to 151 MHz, and (2) less than -50 dBm in the band from 108 to 109 MHz. These frequency bands include the command receiver rf and image frequencies.

TABLE IX-6. BEACON TRANSMITTER SPECIFICATIONS

Characteristic	Value
Modulation	Phase-modulated
Frequency	136.77 MHz
Frequency Stability	±0.005 percent
Peak Phase Deviation	1.20 radians
Subcarrier Inputs	
2.3 kHz Subcarrier	
Bandwidth	1240 Hz
Carrier Phase Deviation	0.70 radian ± 12.5 percent
3.9 kHz Subcarrier	
Bandwidth	703 Hz
Carrier Phase Deviation	0.50 radian ± 12.5 percent
rf Power Output	250 milliwatts (min)
rf Information Bandwidth	8.5 kHz

5. Antenna Subsystem

The beacon antenna subsystem of the ITOS D and E Spacecraft is identical to that flown on TIROS-M/ITOS-1.

A single quarter wave radiating element serves as both the transmitting antenna for the beacon signals and as the receiving antenna for the command receiver.

In addition to the antenna, the beacon antenna subsystem comprises a 148-MHz notch filter, an rf switch and interconnecting cables. A simplified block diagram is shown in Figure IX-10.

The antenna radiates a linearly polarized dipole pattern. The 148-MHz notch filter suppresses any spurious signals from the beacon transmitter at the command receiver frequency. In addition, it performs a diplexing function, in conjunction with the 136-MHz notch filter in the command receiver feed line, permitting a single antenna to be simultaneously used for beacon transmission and command reception.

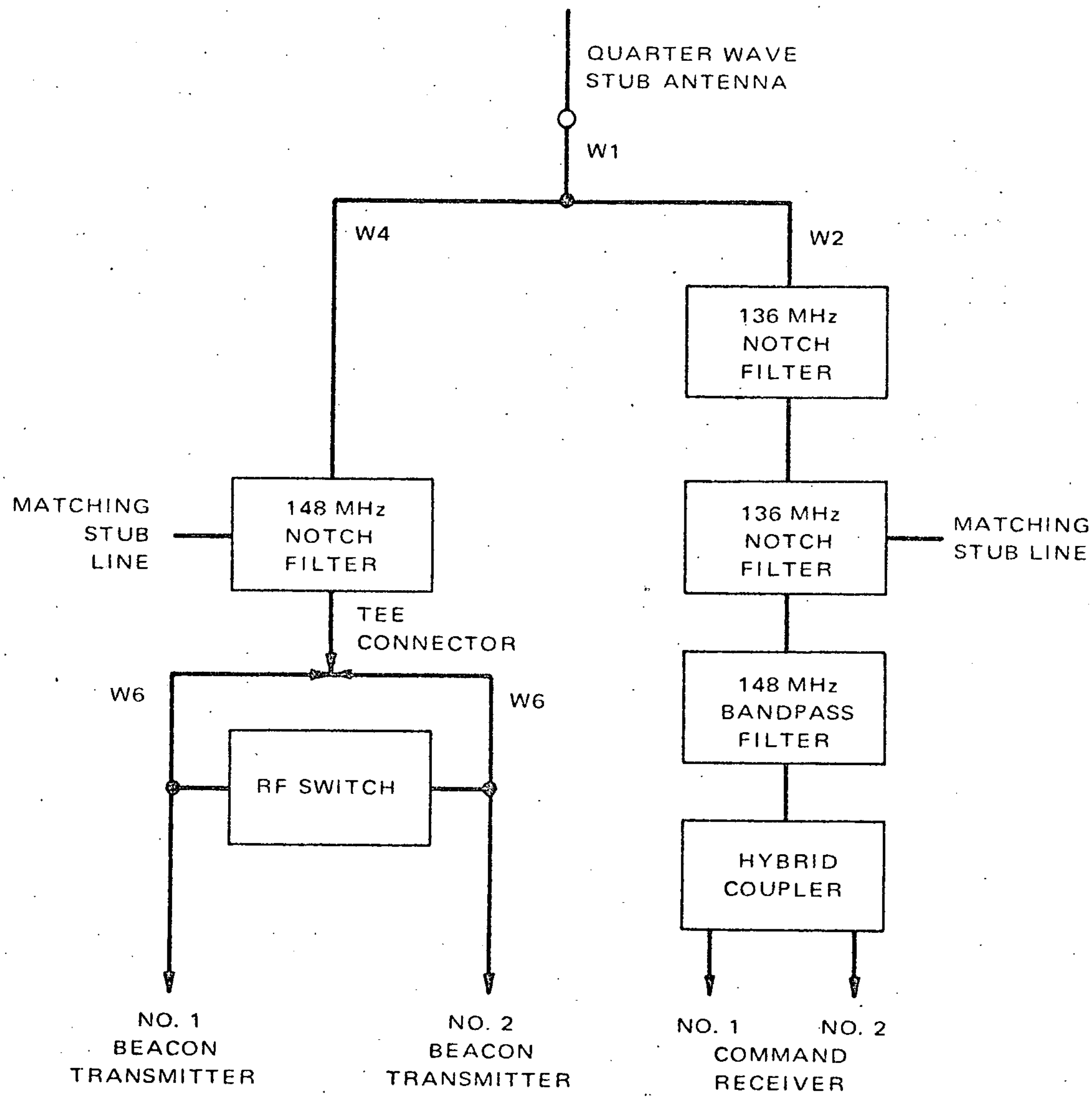


Figure IX-10. Beacon and Command Antenna Group

The rf switch is used in conjunction with the rf cable network to place the output of the selected beacon transmitter electrically at the beacon and command antenna port; this is accomplished by shorting the "off" transmitter to ground through relay contacts and an associated series resonant L-C circuit. The active transmitter is then isolated by a 1/4 wave length of cable (W6) which reflects the short as an open circuit at the tee connector through which the "on" transmitter feeds the remainder of the beacon and command subsystem. The interconnecting cables and connectors have been selected for proper match between components.

6. Subsystem Analysis Summary

A complete treatment of the Beacon Subsystem Analysis and Link Calculation is given in Appendix C. The results of that analysis are summarized below:

a. Required receiver bandwidth (worst case) = 27.5 kHz
   Present receiver bandwidth = 30 kHz

b. Intermodulation distortion products all lie outside discriminator bandwidth.

c. Worst case phase lock loop margin above threshold.

Panels stowed, unstabilized	= 26.4 dB
Panels deployed, unstabilized	= 21.4 dB
Panels deployed, stabilized	= 26.4 dB

d. Worst case baseband S/N (p-p/rms) 3.9 kHz channel.

Panels stowed, unstabilized	= 52.7 dB
Panels deployed, unstabilized	= 47.7 dB
Panels deployed, stabilized	= 52.7 dB

e. Worst case baseband S/N (p-p/rms) 2.3 kHz channel.

Panels stowed, unstabilized	= 47.1 dB
Panels deployed, unstabilized	= 42.1 dB
Panels deployed, stabilized	= 47.1 dB

D. VHF REAL-TIME VIDEO LINK

1. General Description

The purpose of the VHF real-time video link is to transmit scanning radiometer (SR) data to real-time local users throughout the world. The sensor input for the real-time video link is obtained from either one of the two redundant SR.

Each SR has an infrared signal output and a visible signal output. Both sensor outputs are processed by the SR processor (SRPR), where telemetry data, and time code and marker information are added to the sensor signals. Under normal operating conditions, the two processed SR signals are then time multiplexed by the operating SR recorder (SRR). A backup mode permits either processed SR signal to be transmitted directly, bypassing the SRR.

As in TIROS-M/ITOS, the processed signal output of the selected sensor amplitude-modulates a 2.4-kHz subcarrier; this modulated subcarrier in turn frequency-modulates one of the two redundant 137.5-MHz* real-time transmitters. The output of each transmitter is coupled through a notch filter and a hybrid coupler to a pair of half-wavelength radiating elements mounted on the extremity of one of the solar panels. Figure IX-11 shows a simplified block diagram of the VHF real-time data video link. Figure IX-12 shows a block diagram of typical APT VHF real-time ground station equipment.

A ground commanded inhibit mode permits turning off the VHF real-time transmission (and/or the S-band real-time transmission), during selected N of 8 segments in each orbit.

2. SR Signal Characteristics

The SR scans at a rate of 48 lines per minute and has an instantaneous field of view of 5.3 milliradians in the IR channel and 2.8 milliradians in the visible channel. The earth scan occupies 109 degrees of the 360-degree rotation, and the IR sensor resolution is 4.0 nautical miles at the center of the scan; the visible sensor resolution is 2.0 nautical miles. The dynamic range of the IR detector is such that the sensor responds to radiation in the temperature range from 180° to 350°K in the spectral region from 10.5 to 12.5 microns. The visible channel detector responds to a scene brightness of 20 to 10,000 foot-lamberts in the spectral region from 0.52 to 0.73 micron.

*Alternate frequency: 137.62 MHz

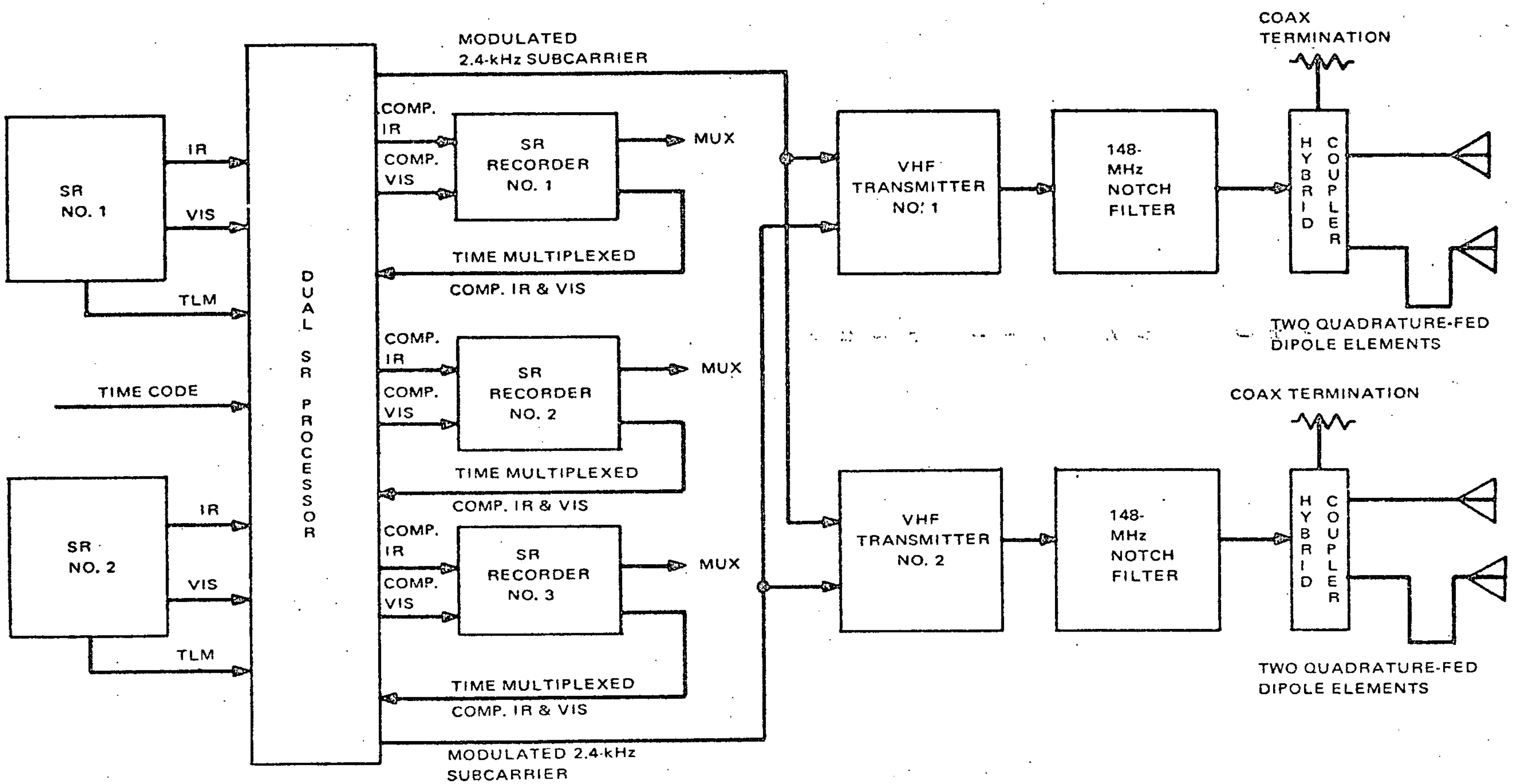


Figure IX-11. VHF Real-Time Link, Spacecraft Equipment

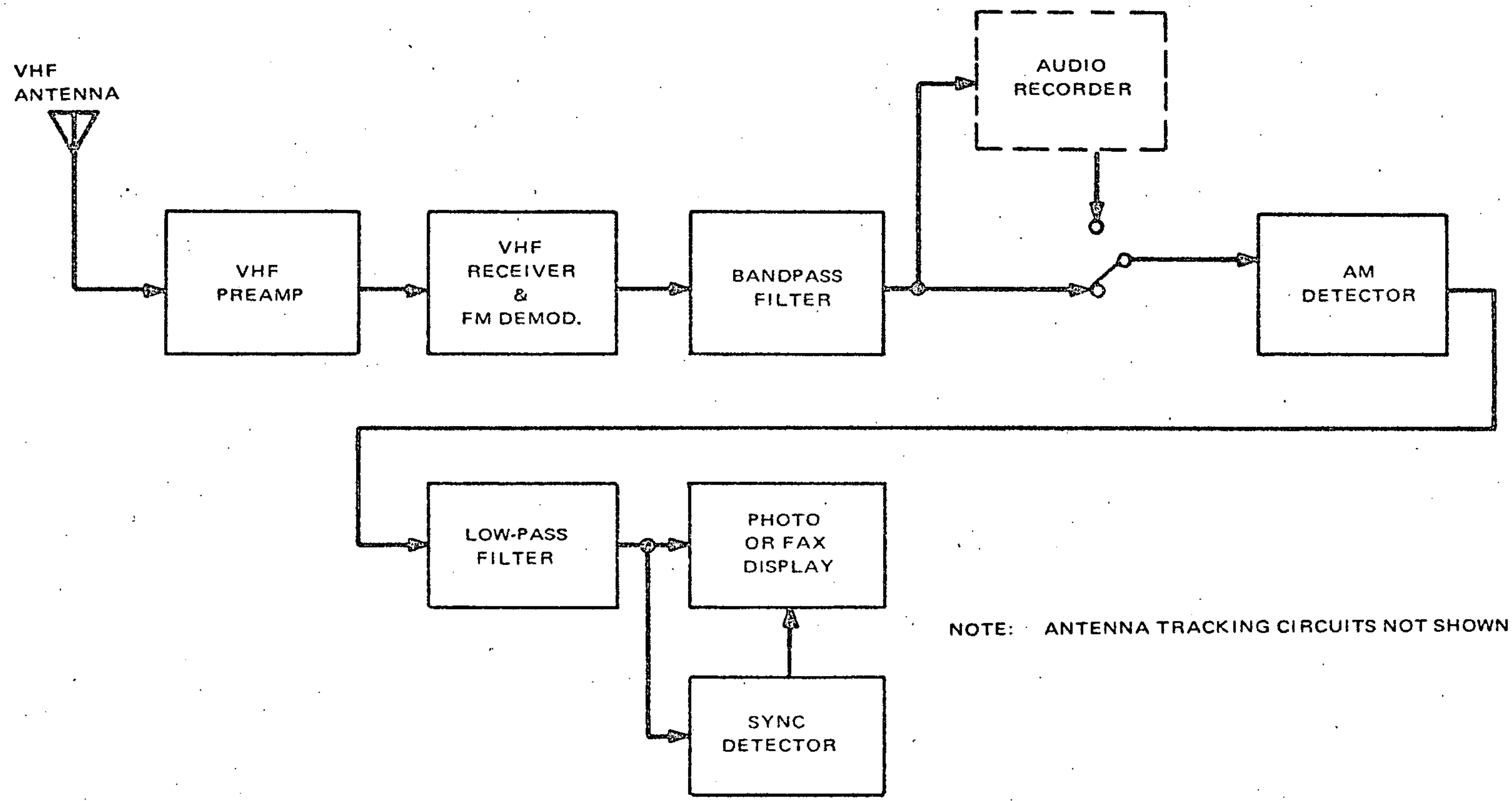


Figure IX-12. VHF Real-Time Link, Typical APT Ground Station Equipment

Figure IX-13 describes the principal characteristics of the composite video waveform obtained from each channel of the scanning radiometer. A primary departure from the format of the SR signals of TIROS-M/ITOS is the relocation of all sync and calibration signals closer to the Earth scan signal so that all desired signals fall within 50% of the time of a full scan. This is to allow time multiplexing of the IR and visible channel signals by the SRR.

The significant spectrum of the infrared video signal is from dc to 450 kHz. The sensor video amplifier bandwidth, however, has been specified as 600 Hz to provide improved transient response by reducing the envelope delay distortion introduced by the amplifier high frequency roll-off.

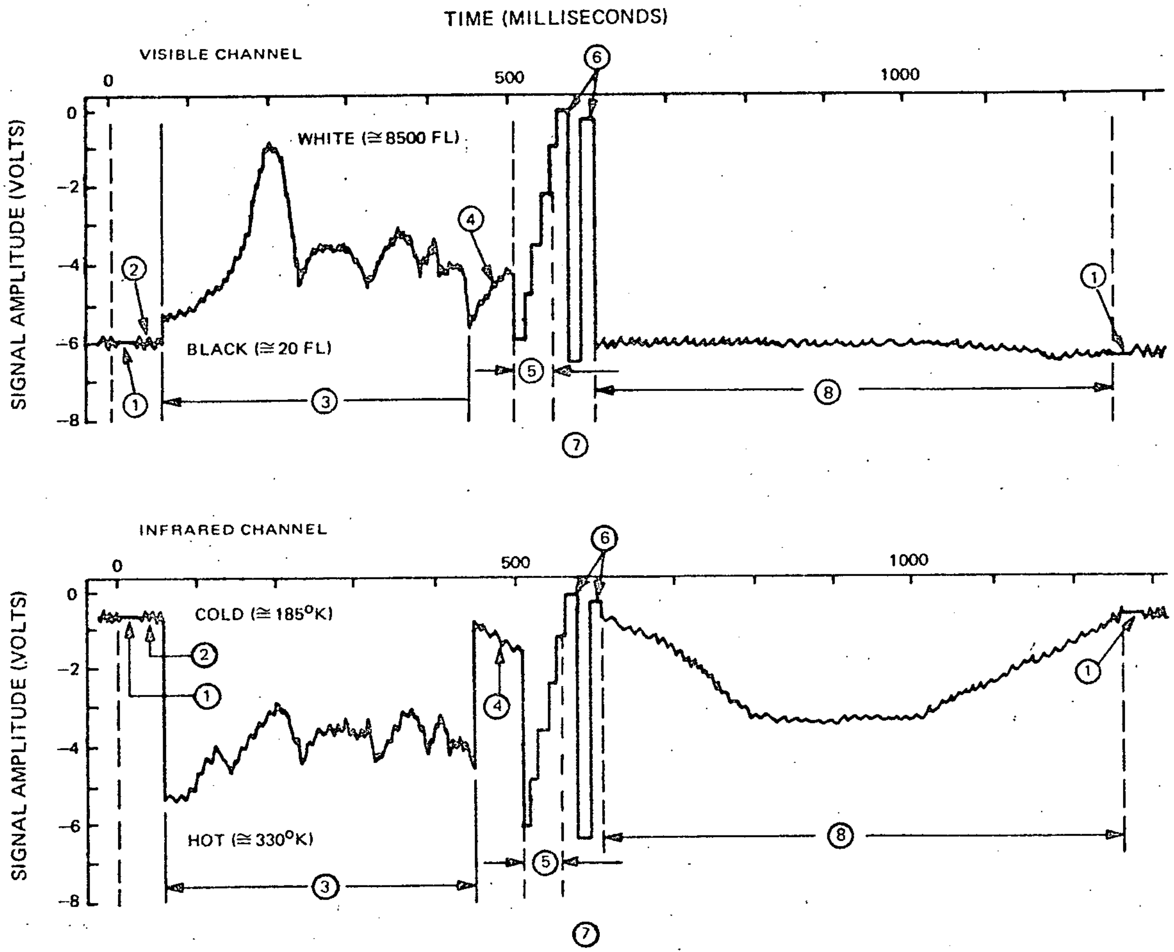
The spectrum of the visible video signal is from dc to 900 Hz. The sensor video amplifier bandwidth of this channel has been specified as 1200 Hz.

3. SR Processor

The SRPR has four primary functions: 1) interleaving the tone burst line sync signal and various telemetry signals with each of the SR video signal channels; 2) controlling the switching of the SRR recording heads to perform the time multiplexing function in synchronism with the SR scan; 3) providing for bypassing of the SRR multiplexing function and selecting either IR or visible radiometer signals to modulate the transmitter as a backup mode of operation; and 4) amplitude modulating either the processed, time multiplexed composite or backup video waveform onto a 2.4-kHz subcarrier which frequency modulates the selected VHF real time transmitter.

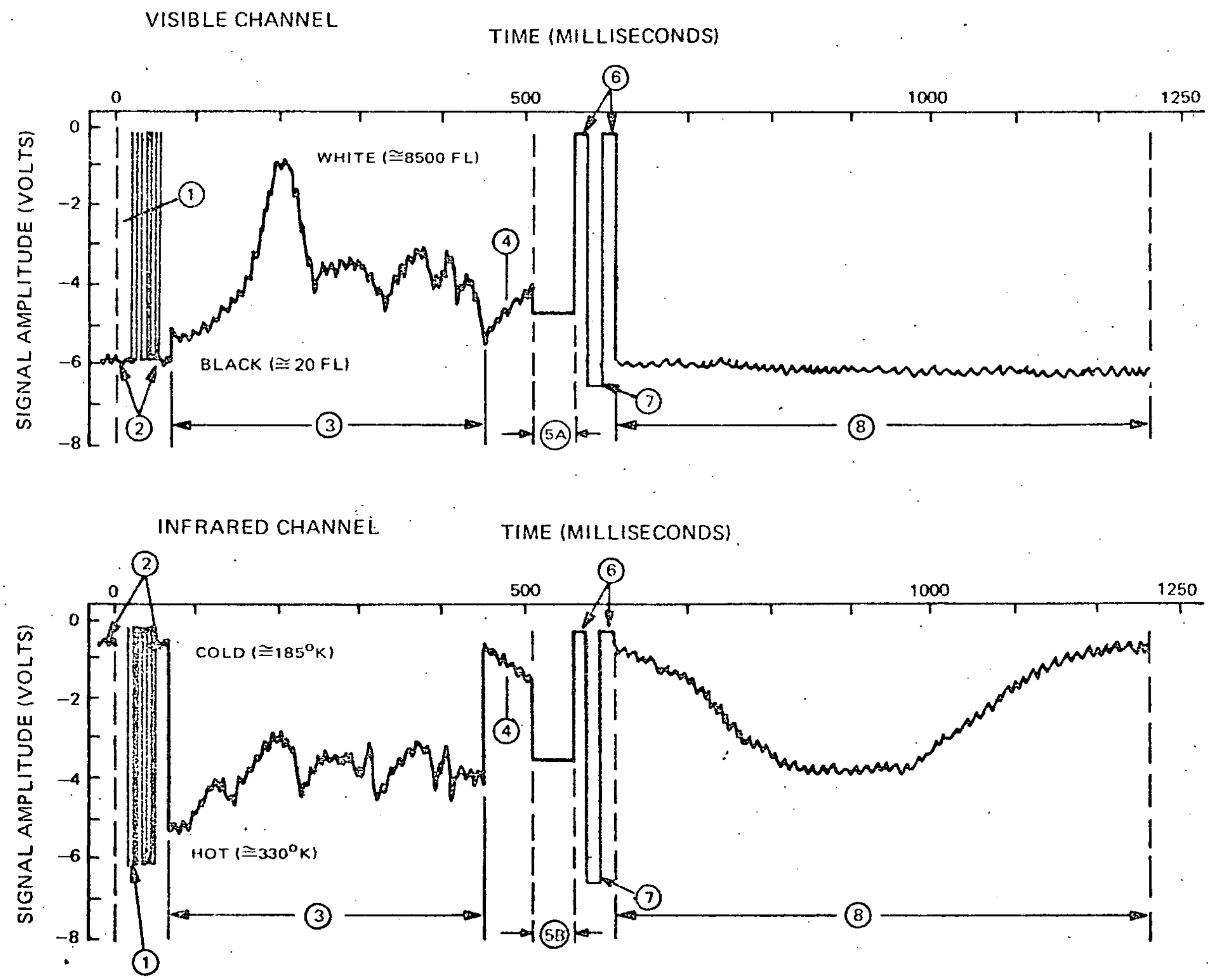
The generated line sync signal consists of a 7-pulse burst of a 300-Hz squarewave added to the IR and visible signals during the dc restore period at the start of each scan line of radiometer data. The telemetry signals are commutated with the IR and visible signals during the period normally assigned to the sensor voltage calibration signal. These signals consist of various calibration, status and housekeeping signals generated within the SR radiometer and SRPR. In addition, spacecraft time code data and the amplitude of the backscan data of the IR channel are also commutated. The composite data format generated by the SRPR is shown in Figure IX-14.

Two complete SRPR, each associated with one scanning radiometer, are contained within one dual SRPR module. Only the processor associated with the radiometer in use will operate at a given time. Each processor consists of a dual commutator, a balanced AM modulator, a 7-pulse sync generator, and control logic.



1. AMPLIFIER RESTORING PERIOD	20 MILLISECONDS
2. OUTER SPACE SCAN	41 MILLISECONDS
3. EARTH SCAN	378 MILLISECONDS
4. VIS CALIB. TARGET (INITIAL PART)	61 MILLISECONDS
5. VOLTAGE CALIB. SIGNAL	50 MILLISECONDS
6. FRONT & BACK PORCH	10 MILLISECONDS
7. SYNC PULSE	30 MILLISECONDS
8. BACK SCAN	650 MILLISECONDS

Figure IX-13. SR Sensor Signal Characteristics Prior to Processing by SR Processor and Time Multiplexing of Channels by SR Tape Recorder



1.	LINE SYNC TONE BURST (300 Hz)	23.3 MILLISECONDS
2.	OUTER SPACE SCAN AND BLANKING PERIOD	38 MILLISECONDS TOTAL
3.	EARTH SCAN	378 MILLISECONDS
4.	VIS CALIB. TARGET (INITIAL PART)	61 MILLISECONDS
5A.	VIS TELEMETRY CHANNEL PERIOD	50 MILLISECONDS
5B.	IR TELEMETRY CHANNEL PERIOD	50 MILLISECONDS
6.	FRONT & BACK PORCH	10 MILLISECONDS
7.	SYNC PULSE	30 MILLISECONDS
8.	BACK SCAN	650 MILLISECONDS

Figure IX-14. SR Signal Characteristics after Processing by the SR Processor

4. Time Multiplexing of SR Signals

A simplified block diagram of the SRR time multiplexing function is shown in Figure IX-15. In the normal operating mode, both SR data channels are continuously supplied to individual 4.22 ±0.64 kHz fm subcarrier modulators in the selected SRR. Useful IR and visible channel data occurs in coincident time intervals of 563 milliseconds every 1250 milliseconds. The two coincident data bursts are recorded simultaneously by two record heads, located at different positions along the data track. The tape is moved at a constant velocity and the two record heads are deenergized for 594 milliseconds between record periods. During this interruption, tape magnetized by useful data moves beyond both heads. About 6.7 milliseconds of the non-useful IR and visible data recorded will overlap each other. For proper operation of the ground station synchronizing circuits there are no gaps between the IR and visible data bursts and the overlap area is separated from the useful data by about 6.7 milliseconds, thus allowing proper detection of the 7-pulse sync burst signal. This separation is necessary because a large transient in the demodulated data occurs at one boundary of each overlap area due to the random phase difference between the IR and visible subcarrier signals at the switch-over point. When the recorded tape passes the playback head, the interleaved subcarrier signal is amplified, limited and supplied to an fm demodulator. After passing through a low pass filter, the composite interleaved IR/visible demodulated signal shown in Figure IX-16 is obtained. This composite signal is then returned to the SRPR for amplitude modulation onto a 2.4-kHz subcarrier which suesequently frequency modulates the selected VHF real-time transmitter.

A backup mode of operation provides for bypassing of the SRR multiplexing function and selecting either IR or visible channel signals to directly modulate the 2.4-kHz subcarrier.

5. VHF Real-Time Transmitter

The VHF real-time transmitter is identical to those flown on TIROS-M/ITOS-1. The principal specifications of the transmitter are listed in Table IX-7. A simplified block diagram is shown in Figure IX-17. The input signal is an amplitude-modulated 2.4-kHz subcarrier with spectrum sidebands from 1.2 to 3.6 kHz, obtained from the SR processor. The modulated subcarrier is, in turn, used to frequency modulate a voltage controlled crystal oscillator. The voltage-controlled crystal oscillator operates at one-eighth of the carrier frequency and is followed by three frequency doublers. Following the doubler chain, the signal passes through class-C driver and power amplifier stages and an output low pass filter. Stability of the power amplifier under a wide range of load VSWR's and phase angles was achieved by the low-Q output circuit. The low pass filter provides additional isolation.

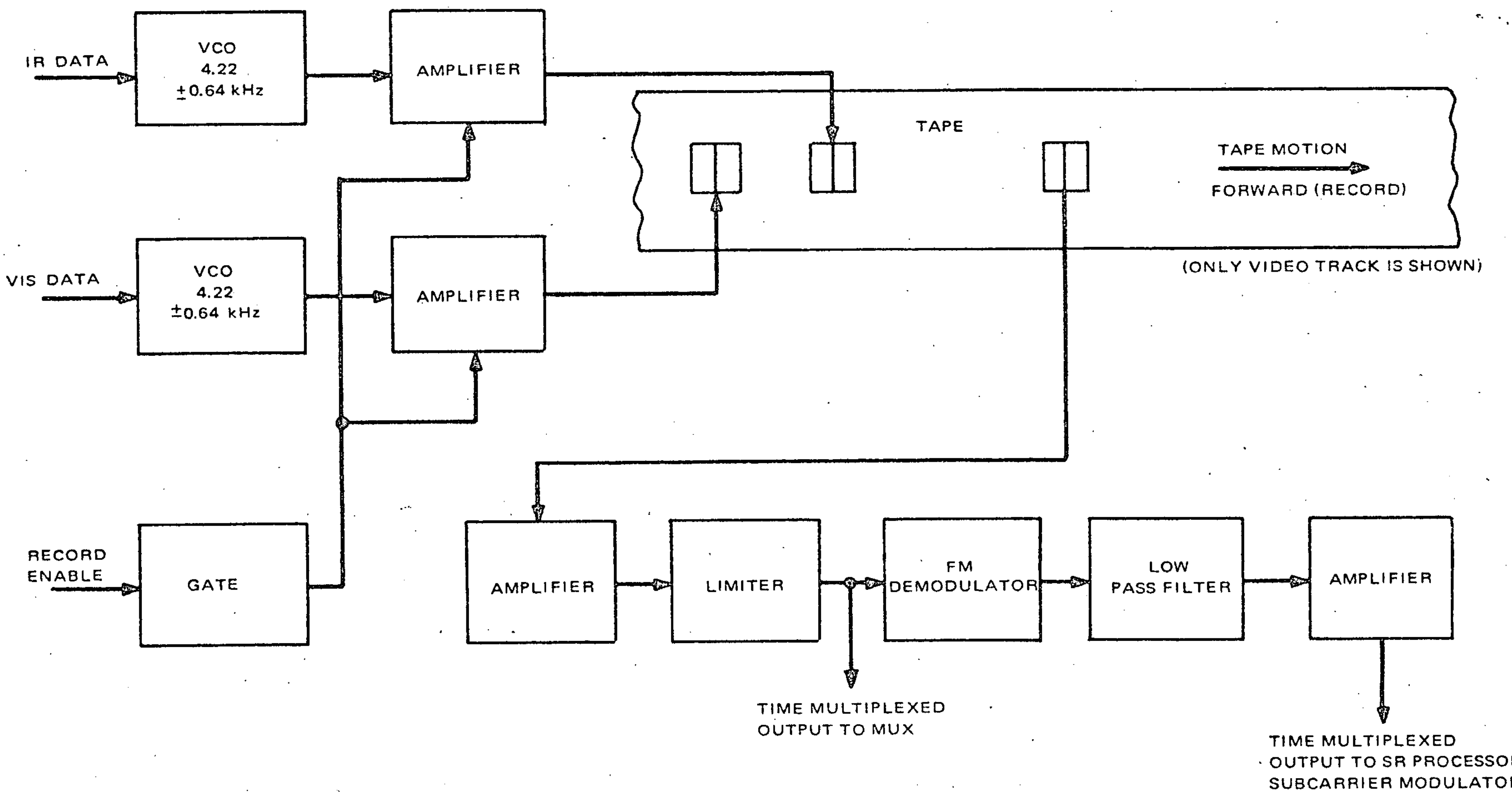
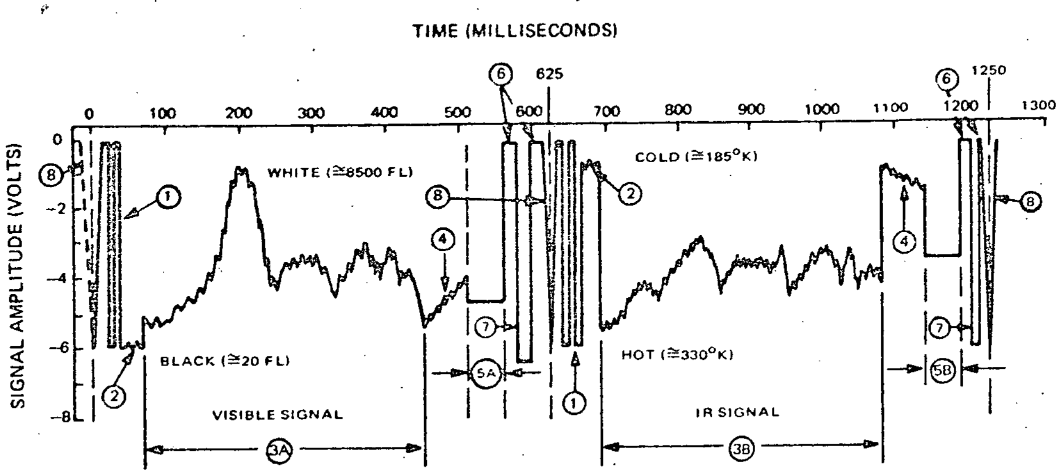


Figure IX-15. SRR Time Multiplexing Circuits, Simplified Block Diagram



1. LINE SYNC TONE BURST (300 Hz)	23.3 MILLISECONDS
2. OUTER SPACE SCAN	24 MILLISECONDS
3. EARTH SCAN A. VISIBLE	378 MILLISECONDS
B. IR	378 MILLISECONDS
4. VISIBLE CALIB. TARGET (INITIAL PART)	61 MILLISECONDS
5A. VIS TELEMETRY CHANNEL PERIOD	50 MILLISECONDS
5B. IR TELEMETRY CHANNEL PERIOD	50 MILLISECONDS
6. FRONT & BACK PORCH	10 MILLISECONDS
7. SYNC PULSE	30 MILLISECONDS
8. HEAD SWITCHING TRANSIENT	2 MILLISECONDS

Figure IX-16. SR Signal Characteristics After Time Multiplexing by SR Recorder

6. Real-Time Antenna Group

The VHF real-time antennas are identical to those flown on TIROS-M/ ITOS-1. Each one of the two transmitters is connected to its own dipole array to form a fully redundant system. One antenna is mounted on solar panel A and the other on solar panel C.

Each of the dipole arrays is composed of two half-wave quadrature-fed dipoles, an antenna hybrid coupler, a 148-MHz notch filter, and the antenna feed lines. Because the real-time link operates only during the earth-lock mode of the spacecraft, a directional radiation pattern is desirable.

The two dipoles in the array are fed in phase quadrature. This produces an antenna pattern which concentrates the rf power in the region $\pm 55^\circ$ about the local vertical in the direction of the earth and minimizes the power wasted in back and side lobes. The quadrature phase shift between elements is obtained by selecting the length of the antenna feed lines. The electrical feed to one dipole has an electrical length L. The other feed has a length L +90°.

The antenna polarization is linear. This is the simplest way of achieving compatibility with the APT field stations which are equipped with an 8-turn

TABLE IX-7. VHF REAL-TIME TRANSMITTER SPECIFICATIONS

Characteristics	Values
Carrier Frequency:	
Group-501	137.500 MHz
Group-502	137.620 MHz
Frequency Stability	±0.005 percent
Power Output	5 watts minimum
Output Load Impedance	50 Ω
Modulation	FM
Deviation Sensitivity	9 ±1 kHz peak deviation for 1V rms input
Frequency Response	0.6 to 4.2 kHz ±1 dB
Modulator Inputs	4
Input Impedance	20 ±2 K Ω
Harmonic Distortion	< 2.5% for ±9 kHz deviation and 2.4 kHz input.
Power Supply	
Voltage	$-24.5\ ^{+0.5}_{-1.0}$ volts
Power Consumption	18 watts, maximum
Efficiency	30 percent, minimum
Operating Temperature	-15 to +60°C
Weight	2.2 pounds, maximum
Size	1.5 x 5 x 7.1 inches

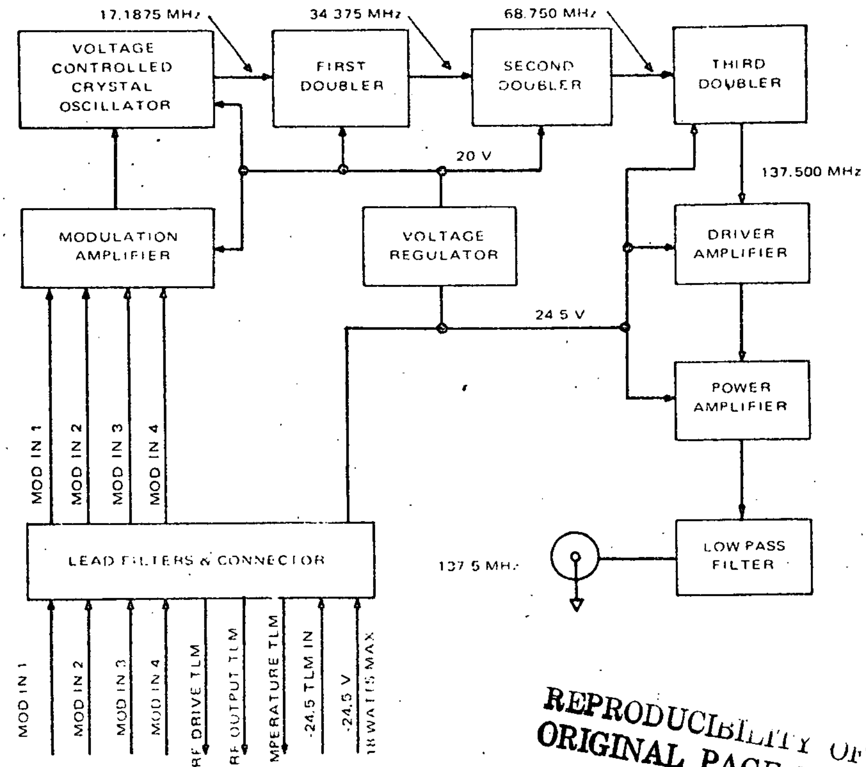


Figure IX-17. Real-Time Transmitter

helical antenna right-hand circularly polarized; however, there is a 3-dB polarization loss.

The selected configuration also yields 25-dB isolation from the real-time antenna to the beacon command antenna at the real-time frequency and provides adequate isolation (22 dB) at the command frequency.

7. Subsystem Analysis Summary

A complete treatment of the VHF subsystem analysis and link calculations is given in Appendix C. The results of that analysis are summarized below:

a. Required receiver bandwidth (worst case) = 43.6 kHz [Present APT Field Station receiver bandwidth = 50 kHz]

b. Worst case peak-to-peak signal/rms noise:

Visible Channel (900 Hz bandwidth) = +33.7 dB

IR Channel (450 Hz bandwidth) = +35.2

E. S-BAND REAL-TIME VIDEO LINK

1. General Description

The S-band real-time video link is a new communications link in ITOS D and E, not previously used in TIROS M/ITOS-1.

The purpose of this link is to transmit very high resolution radiometer (VHRR) data to new real-time local user stations throughout the world.

The data for the S-band real-time video link is obtained from both VHRR radiometers under normal operating conditions or from a single VHRR sensor in a backup mode of operation. A degraded, received signal-to-noise performance results when the backup mode is selected, due to the decreased carrier deviation per channel available when two channels are transmitted within the same RF spectrum bandwidth.

Each VHRR sensor has an infrared signal output and a visible signal output. Under normal operating conditions, the scanning mirror of one VHRR sensor is slaved to the scanning mirror of the other sensor. The mirrors are phase locked so that when one sensor is scanning the Earth, the other is scanning the sensor housing. By combining the infrared Earth scan signal from one sensor and the visible Earth scan signal from the other, a video signal containing both infrared and visible Earth scan data in time multiplex form is generated. In normal operation, this composite signal frequency modulates an 80-kHz subcarrier.

A backup mode permits both the infrared and visible outputs from a single VHRR sensor to be transmitted. This is accomplished by using one of the output signals to modulate the 80-kHz subcarrier and using the other output signal to frequency modulate a separate 230-kHz subcarrier.

In either mode of operation, the modulated subcarriers, in turn, frequency modulate one of the two redundant 1697.5-MHz S-band transmitters. The output of each transmitter is permanently connected to its own S-band antenna. The radiated wave from either antenna is right-hand circularly polarized.

A ground commanded inhibit mode permits turning off the S-band real-time transmission (and/or the VHF real-time transmission) during any selected N of 8 segments in each orbit. In addition, the S-band real-time data transmission is inhibited during the playback of recorded data to the CDA stations, since the same S-band transmitters and antennas are used for this function.

At the local user stations, the S-band signal is received by a 10-foot diameter antenna and demodulated by an fm receiver. The subcarriers are then individually demodulated by fm discriminators to recover their video basebands.

Figure IX-18 shows a simplified block diagram of the S-band real-time video link; and Figure IX-19 shows the local user ground station equipment.

2. VHRR Signal Characteristics

The VHRR scans at the rate of 400 lines per minute and has an instantaneous field of view of 0.6 milliradian in both the IR and visible channels. The Earth scan occupies 109° of the 360° rotation. The sensor resolution is 0.5 nautical mile at the satellite subpoint. The IR detector responds to radiation in the temperature range from 180° to 315° K in the spectral region from 10.5 to 12.5 microns. The Visible channel detector responds to a scene brightness of 50 to 10,000 foot-lamberts in the spectral region of 0.60 to 0.70 micron.

Figure IX-20 describes the principal characteristics of the composite video waveform obtained from each channel of the VHRR. The useful data falls within 1/2 of the period of a full scan. In the normal mode of operation, the scanning mirror of one (slave) VHRR is slaved to the scanning mirror of the other (master) VHRR. The mirrors are phase locked so that when one sensor is scanning the Earth, the other is scanning the sensor housing. The IR channel signal from the master VHRR and the visible channel signal from the slaved VHRR are combined within the master VHRR to produce a composite video signal with interleaved IR and visible channel signals. The format of the resulting time multiplexed signal is shown in Figure IX-21.

The spectrum bandwidth of the VHRR IR and visible channel signals is 1 Hz to 35 kHz. The sensor output signal-to-noise ratio is at least 45.2 dB peak-to-peak/rms for the IR channel signal and 43.7 dB peak-to-peak/rms for the visible channel signal.

3. VHRR Processor

The VHRR processor, described in detail in section VII of this report, has five primary functions: 1) Frequency modulating an 80-kHz subcarrier with the composite time multiplexed IR/visible VHRR signal in the normal operation mode, or with the IR channel signal in the single VHRR backup mode; 2) Frequency modulating a 230-kHz subcarrier with the visible channel signal in the single VHRR backup mode; 3) Linearly combining the two fm subcarriers and adjusting their voltage amplitudes depending on the selected operational mode; 4) Adding spacecraft time code information into the VHRR video signals selected for remote recording; and 5) Appropriately selecting, in accordance with the commanded mode of operation, the information signals to be routed to the S-band transmitters for transmission to Earth. These signals include redundant combinations of signals from the two VHRR sensors and redundant sections of the VHRR processor, and also include the output of the dual multiplexer (MUX) during playback of recorded data to the CDA stations.

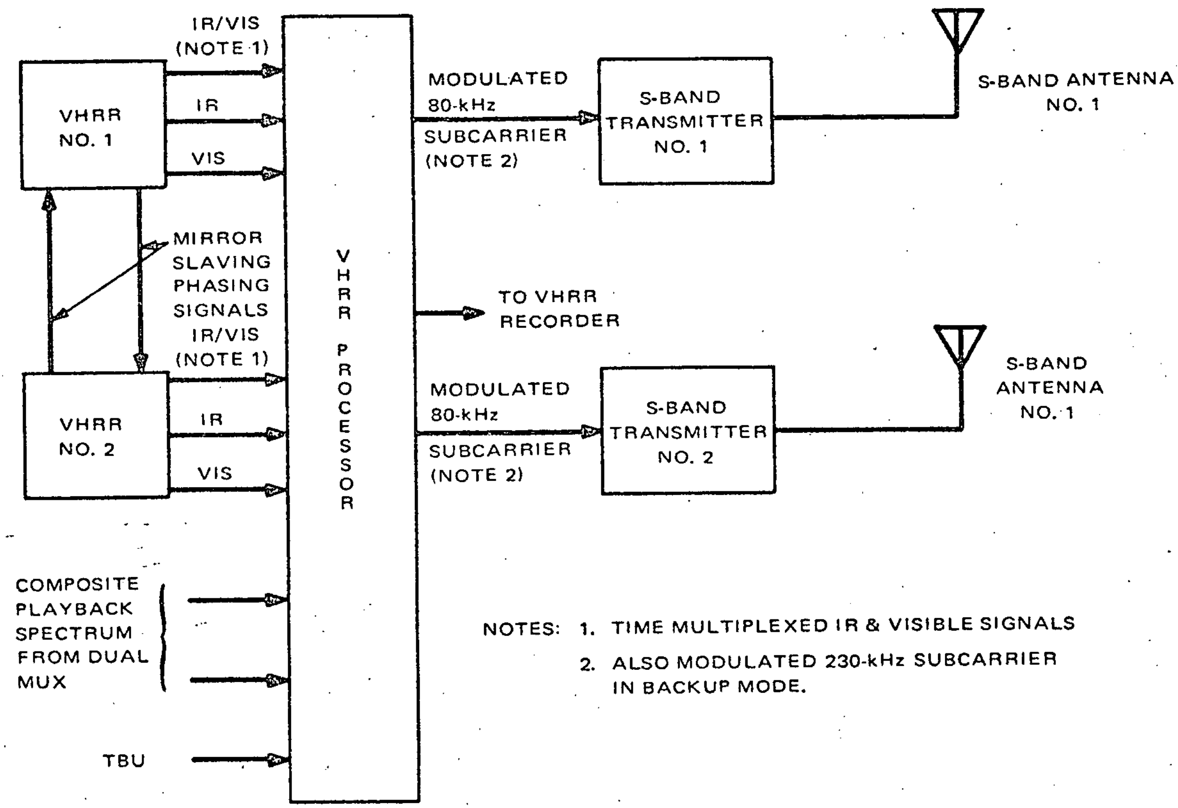


Figure IX-18. S-Band Real-Time Video Link, Spacecraft Equipment

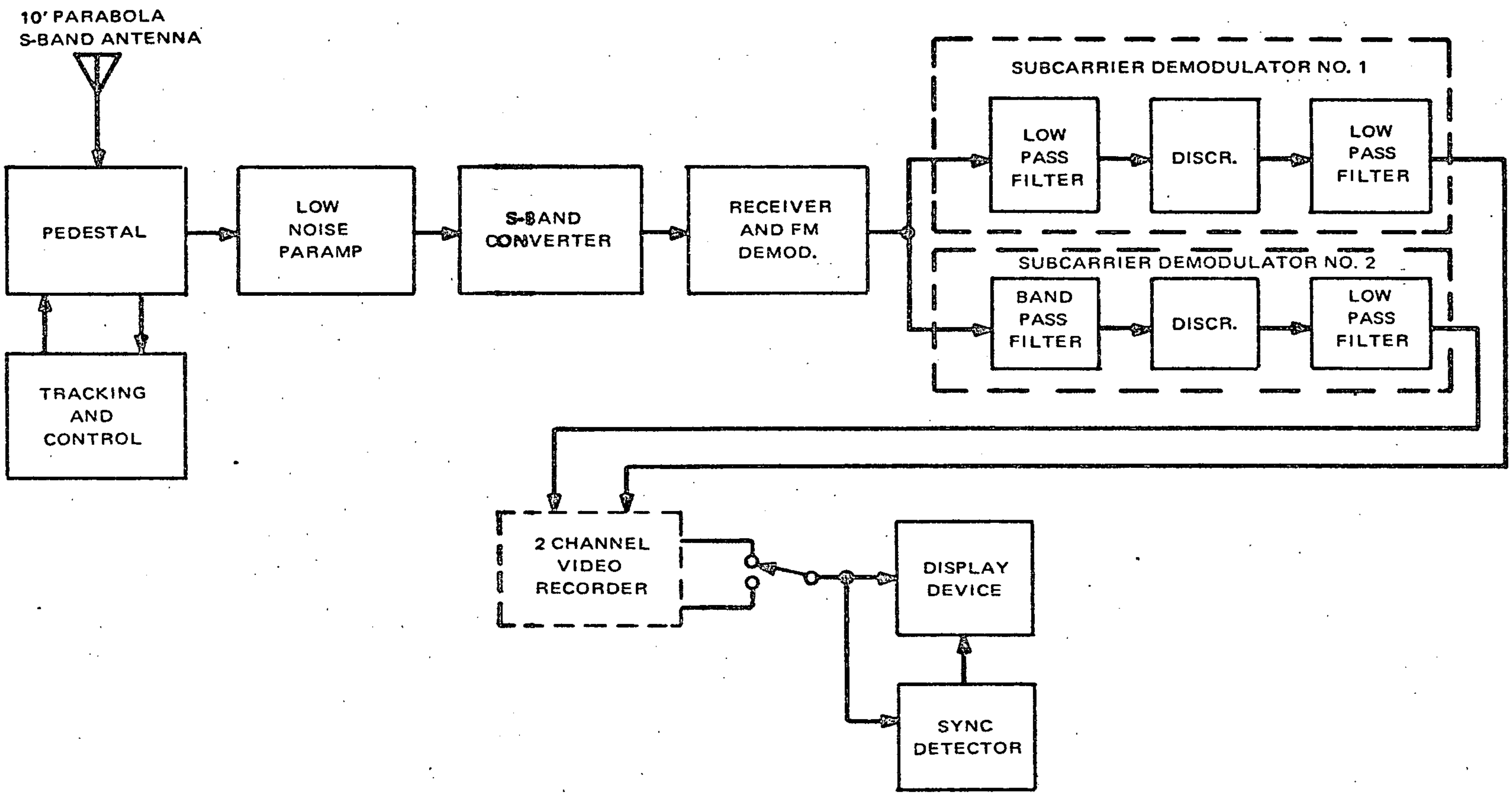


Figure IX-19. S-Band Real-Time Link, Typical Local User Ground Station Equipment

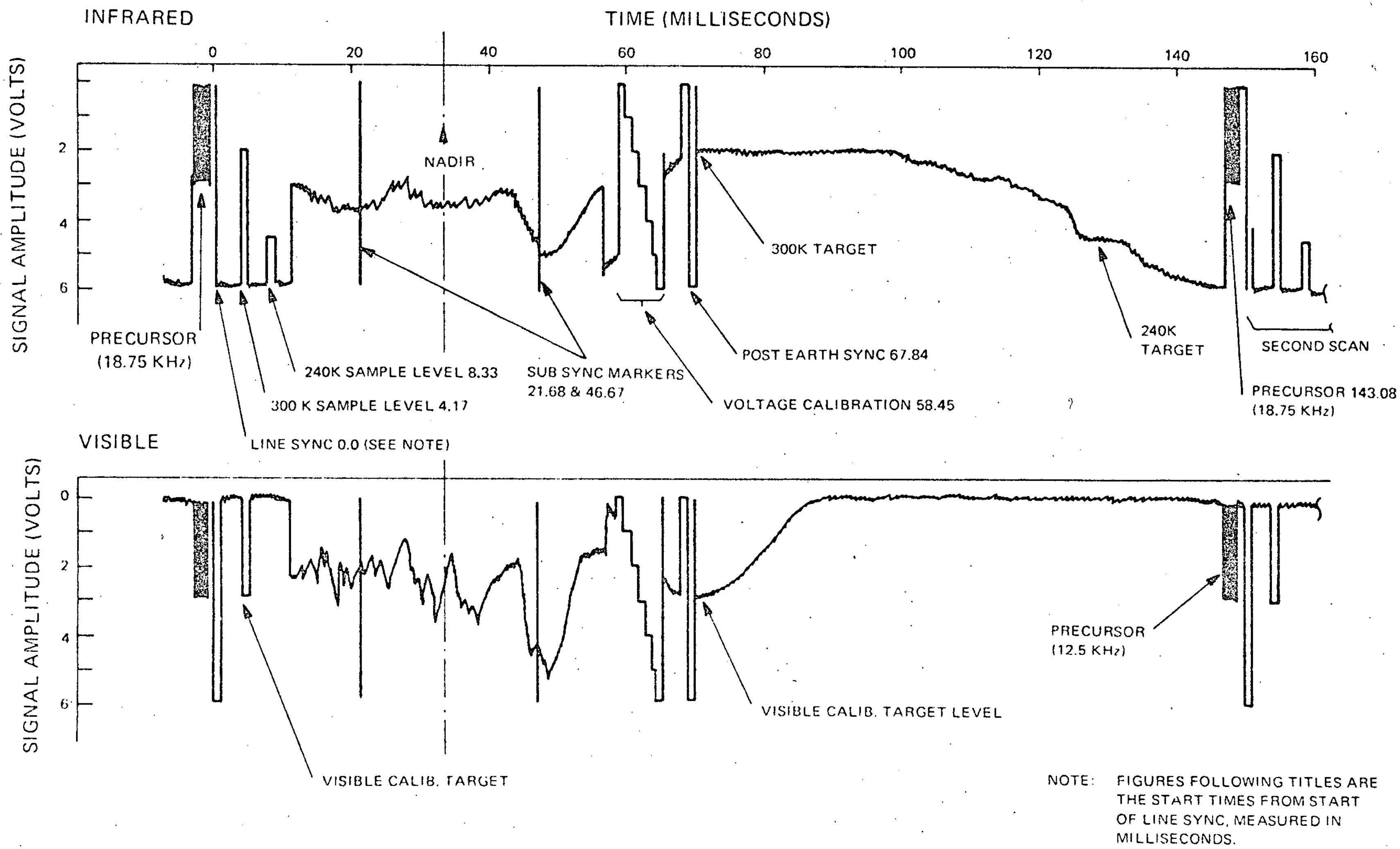


Figure IX-20. VHRR Signal Characteristics Prior to Time Multiplexing of IR and Visible Signals

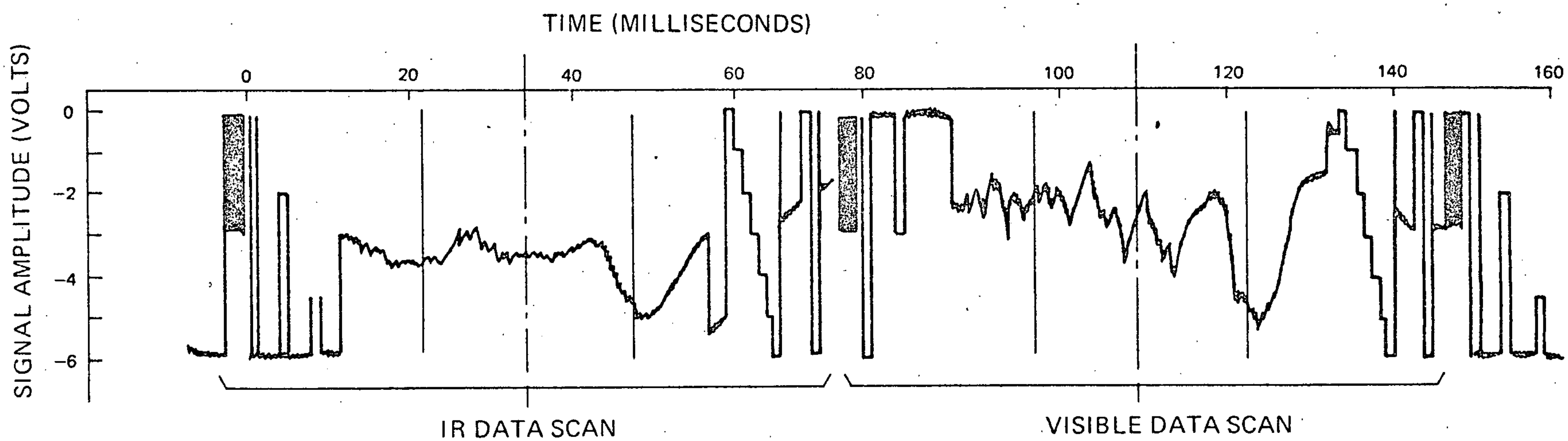


Figure IX-21. Time Multiplexed IR and Visible Signals from the VHRR Sensors

The output spectrum of the VHRR Processor in the real-time S-band transmission mode is shown in Figure IX-22 for both the normal mode of operation (phased radiometers) and the backup mode of operation (single VHRR radiometer). A subcarrier deviation index of unity has been selected to provide the required baseband signal-to-noise ratio. The output of either redundant section of the VHRR Processor can be steered to either of the two redundant S-band transmitters on board the spacecraft.

4. S-Band Transmitter

a. INTRODUCTION

The ITOS D and E mission requires that VHRR data be transmitted in real-time via S-band to local ground stations having a 10-foot parabolic antenna. rf link calculations show that, with an uncooled parametric amplifier front end at the ground stations, a spacecraft transmitter power of 5 watts will support an fm communications link with a 1.0-MHz if. bandwidth. This bandwidth is necessary for satisfactory operation in the 2-subcarrier back-up mode. Since the TIROS-M/ITOS-1 S-band transmitter provides only 2 watts of output power, a new transmitter is required for ITOS D and E. Since operation of the VHRR real-time video link continuously over most of the orbit is desirable, available power considerations require that the S-band transmitter be as efficient as possible. The design approach proposed to achieve these objectives is described in the following section. Two identical transmitters will be provided for redundancy.

On command from a CDA station, the transmitter input will be switched from the VHRR real time data to transmit the Dual Multiplexer (playback) data to the CDA station. After completion of playback of the recorded data to the CDA station, the S-band transmitter will be switched back to transmit real time VHRR data. The transmitters will be designed for continuous operation. The principal specifications of the S-band transmitter are listed in Table IX-8.

b. DESIGN APPROACH

To increase the power level from the 2.0 watt minimum level of TIROS M/ITOS-1, and to increase the dc to rf efficiency, power amplification at 1.7 GHz will be used. The 2.0 watt unit from TIROS M/ITOS-1 (RCA 1975128) used power amplification at 500 MHz followed by a x3 multiplier. It is proposed to use the basic TIROS M/ITOS-1 unit with reduced power input and output as a driver for a two stage 1.7 GHz amplifier. It is estimated that such a driver unit will require less than 4 watts from the unregulated bus (-26 to -36V) to deliver 0.1 watt to the new amplifier. The first stage of the amplifier will raise the power level to 1.0 watt and the final stage to more than 5.0 watts (including losses for filtering and a circulator). Input to the amplifier (worst

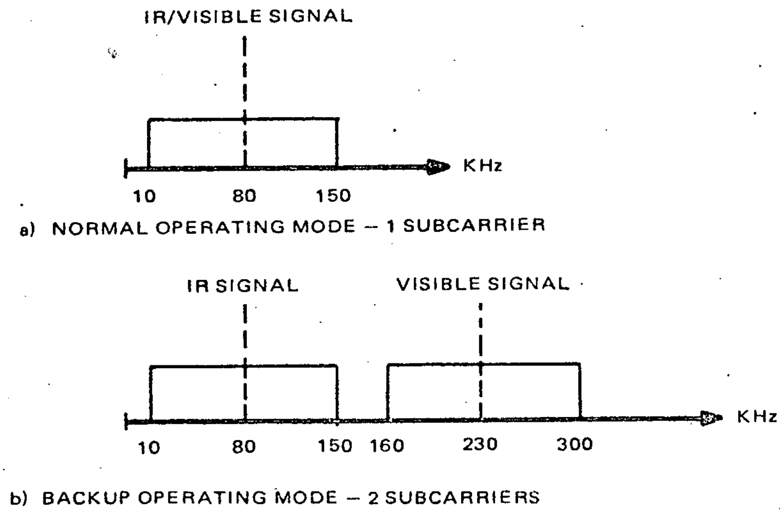


Figure IX-22. VHRR Processor, Output Spectrum

case) will not exceed 23 W at +28 V or 30 watts at -26 to -36 V. Adding the driver requirement of 4 watts, the total input power drain is less than 35 watts.

c. DESCRIPTION

The S-band transmitter will consist of three assemblies, the modified TIROS M/ITOS-1 driver, the S-band 5.0 watt amplifier and the +28V converter/regulator. Figure IX-23 is a block diagram of the S-band transmitter. As shown, the frequency-modulated oscillator (FMO) has a basic frequency of 76.567 MHz, and the crystal oscillator operates at 107.067 MHz. Spurious response is minimized by multiplying the crystal oscillator frequency six times (6 x 107.067 MHz = 642.402 MHz) before mixing with the FMO signal, and then taking the difference frequency from the mixer (642.402 MHz - 76.567 MHz = 565.835 MHz).

Carrier modulation is achieved by application of the modulating signal to a volatage-variable-capacitance diode which is connected across the tank circuit of a common base, modified Colpitts oscillator.

TABLE IX-8. ABBREVIATED SPECIFICATIONS OF ITOS D AND E S-BAND TRANSMITTER

Carrier Frequency	1697.5 MHz
Modulation	FM
Frequency Accuracy (-15°C + 65°C)	±.005%
Peak Deviation (1% linearity)	±1.5 MHz
Modulation Bandwidth (-1 dB)	10 kHz - 1 MHz
Spurious Outputs	
100-110 MHz	-70 dBm/50 kHz
110-140 MHz	-80 dBm/50 kHz
140-150 MHz	-90 dBm/50 kHz
Baseband Input Impedance	600 ±60 ohms, 40 pf
Output Load Impedance	50 ohms
RF Power Out (+5° to +35° C)	5.0 watts, minimum
Power Input: Maximum (-26 to -36v)	35.0 watts
Duty Cycle	Continuous
Weight (with +28V converter)	5.5 pounds

The crystal oscillator is also a common base, modified Colpitts oscillator. A fifth overtone crystal is used in the base to provide a low impedance signal path at the frequency of operation.

The frequency multiplier is driven into class C operation by the drive signal from the crystal oscillator. The tripler is followed by the doubler transistor which multiplies the signal frequency to 642.402 MHz.

The mixer is tuned to select the difference of the FMO and the sixth harmonic of the crystal oscillator. This is followed by a three-stage bandpass filter which will pass the sideband components of the modulating signal while reducing the spurious signals generated by mixing. The amplifier shown in the mixer-amplifier box consists of two stages of amplification. The output of the mixer-amplifier is 20 milliwatts.

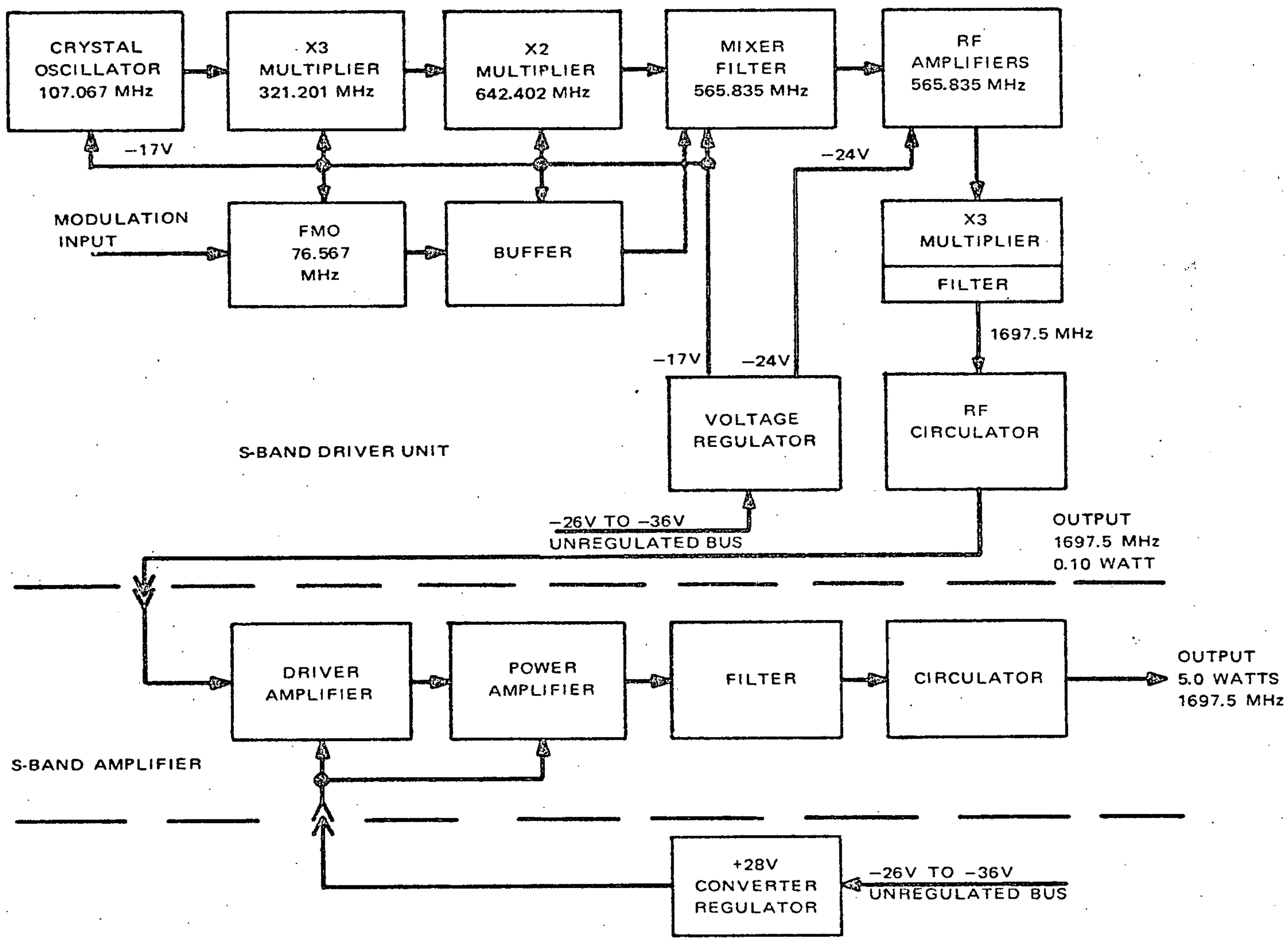


Figure IX-23. ITOS D and E S-Band Transmitter

The power amplifier contains three stages of amplification. The output level is 250 milliwatts at 565.833 MHz. A bias amplifier transistor provides a stable low impedance source. The first two amplifier stages are operated with the transistors in class A condition in the absence of signal, but each stage is driven into class C operation when the signal is applied. The last stage is operated with no bias applied and is driven into conduction by the drive signal. The rf amplifier is separated into two chassis to distribute gain and prevent oscillations.

In the multiplier-filter chassis, lumped constants are used for input matching, and coaxial cavities are used for output matching. A step recovery diode serves as the multiplier. The output filter contains four high-Q cavities. This filter prevents any spurious signal generated by the multiplying process from appearing with the output signal.

The purpose of the rf circulator at the output of the multiplier-filter is to isolate the output devices from load variations. The circulator has an internal load which is capable of continuously dissipating the reflected power if the rf output were open or short-circuited. The rf circulator also includes a telemetering network for monitoring rf power output.

The S-band amplifier receives a drive level of 0.1 watt from the driver unit. The driver amplifier raises this to 1.0 watt level and the power amplifier to a level providing over 5.0 watts output after the loss in the filter and circulator. A +28V converter and high efficiency regulator supply the S-band amplifier from the unregulated bus while the driver-modulator unit runs on the unregulated bus as in TIROS M/ITOS-1.

d. TELEMETRY

The hot spot temperature in the S-band driver amplifier and +28V supply will be telemetered. The rf output level of the amplifier will be telemetered as well as the +28V supply.

5. S-Band Antenna

At a satellite altitude of 790 nautical miles, the Earth subtends an angle of 108.8°. The spacecraft attitude pointing error is specified as ±1° maximum. The S-band antenna must, therefore, have a radiation pattern that covers nadir angles from 0° to 55.4°. For a given orbital altitude, there exists an ideal radiation pattern that provides a uniform power density at all ground stations regardless of the satellite elevation. The S-band antenna used in TIROS M/ITOS-1 is a near optimum solution for the gain and coverage requirements of the ITOS D and E mission, therefore this antenna will be used. Radiation from the antenna is right-hand circularly polarized.

The system requirement to operate with a 10-foot parabolic receiving antenna requires that radiated rf power be considerably increased over the TIROS M/ITOS-1 requirements. Available power considerations dictate that the S-band transmission system be as efficient as possible. For the ITOS D and E mission, therefore, two S-band antennas will be utilized, one coupled to each S-band transmitter. This eliminates the 3-dB splitting loss and the 0.15 dB insertion loss of the stripline hybrid coupler that was used to couple both transmitters to the same antenna in TIROS M/ITOS-1. The two S-band antennas will be mounted on the Earth-facing panel of the spacecraft.

The pattern radiated by the S-band antenna consists of radiation from the antenna assembly and, to a lesser degree, from induced spacecraft currents and reflections from protruding sensors. In order to determine the effect of the new sensor contours and antenna mounting locations on the antenna radiation characteristics, tests were made of the proposed ITOS D and E S-band antenna arrangement. These tests included measurement of the patterns of both S-band antennas, the VSWR of both antennas and the isolation between the two antennas. The results of these tests show the proposed antenna configuration to be acceptable and capable of meeting required mission per ormance. As compared with the TIROS M/ITOS-1 antenna, there is some attenuation of antenna gain in certain regions due to the projection of the spacecraft sensors into the fringes of the antenna field. This attenuation, however, is offset by the increase in transmitter power and the use of two antennas, which eliminates the hybrid coupler and its attendant loss. The results of the S-band antenna tests performed on the proposed ITOS D and E arrangement are given in Appendix D of this report.

6. Subsystem Analysis Summary

A complete treatment of the S-band real-time subsystem analysis and link calculations is given in Appendix C. The results of that analysis are summarized below:

a. Required ground receiver bandwidth (worst case) = 1.0 MHz*

b. RF margin above fm threshold (10 foot parabolic antenna, 1.5 dB noise-figure parametric amplifier front end) = 1.25 dB

c. Baseband peak-to-peak signal to rms noise (35 kHz bandwidth)

normal mode (phased VHRR mirrors) = 40.2 dB VIS, 40.8 dB IR

backup mode (two subcarriers) = 29.7 dB VIS, 29.8 dB IR

* Utilizing AFC tracking receiver

F. S-BAND PLAYBACK LINK

1. General

The S-band playback link (see Figures IX-24 and 25) is the major means of sensor data readout from the spacecraft to the CDA Stations. Information that has been recorded throughout the satellite orbit is played back on command and transmitted as one multiplexed signal on a 1697.5 MHz carrier. At the CDA Stations, this signal is demultiplexed, recorded and subsequently transmitted by land lines to NESC* at Suitland, Maryland.

There are three major sources of data for the S-band playback link: (a) the VHRR subsystem, (b) the SR subsystem, and)c) the digital data subsystem. In the normal mode of operation, time multiplexed infrared and visible signals from the two synchronously scanning VHRR sensors frequency modulate a subcarrier oscillator whose output is recorded by the VHRR recorder during a selected 9-minute period in the orbit.

The infrared and visible channel outputs of the operating SR sensor frequency modulate individual subcarrier oscillators, whose outputs are recorded on the same track of the operating SR recorder by individual heads which are physically displaced along the tape. The resulting time multiplexed signal is recorded continuously during the orbit period.

Digital signals, generated by the operating vertical temperature profile radiometer (VTPR) sensor and by the SPM sensor, are combined by the digital data processor (DDP) unit with digital housekeeping telemetry signals into a single digital data stream. This digital data is continuously recorded during the orbit period on a separate track of the operating SRR.

The VHRR recorder and any two of the three SRR on board the spacecraft may be played back simultaneously. During playback, the various data signals are combined in one of the redundant multiplexer sections to produce a composite frequency division multiplexed (FDM) signal having a spectrum from 11 to 501 kHz (see Figure IX-26).

The composite FDM spectrum frequency modulates the operating S-band transmitter. During the playback period, real-time transmission of VHRR data is inhibited. Each of the two redundant S-band transmitters is permanently connected to its own S-band antenna, which produces a right-hand circularly polarized wave.

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* National Environmental Satellite Center.

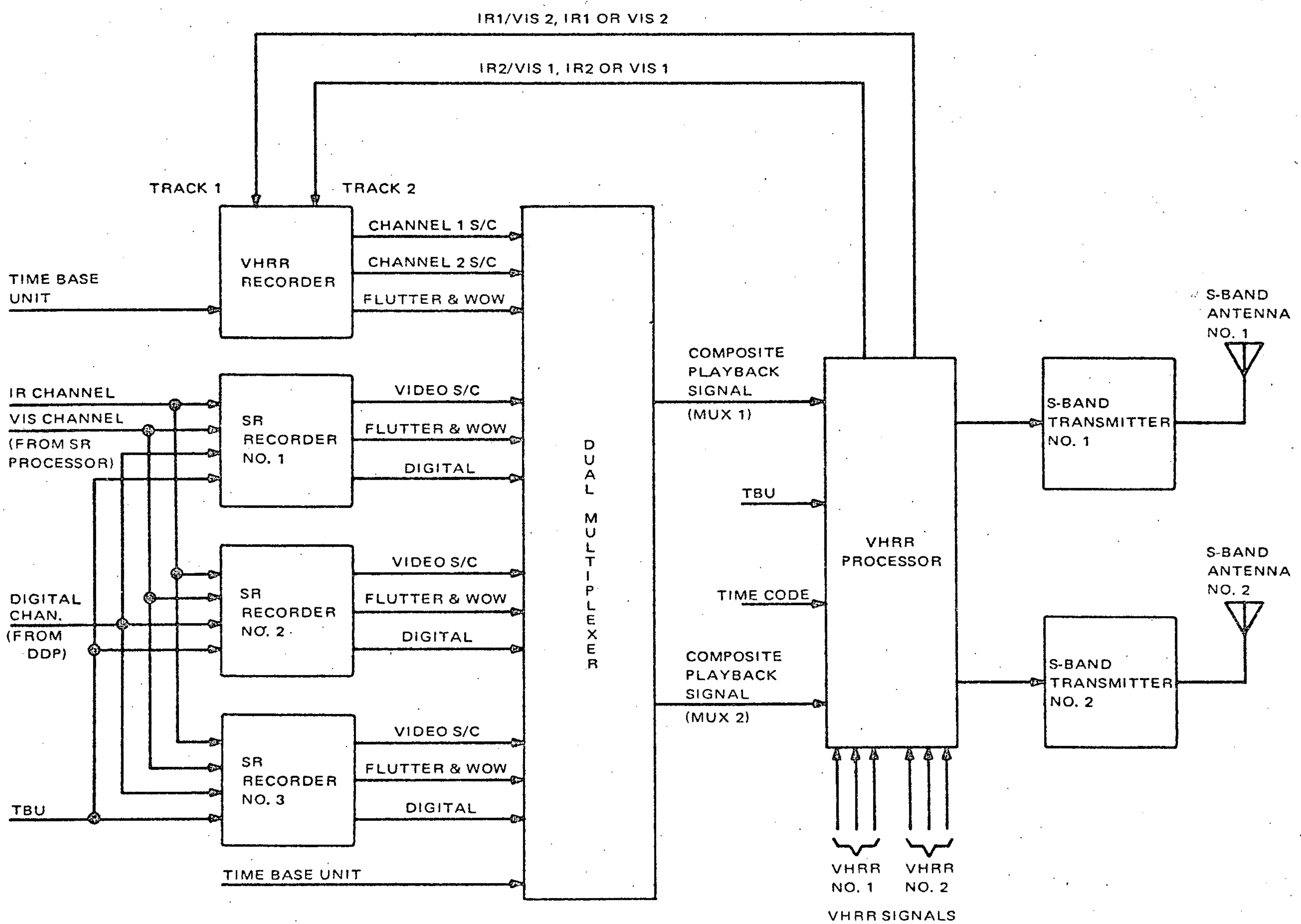

Figure IX-24. S-band Playback Link, Spacecraft Equipment, Block Diagram

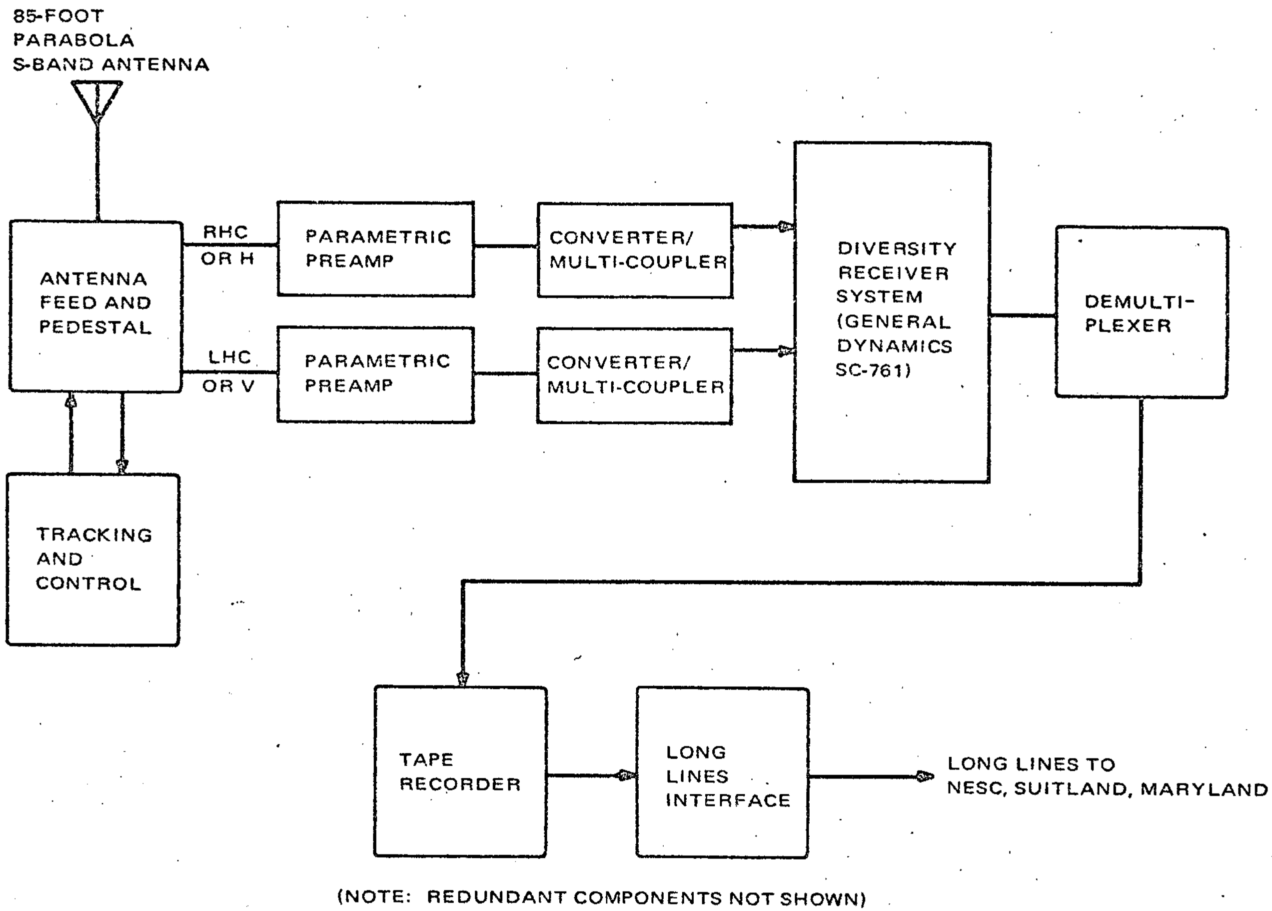

Figure IX-25. S-band Playback Link, CDA Station Equipment Block Diagram

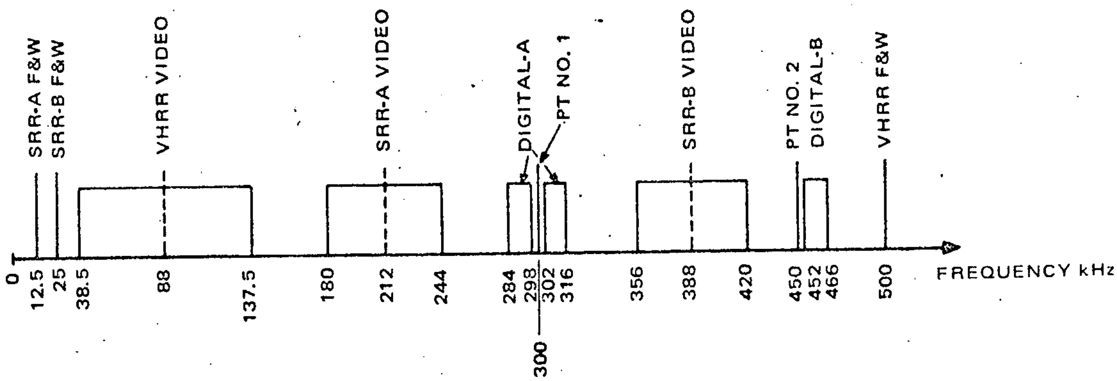

Figure IX-26. Composite Playback Spectrum

At the CDA Station, the S-band signal is received by the 85-foot diameter antenna and demodulated by an fm receiver. The individual data subcarriers are then demultiplexed, shifted to the desired output frequency bands, and recorded on a multi-channel tape recorder. The tape recorder is played back at reduced speed and the output is fed into leased long lines for transmission to Suitland, Maryland. There, the fm subcarriers are individually demodulated by fm discriminators into baseband signals. The baseband signals are sampled, corrected for tape recorder flutter, and converted into digital form for computer processing. The spacecraft digital data subcarriers are conditioned to remove transmission noise and jitter, and converted into the proper form for computer recovery of the original data.

2. Signal Characteristics

a. VHRR SIGNALS

The principal characteristics of the very high resolution radiometer (VHRR) signals have been described in Section IX, Paragraph E.2 of this report. When remote recording of VHRR signals is enabled by the programmer, the VHRR signals to the recorder are inhibited by the VHRR processor and several frames of spacecraft time code information are gated to the recorder at the beginning of the record cycle. In the normal mode of operation, the time-multiplexed composite video signal from the phased VHRR's is then fed to one of the VHRR recorder channels. In the backup mode of operation, the infrared channel signal from the active VHRR is fed to one of the VHRR recorder channels and the visible channel signal is fed to the other channel. The various VHRR modes of operation and resultant VHRR recorder channel assignments are shown in Table IX-9.

TABLE IX-9. VHRR RECORDER CHANNEL ASSIGNMENTS

VHRR Mode	VHRR Recorder Assignments	
	Channel 1	Channel 2
IR 1 - VIS 2 (phased radiometers)	IR 1/VIS 2*	not used
IR 2 - VIS 1 (phased radiometers)	not used	IR 2/VIS 1*
IR 1 - VIS 1 (backup mode)	IR 1	VIS 1
IR 2 - VIS 2 (backup mode)	VIS 2	IR 2
*Time multiplexed signal.		

In each VHRR recorder data channel, the composite video signal modulates a voltage-controlled oscillator to produce a 73.5 kHz black (or hot) level output, and a 102.5 kHz white (or cold) level output. A third track of the recorder is simultaneously fed an accurate 50-kHz unmodulated signal. This channel, called the flutter-and-wow channel, is frequency modulated by tape speed variations, and thus provides data for later ground correction of time base error of the video data channel.

When either of the VHRR recorder playback commands is received, the direction of tape motion is reversed and playback takes place. The tape speed during playback is the same as during record. Only one of the data channels of the VHRR recorder is played back. The playback modulated subcarrier from the selected recorder channel and the flutter-and-wow signals are then combined with the other playback signals in the active section of the dual multiplexer and then steered to the active S-band transmitter for modulation and transmission to the CDA Stations.

After reception and carrier demodulation by the CDA Station receiver, the signals are separated from the other playback signals by the ground demultiplexer. The instantaneous output frequency of the video channel is doubled in the demultiplexer to produce a frequency modulated spectrum of 112 to 240 kHz to the ground tape recorder. On playback, the ground tape recorder speed is reduced 8 to 1, thus reducing the signal spectrum to 14 to 30 kHz and the flutter-and-wow subcarrier to 6.25 kHz to enable transmission over the long lines to NESC. A summary of the signal parameters at the principal interfaces of the VHRR data channel is shown in Table IX-10.

b. SR SIGNALS

The principal characteristics of the SR signals, and the processing of these signals by the SRPR, have been described in Section IX D.2 of this report.

TABLE IX-10. VHRR CHANNEL SIGNAL PARAMETERS

Interface	Video Baseband (kHz)	Video S/C Center Frequency (kHz)	Video S/C Peak Deviation (kHz)	Video S/C Nominal Spectrum (kHz)	F&W S/C Center Frequency (kHz)	Notes
VHRR Sensor & Recorder Input	35	----	----	----	----	----
VHRR Recorder & Recorder Amplifier	35	88	±14.5	38.5 to 137.5	50	30 ips tape speed.
VHRR Recorder Playback Amplifier & MUX Input	35	88	±14.5	38.5 to 137.5	50	30 ips tape speed
MUX Output & DEMUX Input	35	88	±14.5	38.5 to 137.5	500	----
DEMUX Output & CDA Recorder Input	35	176	±29	112 to 240	50	60 ips tape speed.
CDA Recorder Output & Long Lines Input	4.38	22	± 3.62	14 to 30	6.25	7.5 ips tape speed.

One of the three SRR on board the spacecraft will usually be in the record mode of operation. The processed IR and visible channel outputs of the SRPR are supplied to individual voltage-controlled oscillators in the selected recorder to produce a 3.58 kHz black (or hot) level output, and a 4.86 kHz white (or cold) level output. The outputs of the two voltage-controlled oscillators are simultaneously gated to two record heads, located at different positions along the data track, as described in Section IX.D.4. The resultant information on the tape is a time multiplexed interleaving of IR and visible earth scan data.

A second track of both recording heads of the SRR is simultaneously fed an accurate 1.2 kHz unmodulated signal. The recording amplifier feeding this track is gated on and off to both heads in synchronism with the video subcarrier data so that the reference tone and the video subcarrier are recorded on the same relative positions of the tape at the same time. The signals on this track, called the flutter-and-wow channel, are frequency-modulated by tape speed variations, and thus provide data for later ground correction of time base error of the video data channel. If recording continues until the end-of-tape is reached, the operating recorder will stop, and a second SRR, selected by the previously set up selection logic in the CDU, will automatically start recording.

Any two of the three SR recorders on board the spacecraft may be played back simultaneously. When the playback command is received from the CDA Station, the direction of tape motion is reversed and playback occurs. Playback tape speed is 20.833 times the record tape speed and the instantaneous frequencies are therefore multiplied by this factor during the playback mode. The 1.2-kHz flutter-and-wow carrier is translated to 25 kHz plus or minus the small deviation caused by tape speed variations. The spectrum of the modulated SR video subcarrier is translated to, 56 to 120 kHz. All data channels of the two selected SRR are played back simultaneously. The signals are combined with the other playback signals in the active section of the dual multiplexer and then steered to the active S-band transmitter for modulation and transmission to the CDA Stations.

After reception and carrier demodulation by the CDA station receiver, the signals are separated from each other and from the other playback signals by the ground demultiplexer. The various signals are then recorded on a multi-track recorder. On playback, the ground tape recorder speed is reduced 4 to 1, thus reducing the video signal spectrum to, 14 to 30 kHz and the flutter-and-wow subcarrier to 6.25 kHz to enable transmission over the long lines to NESC. A summary of the signal parameters at the principal interfaces of the SR data channels is shown in Table IX-11.

c. DIGITAL DATA SIGNALS

The spacecraft DDP combines the VTPR sensor data, the SPM sensor data, digital housekeeping telemetry data and spacecraft time code information into a single digital data stream. The output data rate of the DDP is 512 bits second. A split phase change (biphase) output signal format was selected to eliminate dc and low-frequency components from the data stream to facilitate recording and to prevent interference with recovery of the reference tones by the ground demultiplexer. The content of the digital data stream is described in detail in Section VII of this report.

The digital signal is directly recorded on a separate track of the operating SRR. The corresponding playback bit rate is 20.833 x 512 = 10.667 K bits/second. The optimum bandwidth required from the point of view of intersymbol interference is of the order of 1.4 times the bit rate. A bandwidth of 1.5 times the bit rate has been selected for the digital channels. Significant spectrum components in playback thus extend from approximately 2 to 16 kHz.

In the playback mode, the digital data channels from the two SRR (in playback) are translated in frequency by two separate pilot tones in the active section of the dual multiplexer. The signals are then combined with the other playback signals in the multiplexer and then steered to the active S-band transmitter for modulation and transmission to the CDA stations.

TABLE IX-11. SR CHANNEL SIGNAL PARAMETERS

Interface	Video Baseband	Video S/C Center Frequency (kHz)	Video S/C Peak Deviation (kHz)	Video S/C Nominal Spectrum (kHz)	F&W S/C Center Frequency (kHz)	Notes
SR Sensor & Recorder Input	900 Hz VIS 450 Hz IR	----	----	----	----	----
SR Recorder & Record Amplifier	900 Hz VIS 450 Hz IR	4.22	± 0.639	2.68 to 5.76	1.2	1.30 ips tape speed.
SR Recorder Playback Amplifier & MUX Input	18.75 kHz VIS 9.38 kHz IR	88	±13.25	56 to 120	25	27.1 ips tape speed.
MUX Output & DEMUX Input	18.75 kHz VIS 9.38 kHz IR	212 MUX Channel A / 388 MUX Channel B	±13.25	180 to 244 MUX Channel A / 356 to 420 MUX Channel B	12.5 MUX Channel A / 25 MUX Channel B	
DEMUX Output & CDA Recorder Input	18.75 kHz VIS 9.38 kHz IR	88	±13.25	56 to 120	25	60 ips tape speed.
CDA Recorder Output & Long Lines Input	4.7 kHz VIS 2.35 kHz IR	22	±3.3	14 to 30	6.25	15 ips tape speed.

After reception and carrier demodulation by the CDA station receiver, the signals are separated from the other playback signals by the ground demultiplexer. The pilot tones are recovered by means of phase-locked loops. This permits translation of the received signals back to baseband with frequency and phase synchronism, thus preserving the signal waveshape.

The baseband signals are then recorded on a multitrack recorder. The signals are played back, one at a time, at the same speed as recorded. The playback signal is translated by a 30-kHz pilot tone in a Long-Lines Digital Interface Unit in order to occupy a signal spectrum of 14 to 30 kHz, suitable for transmission over the long lines wideband channel to NESC. At the NESC end of the long lines, the signal is translated back to baseband by the 30-kHz pilot tone which is recovered by means of a phase-locked loop, thus preserving signal waveshape. The baseband signal is then conditioned to reconstruct the waveform, remove noise and jitter and convert the signal to a suitable format for computer processing and separation of the data.

A summary of the signal parameters at the principal interfaces of the digital data channels is shown in Table IX-12.

TABLE IX-12. DIGITAL CHANNEL SIGNAL PARAMETERS

Interface	Bit Rate	Signal Format	Nominal Spectrum	Remarks
DDP Output & SR Recorder Input	512 b/s	Biphase Digital	102 to 770 Hz	1.30 ips tape speed.
SR Recorder Output & MUX Input	10.667 kb/s	Biphase Digital	2 to 16 kHz	27.1 ips tape speed.
MUX Output & DEMUX Input	10.667 kb/s	Biphase DSB-SC & Pilot Tone	284 to 316 kHz MUX Channel A	300-kHz Pilot Tone Reference Double Sideband
		Biphase Modulated SSB-SC & Pilot Tone	452 to 466 kHz MUX Channel B	450 kHz Pilot Tone Reference Single (Vestigial) Sideband
DEMUX Output & CDA Recorder Input	10.667 kb/s	Biphase Digital	2 to 16 kHz	60 ips tape speed.
CDA Recorder Output & Translator Input (CDA)	10.667 kb/s	Biphase Digital	2 to 16 kHz	60 ips tape speed.
Translator Output (CDA) & Long Lines Input	10.667 kb/s	Biphase Modulated SSB-SC & Pilot Tone	14 to 30 kHz	30-kHz Pilot Tone Reference
Translator Output (Suitland)	10.667 kb/s	Biphase Digital	2 to 16 kHz	To EMR 2720 or 2721 signal conditioner and computer.

3. Dual Multiplexer

The ITOS D and E dual multiplexer (MUX) combines the signals from the VHRR recorder and up to two of the three SRR into a single broadband frequency division multiplexed spectrum with minimum distortion and crosstalk. There are two identical multiplexers in the MUX, only one of which is powered by the CDU at any given time. The outputs of the MUX are sent to the VHRR processor, where the active output is then sent, during the playback mode, to modulate either of the two S-band transmitters. The routing of the selected MUX output to the selected S-band transmitter input is accomplished in the VHRR processor. The VHRR processor also selects whether playback data from the MUX or real-time VHRR data is to be transmitted by the S-band transmitter.

The ITOS D and E mission requirements which represent changes from the TIROS M-1 ITOS-1 mission requirements and which necessitate changes in the present MUX are: (1) an effective increase in the SR resolution capability achieved by an increase in the baseband video bandwidth, (2) additional operational requirements to select signals from any two of the three SRR for processing by the two SR MUX channels, (3) the requirement to record the digital data from the DDP on a separate track of the SRR and to process this data through the MUX on playback, and (4) replacement of the AVCS with the VHRR, which has a smaller video bandwidth. A listing of the signals that must be accommodated by the MUX is given in Table IX-13.

Only two of the three SRR may be played back simultaneously through the MUX. Figure IX-27 shows schematically how the signals from the three SRR are selected. The SRR No. 1 signals are hardwired to the SRR-A video, flutter-and-wow and digital MUX channels, while the SRR No. 3 signals are hardwired to the SRR-B channels. The routing of the SRR No. 2 signals to either the SRR-A or SRR-B set of channels is controlled by two signals from the CDU. These control signals, designated "Select SRR No. 2 but not SRR No. 1" and "Select SRR No. 2 but not SRR No. 3", are derived from the SRR playback commands and activate analog switches in the MUX which route the SRR No. 2 signals to the proper MUX channels. Table IX-14 lists the various SRR playback selection combinations and describes which SRR signals will be present in each MUX SRR channel.

The MUX input signals are buffered from the two redundant multiplexer sections and the redundant inputs are also buffered from each other. This isolation insures that a failure in one of the redundant sources or redundant multiplexer sections does not degrade the operation of the rest of the system. As in the TIROS M/ITOS-1 unit, this isolation is accomplished by one-and two-input, two-output cross-strapped resistive Pi networks.

The MUX relocates the spectrum of each input signal to a different frequency range by linear translation or frequency division. These relocated signals are then linearly added to form the composite FDM signal spectrum shown in Figure IX-26. Figure IX-28 is a block diagram of one of the redundant sections of the MUX. This configuration represents the system which requires the least amount of change from the TIROS M/ITOS-1 configuration while meeting the specified performance criteria. Table IX-15 summarizes the principal characteristics of the output signals from the MUX. Two pilot tones, one at 300 kHz and another at 450 kHz are transmitted in order to provide an exact phase reference for coherent demultiplexing of the digital data signals.

TABLE IX-13. MUX INPUT SIGNALS

Signal Designation	Signal Type	Center Frequency (kHz)	Peak Dev. (kHz)	Baseband BW (kHz)	Bit Rate (k bits/sec)	Nominal Spectrum (kHz)
VHRR Video	FM Subcarrier	88.0	14.5	35.0	---	38.5 to 137.5
VHRRR F&W	FM Subcarrier	50.0	0.3*	0.5	---	49.2 to 50.8
SRR #1 Video	FM Subcarrier	88.0	13.25	18.75 (VIS) 9.38 (IR)	---	56.0 to 120.0
SRR #1 F&W	FM Subcarrier	25.0	0.15*	0.5	---	24.3 to 25.7
SRR #1 Digital	Biphase Digital	---	---	16.0	10.667	2.0 to 16.0
SRR #2 Video	FM Subcarrier	88.0	13.25	18.75 (VIS) 9.38 (IR)	---	56.0 to 120.0
SRR #2 F&W	FM Subcarrier	25.0	0.15*	0.5	---	24.3 to 25.7
SRR #2 Digital	Biphase Digital	---	---	16.0	10.667	2.0 to 16.0
SRR #3 Video	FM Subcarrier	88.0	13.25	18.75 (VIS) 9.38 (IR)	---	56.0 to 120.0
SRR #3 F&W	FM Subcarrier	25.0	0.15*	0.5	---	24.3 to 25.7
SRR #3 Digital	Biphase Digital	---	---		10.667	2.0 to 16.0
TBU	Reference	300.0	---	---	---	Square Wave

*2 σ value

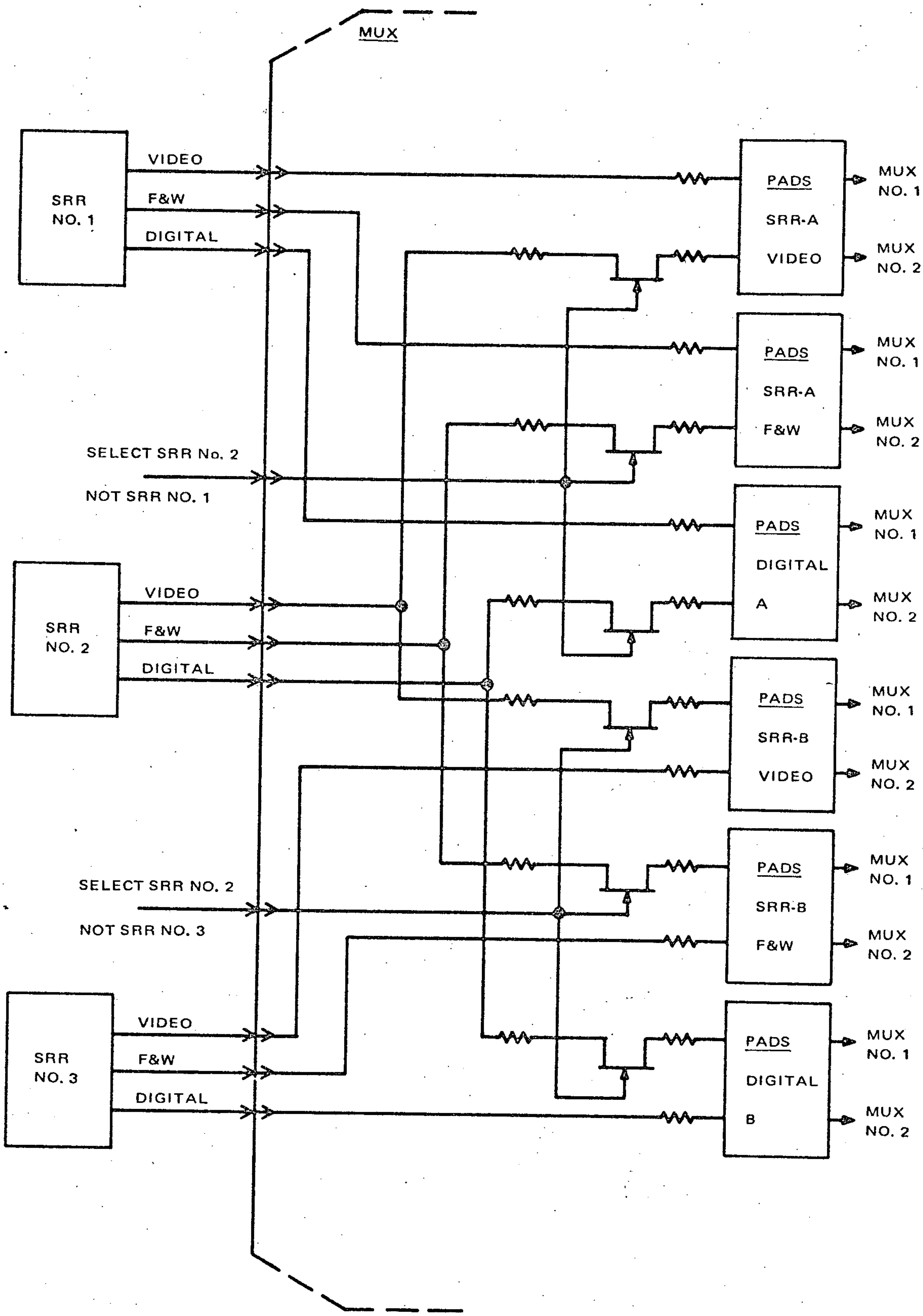

Figure IX-27. SR Recorder — MUX Interface

TABLE IX-14. SRR PLAYBACK SELECTION MODES

Playback Mode Selected	Signals Present in MUX Channel					
	SRR-A Video	SRR-A F&W	Digital A	SRR-B Video	SRR-B F&W	Digital B
SRR No. 1 Only	SRR No. 1 Video	SRR No. 1 F&W	SRR No. 1 Digital	No Signal	No Signal	No Signal
SRR No. 2 Only	SRR No. 2 Video	SRR No. 2 F&W	SRR No. 2 Digital	SRR No. 2 Video	SRR No. 2 F&W	SRR No. 2 Digital
SRR No. 3 Only	No Signal	No Signal	No Signal	SRR No. 3 Video	SRR No. 3 F&W	SRR No. 3 Digital
SRR No. 1 and SRR No. 2	SRR No. 1 Video	SRR No. 1 F&W	SRR No. 1 Digital	SRR No. 2 Video	SRR No. 2 F&W	SRR No. 2 Digital
SRR No. 1 and SRR No. 3	SRR No. 1 Video	SRR No. 1 F&W	SRR No. 1 Digital	SRR No. 3 Video	SRR No. 3 F&W	SRR No.3 Digital
SRR No. 2 and SRR No. 3	SRR No. 2 Video	SRR No.2 F&W	SRR No. 2 Digital	SRR No. 3 Video	SRR No. 3 F&W	SRR No. 3 Digital

The filters required for the proposed MUX configuration are all realizable. All of the filter requirements can be fulfilled by 5-stage Cauer filters having 0.028 dB passband ripple and 50 dB minimum stopband attenuation. These filters have been chosen to make the delay equalization required on the ground demultiplexer as simple as possible.

The output cross-strapping function present in the TIROS M/ITOS-1 MUX is not necessary in the ITOS D and E MUX, since the VHRR processor has the function of selecting which of the two MUX outputs or which of the real-time VHRR signals are to be sent to the active S-band transmitter.

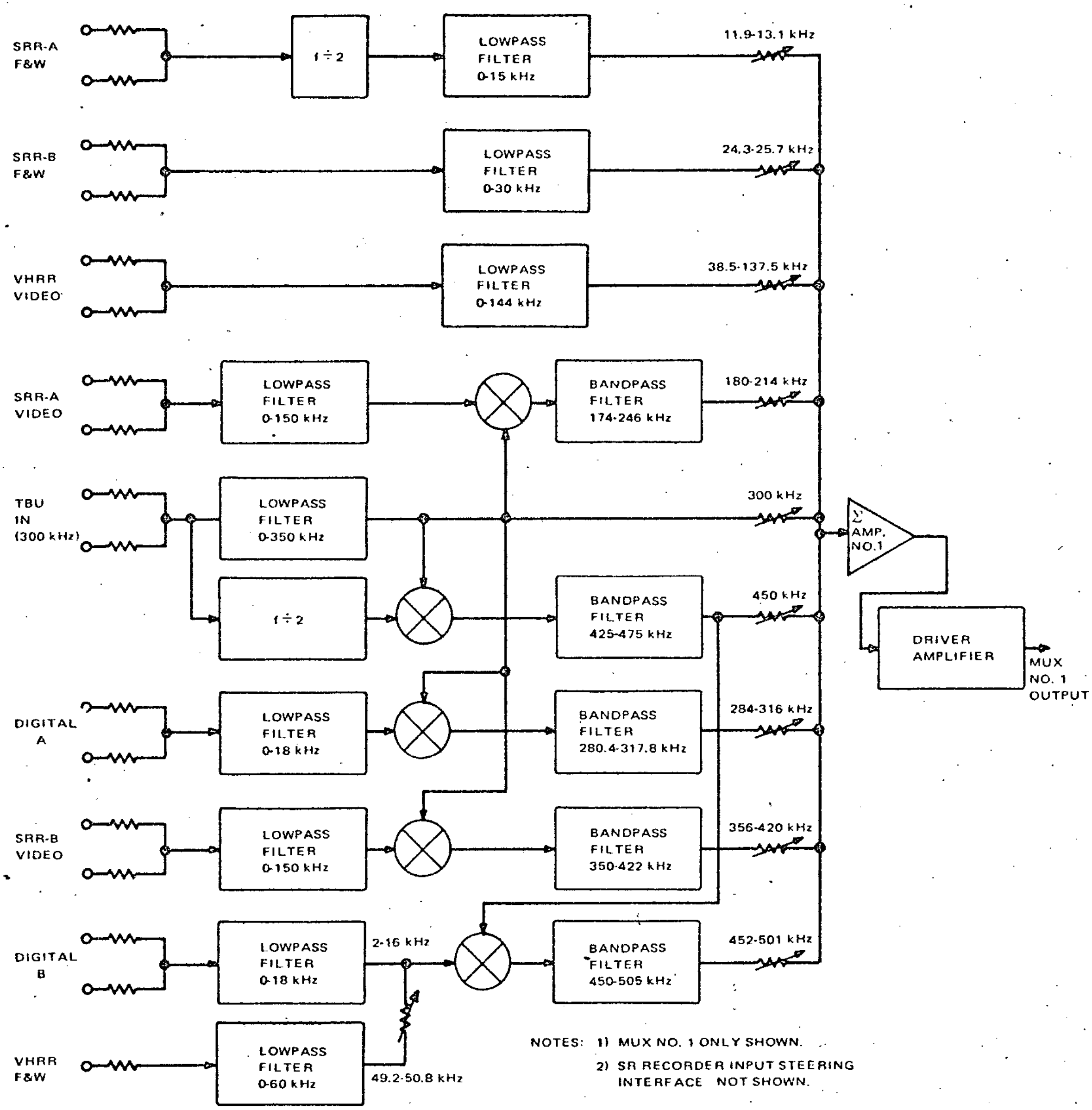

Figure IX-28. Dual Multiplexer, Block Diagram

TABLE IX-15. MUX OUTPUT SIGNALS

Signal Name	Nominal Input Frequency Spectrum (kHz)	Nominal Output Frequency Spectrum (kHz)	Relative Amplitude
SRR-A F&W	24.3 to 25.7	11.9 to 13.1	25
SRR-B F&W	24.3 to 25.7	24.3 to 25.7	25
VHRR Video	38.5 to 137.5	38.5 to 137.5	160
SRR-A Video	56 to 120	180 to 244	160
Pilot Tone No. 1	300	300	25
Digital A	2 to 16	284 to 316	80
SRR-B Video	56 to 120	356 to 420	285
Pilot Tone No. 2	450	450	35
Digital B	2 to 16	452 to 466	80
VHRR F&W	49.2 to 50.8	499.2 to 500.8	50

4. S-Band Transmitter

The characteristics of the S-band transmitter have been described in Section IX.E.4 of this report. The carrier deviations assigned to each of the playback subcarriers are listed in Table IX-16. The required peak carrier deviations is 925 kHz.

TABLE IX-16. S-BAND CARRIER DEVIATIONS AND RESULTANT RF LINK BASEBAND S/N RATIOS

Channel	S/C Center Frequency (kHz)	Peak Carrier Deviation (kHz)	Rf Link Baseband S/N p-p/rms (dB)
SRR-A F&W	12.5	25	62.0
SRR-B F&W	25	25	62.0
VHRR Video	88	160	47.2
SRR-A Video	212	160	47.1 VIS 56.1 IR
Pilot Tone No. 1	300	25	53.1
Digital-A	300	80	38.1
SRR-B Video	388	285	46.8 VIS 55.9 IR
Pilot Tone No. 2	450	35	52.5
Digital-B	460.7	80	37.4
VHRR F&W	500	50	48.0

5. S-Band Antenna

The characteristics of the S-band antennas have been described in Section IX of this report.

6. Subsystem Analysis Summary

A complete treatment of the S-band playback subsystem analysis and link calculations are given in Appendix C. The results of that analysis are summarized below:

- Required receiver bandwidth (worst case) = 2.9 MHz.
- Rf margin above fm threshold at CDA station (85-foot parabolic antenna, 3.0 MHz if bandwidth, 5-degree elevation) = 11.9 dB.
- Baseband peak-to-peak signal to noise ratios due to rf link contributions only. See Table IX-16.
- Overall baseband peak-to-peak signal-to-noise ratios. See Table IX-17.

TABLE IX-17. OVERALL BASEBAND SIGNAL-TO-NOISE RATIOS OF PLAYBACK VIDEO CHANNELS

Channel	Equivalent Sensor Baseband Bandwidth (kHz)	Baseband S/N Ratio (p-p signal/rms noise)
VHRR Video	35	36 dB
SRR Video		
IR data	0.45	37 dB
VIS data	0.90	36 dB

SECTION X
SPACECRAFT TESTING

A. ITOS D AND E TEST PHILOSOPHY

The general test plan for ITOS D and E, at the unit and spacecraft levels, will be similar to the TIROS M test plan. During the manufacturing cycle, each unit of the spacecraft will be tested under environmental conditions exceeding those expected in flight in order to demonstrate its flight worthiness. These tests are designed to obtain the maximum required data with a minimum of operation time, without endangering the required life of the units through overtesting. These operational verification tests demonstrate that the units will operate within design performance limits after exposure to specified temperature, vibration, and thermal-vacuum testing. Detailed information for the Alignment and Calibration Book will be obtained during this test phase.

The units and subsystems will be subjected to a test sequence outlined in general terms in Figure X-1. The vibration levels and durations, and the temperature levels that the units will be exposed to are outlined in each units's detailed performance specification. As far as possible, the unit test will demonstrate unit operation such that spacecraft measurements can be readily related back to these tests.

B. SPACECRAFT QUALIFICATION TESTING

1. Test Flow

Spacecraft integration testing consists of (a) the mechanical and electrical integration of the qualified subsystems on the spacecraft assembly and (b) the calibration and environmental qualification of the integrated spacecraft as a complete system. A detailed flow diagram of the spacecraft test program is presented in Figure X-2.

All operations performed during spacecraft integration, test and calibration were designed to demonstrate the proper performance characteristics of the spacecraft while not compromising flight equipment through overtesting.

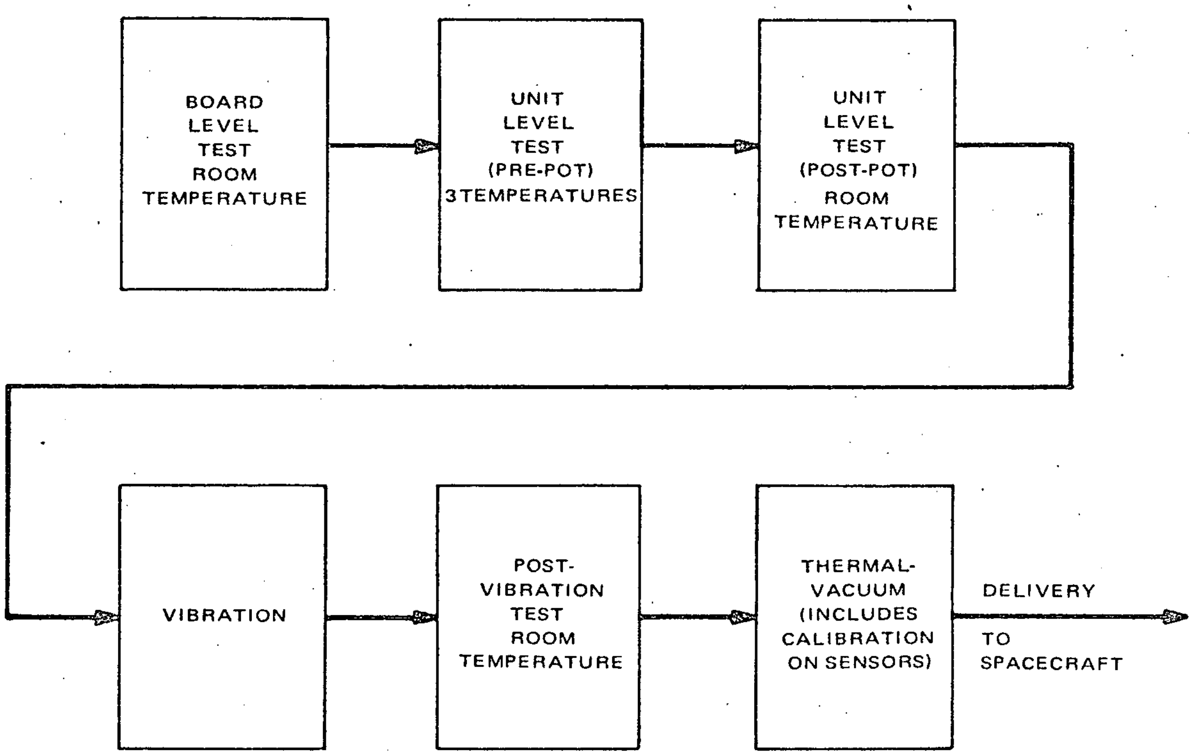

Figure X-1. General Unit Test Flow

2. Vibration

ITOS D and E spacecrafts will be exposed to sinusoidal and random vibration in three axes, as were the TIROS M spacecraft. ITOS D will contain sufficient instrumentation to allow a complete survey of the vibration levels throughout the spacecraft. ITOS E instrumentation will be limited to the g-level notching and accelerometer package readout similar to the test instrumentation employed on the ITOS A, B, and C spacecraft.

The test conditions for the sinusoidal vibration test of the spacecraft are given in ITOS test procedure TP-V-1975000. ITOS D will be exposed to prototype levels at flight sweep rates; ITOS E to flight levels and rates.

3. Thermal-Vacuum Tests

The vacuum pressure for spacecraft thermal-vacuum tests will not be greater than 5×10^{-5} mm Hg. The temperature levels to which the spacecraft will be exposed are given in Table X-1.

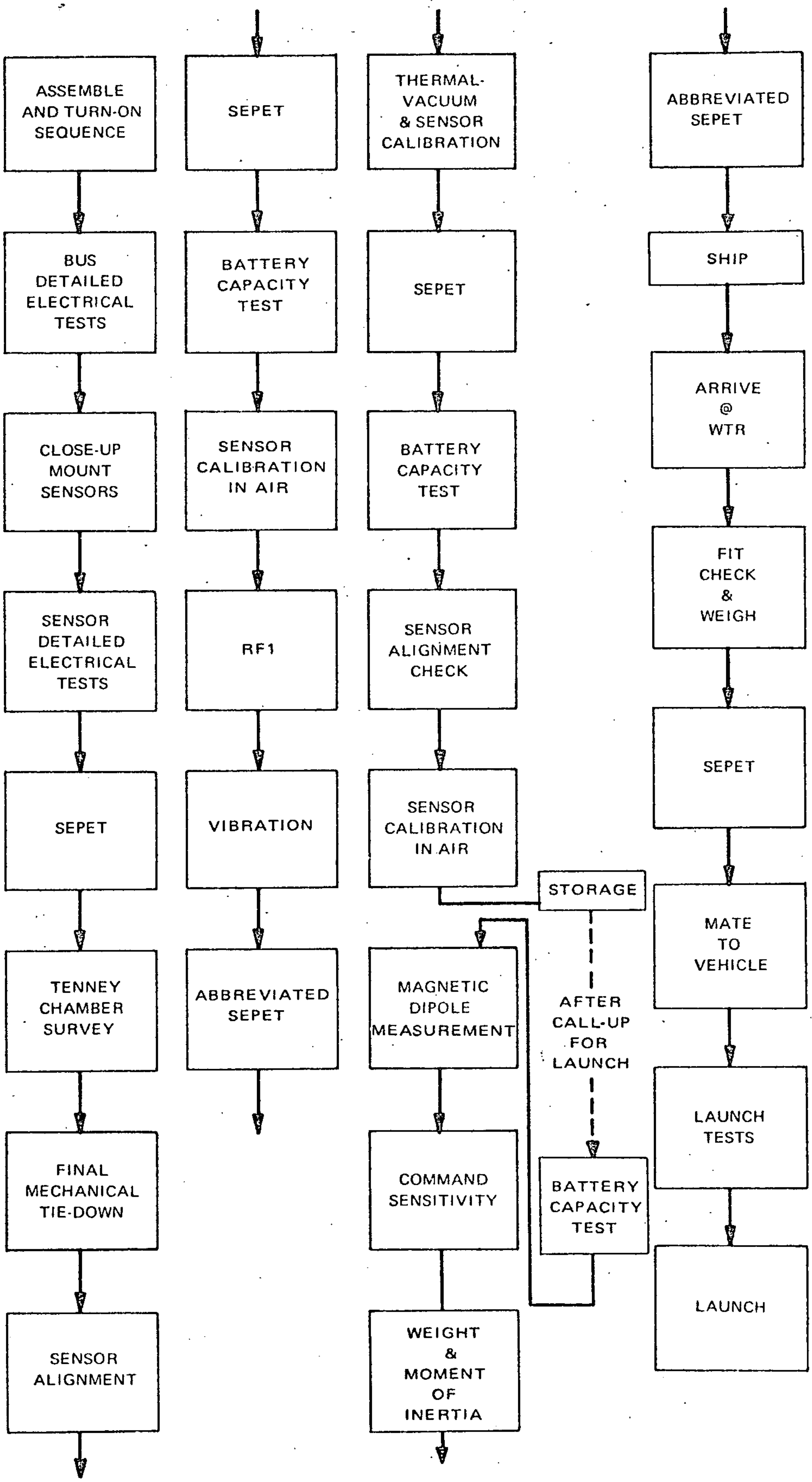

Figure X-2. ITOS D and E Spacecraft Test and Calibration Program

TABLE X-1. TEMPERATURES AND DURATIONS FOR THERMAL-VACUUM TESTING

Temperature °C	Duration (Hours)
+40	24
- 5	24*
+35	24
0	24
+ 5	48*
+15	168*
+25	24*
+30	24

*Calibration Check

A calibration check of the spacecraft sensors will be made at temperature plateaus of -5°, +5°, +15°, and +25°. This check consists of two simulated orbits during which the sensor target characteristics are monitored while sensor outputs are measured. The measurements are then correlated with vendor-provided calibration data. Magnetic tape recordings of calibration data will be supplied to NESC for processing by the data handling system.

In addition to the qualification thermal-vacuum test, ITOS D will undergo an all-up thermal test. This test will simulate the thermal conditions of the mission and serve as a thermal design verification. Both the 45° beginning of life and the 45° acquisition-standby sun angles will be simulated and spacecraft temperature measurements will be correlated to the computer model predictions.

4. Test Implementation

The spacecraft test program starts with the assembly and integration of the various units into a complete spacecraft. Following successful integration, the Prequalification Alignment and In-air Calibration phase is entered. This data is used for comparison with post-environmental data to evaluate any possible equipment degradation due to environmental exposure.

Environmental qualification consists of vibrating a flight-configured spacecraft, followed by the thermal-vacuum test cycle. During the thermal-vacuum test, sensor calibration is checked.

The post-qualification tests establish that the spacecraft has suffered no degradation and is in a satisfactory state for launch.

a. SPACECRAFT INTEGRATION

As shown in Figure X-2, the first portion of the spacecraft test program is the mechanical and electrical integration of the qualified subsystems into the spacecraft assembly. Since each unit is tested before integration, tests at the spacecraft level are designed to eliminate interface problems between the various subsystems.

The first phase of the integration cycle is the installation of the main electrical harness on the baseplate and the performance of a complete electrical continuity test. Spacecraft units are not connected to the main harness until the proper electrical configuration is verified. Before any unit is connected to the harness, its complete interface is given a final check.

An orderly sequence of integration has been established to prevent catastrophic spacecraft malfunctions. The first electronic components connected to the main electrical harness are the units of the power supply subsystem. When installed and connected, a functional check of the power supply subsystem is performed to ensure that a safe and satisfactory power source is available for the units of the remaining spacecraft subsystems.

After the power supply subsystem has been checked and found to be operating satisfactorily, the command subsystem is integrated. Functional tests are performed on this subsystem to ensure that a safe and reliable command facility is available. Next, the communications subsystem is connected, and the same functional checking process is performed. The vehicle dynamics subsystem is then integrated, followed by integration of the sensor subsystems.

After the subsystems have been functionally checked and the spacecraft is assembled, a thorough system-by-system detailed check is performed of the spacecraft in all operational modes. After all subsystem interfaces are verified, a Spacecraft Electrical Performance Evaluation Test (SEPET) is performed. This demonstrates the satisfactory performance of all spacecraft subsystems by measuring specific parameters and by operating the spacecraft to simulate orbital operation. After the SEPET, the spacecraft undergoes thermal (Tenney Chamber) test. With the chamber held at the thermal-vacuum temperature extremes, the spacecraft is operated in simulated orbits. Specific measurements are made at each temperature. After the thermal test is complete, the spacecraft is subjected to the qualification and calibration cycle.

b. PREQUALIFICATION ALIGNMENT AND CALIBRATION

The first test performed in this phase of spacecraft testing is a check of sensor alignment with respect to the spacecraft pitch axis. Next, spacecraft balance and moment of inertia are measured.

Next, a complete SEPET is performed and the data from these tests establishes a standard for evaluating the effects of the environmental qualifications phase on the overall performance characteristics of the spacecraft. In addition, an Abbreviated SEPET is performed after each environmental exposure to ensure that no spacecraft degradation is encountered.

After the SEPET, the battery packs are subjected to a conditioning cycle and their energy capacity is measured. Those portions of sensor calibration which can be done in an air environment are performed next. (Primary IR calibration for the sensors is checked in vacuum). With the spacecraft in flight configuration, rf interference testing is performed. When the spacecraft passes this test, the environmental qualification phase begins.

c. ENVIRONMENTAL QUALIFICATION

Following sensor calibration, the spacecraft is vibrated in three axes with both sinusoid and random excitation. System operation during vibration testing is limited to those units which operate during launch. A solar panel deployment check is performed before and after vibration. After vibration exposures, an Abbreviated SEPET is performed.

After completion of the Abbreviated SEPET, the spacecraft is prepared for the thermal-vacuum test cycle. During evacuation of the thermal-vacuum chamber, the spacecraft is operated in the launch configuration. During the thermal-vacuum test cycle (see Table X-1), specific spacecraft operating parameters are measured daily to ascertain performance in the simulated orbital environment. The main program of spacecraft operation throughout the thermal-vacuum profile duplicates orbital operation. At selected thermal plateaus, a check of sensor IR calibration at several point, is made and compared to vendor data. The satisfactory completion of thermal-vacuum testing terminates the environmental qualification phase of the spacecraft test program.

d. FINAL SPACECRAFT CALIBRATION

After completion of the thermal-vacuum tests, final calibration of the spacecraft is performed. The final calibration cycle is initiated with the performance of a complete SEPET. At this time, battery capacity tests are performed and the solar array panels are retested in the solar illuminator. Sensor alignment is verified and sensor calibration in the air environment is performed.

If a launch is not imminent, the spacecraft is put into storage. After storage, a battery capacity test is performed. The spacecraft is then taken to the magnetic test site, where magnetic dipole measurements are made. A trimming magnet is installed to produce the proper residual dipole moment. Next, the rf command sensitivity and final rf interference are measured on the rf test range. Command sensitivity is measured with the solar array panels in both the stowed and deployed positions. Next, spacecraft weight and moment of inertia are measured. The final abbreviated SEPET is performed on the spacecraft prior to preparation for shipment to the launch site.

At the launch site, the first operation is to perform a Go/No Go test to quickly determine that the spacecraft has survived the shipment. Next, the spacecraft is weighed and fit-checked with the flight attach fitting. Following the fit check, a SEPET is performed followed by arming of the pyrotechnic devices. The spacecraft is then mated to the launch vehicle and launch checks are performed periodically as the vehicle is prepared for launch. Following the final launch check, the flight enable plugs are inserted and checked.

5. Test Equipment

The changes required to the special test equipment and to the CDA and checkout stations are outlined below.

a. SPACECRAFT TEST CONSOLE

The spacecraft test console is a test unit which is used for hardlined testing of the TIROS M and ITOS D and E spacecraft configurations. In the overall testing scheme, console supports the associated ground stations by providing spacecraft test points, prime power, lamp displays of spacecraft operation, and other minor control and monitoring functions.

Three test consoles are in use at AED. One of the three is used as required at the launch site. The following modifications will be incorporated into the existing units to enable them to be used for testing either the TIROS M or the ITOS D and E spacecraft.

1) Lamp Display - An independent ITOS D and E lamp display module will be provided. Additional logic in the existing chassis will enable operation with either display. The display changeover is a 5-minute operation.

2) Patchboard - An independent ITOS D and E patchboard will be provided. The patchboard will contain an interlock, through the spacecraft, to identify ITOS D and E spacecraft operation.

3) Events Recorder - A removable legend plate will be provided. Additional logic is necessary.

4) Elapsed Time Meters - The number will be increased to eight; two each for VHRR, VTPR, SR, and Pitch Loop Motors. Since five of the meters are used in TIROS M operation, a removable function plate will be provided.

In order to simplify the design, dc rather than ac meters will be used throughout.

5) Legend Plates - Removable test point legend plates will be provided for TIROS M and ITOS D and E operation.

6) Real-Time Clock - The counters for TIROS M picture and QOMAC program times will be replaced by a real-time clock which is slaved to the associated ground station.

b. TARGET CONTROL RACK

The TIROS M target control rack is used to supply power to the Pitch and Roll Targets, the SR targets and the DSAS target. In addition, it provides temperature monitoring capabilities for these targets.

Another target control rack will be required for ITOS D and E to power the VHRR targets and the VTPR targets. A temperature recorder/printer will be mounted in this rack to provide the additional temperature monitoring for these new targets.

A more complete discussion of the ITOS D and E targets is included in the discussion of the thermal-vacuum test configuration.

c. DATA REDUCTION COMPUTER

The present data reduction computer has two functions in the spacecraft test program:

- Presents the analog telemetry frame as a decimal number list. It also has the facility to check telemetry channels against pre-programmed limits.

- Reduces the solar proton monitor data to engineering units and performs frame-by-frame comparison of the secondary sensor bit stream. This mode has the two-fold purpose of evaluating the secondary sensors and of evaluating the ITR.

The computer must be modified to accept the new ITOS D and E housekeeping telemetry frame and to accept and process the recorded data from the Digital Data Processor. This modification will require changing the rack configuration from the present single rack to a double rack in order to accommodate the new interface equipment. Other modifications required for the ITOS D and E configuration are listed below.

- Update the Varian 620i to include all Varian generated revisions to date.

- Upgrade the Central Processing Unit to include hardware multiply and priority interrupt.

- Add a high-speed paper tape reader and punch to one rack for program assembly and edit, and a cartridge magnetic tape unit to both racks for operational system program and data storage.

- Use a commercial PCM signal conditioner and bit synchronizer to interface the DDP data in biphase form to the computer.

These modifications will allow each telemetry rack to be used with data from either TIROS M or the ITOS D and E with a minimum of changeover time. With the changes listed above, the memory size will not require expansion for ITOS D and E use.

When processing DDP data, the computer output will be either:

- A VTPR data list in decimal numbers followed by a frame-to-frame comparison of VTPR data during which only changes from the first frame are printed.

- A telemetry frame list in decimal numbers, plus SPM data, followed by a frame-to-frame comparison of telemetry and SPM data during which only changes from the first frame are printed.

There will also be a special DDP telemetry mode, during which only selected telemetry channels are decoded and printed.

d. SPACECRAFT TEST CONFIGURATION IN THERMAL-VACUUM

As part of the ITOS D and E System Design, a conceptual review was made of the spacecraft test configuration in the thermal-vacuum chamber. The primary purpose of this review was to define and evaluate the necessary targets and calibration equipment required for the new sensing equipments aboard the spacecraft. The design evaluations revealed that the spacecraft, fixture, targets, and collimators will fit within the confines of the SEPET fixture (without major modifications); and, that the spacecraft/fixture/target combination will fit within the 8-foot diameter x 10-foot long thermal-vacuum chamber. Figure X-3 shows the results of these studies. Although these investigations were conceptual and did not delve into the design detail level, the evaluations nevertheless revealed that through prudent design the test targets, plumbing and fixturing will fit within the confines of the SEPET fixture and thermal-vacuum chamber.

The various targets envisioned for each of the ITOS D and E sensors are described below:

1) VHRR - (2 required)

   a) LN_2 cooling plate to radiatively cool the 240°K calibration target aboard the instrument.

   b) LN_2 sky-clamp target to provide the necessary dc restoration to the instrument prior to sky/earth transition.

   c) IR and visible collimator so that an instantaneous scan image from a visible or IR target is projected through an off-axis parabolic mirror and displayed by the VHRR output.

   d) LHe (liquid helium) target to cool the IR detector to a temperature of ≈ 90°K. This will require a LHe cryogenerator of approximately 75 watts cooling capacity on the exterior of the chamber, with special techniques of surrounding the ≈ 20°K LHe transfer lines with LN_2

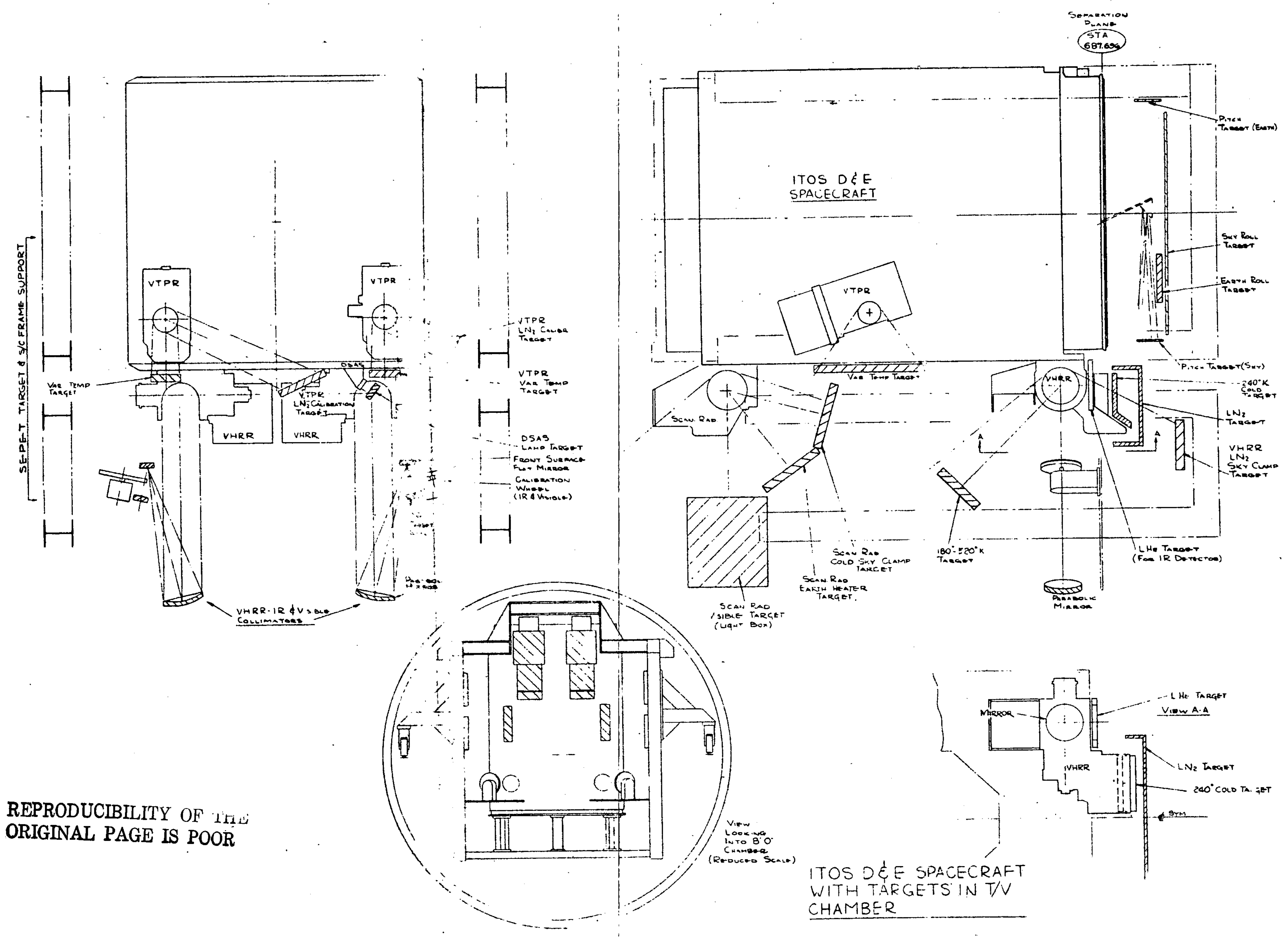

Figure X-3. Spacecraft Test Configuration in Thermal-Vacuum Chamber

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concentric targets to reduce the radiative coupling losses at these extreme low temperatures.

e) 260° to 325°K target from the chamber variable temperature brine supply to simulate the variations in global temperatures of the earth.

2) VTPR - (2 required)

a) Variable Temperature Target (200° - 320°K) to provide a variable irradiance into the detector as it scans across a simulated earth target.

b) LN_2 target upon which the instrument calibrates itself once every 20 minutes.

NOTE: A calibration target is included within the confines of the instrument upon which the detectors calibrate, in-flight, once every 20 minutes.

3) SR - (2 required) - Same as on present TIROS M fixture

a) Brine cooled (≈200°K) sky-clamp target for the instrument dc restore function.

b) Warm target (≈320°K) simulating earth.

c) Light box for readout of the visible portion of the instrument.

4) DSAS - Flashing light target to obtain a digital readout of simulated sun input at no discrete sun angle.

5) Pitch Target - Same as used on present TIROS M fixture; i.e., a LN_2 sky target, plus a heated earth-simulated target.

6) Roll Target - Same as used on present TIROS M fixture; i.e., a LN_2 sky target, plus a heated earth-simulated target.

SECTION XI

GROUND STATION EQUIPMENT

A. INTRODUCTION

The ITOS D and E ground complex will comprise three major groups of facilities:

- Command, programming, and analysis centers,
- Command and data acquisition (CDA) stations, and
- Spacecraft checkout facilities, which include the AED checkout stations and the go/no-go van.

The CDA stations and the command, programming, and analysis centers are interconnected by a ground communications system of telephone-type long lines.

The ITOS D and E system will also use the facilities of the NASA Space Tracking and Data Acquisition Network (STADAN). APT field stations throughout the world will use data from the spacecraft's scanning radiometer (SR). VHRR field stations throughout the world will use data from the very high resolution radiometer (VHRR). The flow of data among the various parts of the ground complex is shown in Figure I-2 in Section I.

The spacecraft checkout facilities include three complete sets of ground equipment as well as the test equipment required during fabrication and assembly of the spacecraft. Two of these are the factory test sets located at RCA, Astro-Electronics Division, Princeton, New Jersey, while the third is installed in a transportable air-conditioned van. The van can be used at the factory or at the launch site for checkout of the spacecraft before launch.

Most of the ground equipment to be used in the ITOS D and E system is already installed as part of the TIROS M/ITOS-1 ground complex. Only a brief description of equipment in this category is presented in this report. Facilities that are unique to the ITOS D and E system and not currently part of the TIROS M/ITOS-1 ground complex are described in more detail. Further information on the existing TIROS M/ITOS-1 ground complex is presented in the Instruction and Operating Handbook for the Improved TIROS Operational System (ITOS) and the TIROS Operational System (TOS), Volumes I thru V, prepared for the Environmental Science Services Administration Under NASA contracts NAS5-9034 and NAS5-10306 by the Astro-Electronics Division, RCA Corporation, Princeton, N.J. CAED M-2156, dated 25 April 1969 and the latest revision thereto dated 3 December, 1969.

B. COMMAND, PROGRAMMING, AND ANALYSIS CENTERS

The three command, programming, and analysis centers in the ITOS D and E ground system are as follows:

Abbreviation	Designation	Location
TEC/TTCC	TOS Evaluation Center/ TIROS-TOS Checkout Center	Goddard Space Flight Center, Greenbelt, May
TOC	TOS Operations Center	National Environmental Satellite Center, Suitland, Maryland
DAPAF	Data Processing and Analysis Facility	National Environmental Satellite Center, Suitland, Maryland

TEC/TTCC is responsible for launch, and postlaunch checkout of the spacecraft. TOC is responsible for ground system operation after the launch and checkout by TEC/TTCC, for satellite operation. DAPAF is responsible for receiving, recording, and processing video, flutter-and-wow, and telemetry data received from the satellite via CDA stations. In the event that satellite performance should depart from mission operational requirements, to the extent that its capabilities require study, TOC will assign control of the satellite to TEC/TTCC for evaluation.

1. TOS Evaluation Center/TIROS-TOS Checkout Center (TEC/TTCC)

a. FUNCTION

TEC/TTCC will be responsible for launch, and postlaunch checkout of the spacecraft. During launch and the initial orientation maneuver, TEC/TTCC will generate command messages, CDA schedules, and CDA operating procedures, relaying this data to the CDA stations via TOC. When the satellite has been fully checked out and is operational, TOC will assume control of satellite operations.

b. NEW FACILITIES

Demodulators for the ITOS D and E data will be needed, along with new modems for long-lines interfacing. Also, new digital conditioners will be required to remove noise and reshape the waveform of the digital data channel.

2. TOS Operations Center (TOC)

a. FUNCTIONS

The functions of TOC include the following:

- Real-time monitoring and assessment of satellite and CDA station operation,
- Near real-time system evaluation,
- Origination of satellite command programs upon consideration of engineering factors,
- Attitude determination,
- Magnetic attitude and momentum control programming, and
- Maintenance of engineering and other records.

The equipment at TOC is capable of real-time data processing and display from only one CDA station at a time, although simultaneous receipt of data from both stations is possible. When simultaneous transmissions are received, one set of data is processed on-line and displayed on the chart recorders, and both sets are recorded on tape. At the conclusion of the simultaneous transmission, the tape recorder can be rewound and replayed so that the second set of data can be processed.

Events data, received through the long lines from the CDA stations in Gilmore Creek, Alaska, and Wallops Island, Virginia, are processed and displayed on a 20-channel events recorder. Certain of these events are also displayed on an 8-channel chart recorder.

No changes are required for handling the ITOS D and E events data. The operator must select the ITOS D and E mode of operation on the switching control panel.

The information received by TOC through the ITOS D and E satellite beacon channel is the same as that received from TIROS M/ITOS-1.

b. NEW FACILITIES

Demodulators for the ITOS D and E data will be needed along with new modems for long-lines interfacing. A digital conditioner is also required to remove noise and reshape the waveform of the digital data channel.

3. Data Processing and Analysis Facility (DAPAF)

a. FUNCTIONS

Spacecraft beacon telemetry data, VHRR video and flutter-and-wow signals, SR video and flutter-and-wow signals, and digital data signals, plus certain status and timing signals generated at the CDA stations will be received, recorded, and processed at DAPAF, located at the National Environmental Satellite Center (NESC), Suitland, Maryland. See Figures XI-1 and XI-2 for block diagrams of the facility and signal processing subsystem, respectively. DAPAF can receive and distribute data simultaneously from the CDA stations at Gilmore Creek, Alaska, and Wallops Island, Virginia. Some data will be processed on-line as it is received; other data will be stored temporarily before processing.

b. DATA INPUTS

(1) SR DATA

(a) Video Signal

The SR data will be received at DAPAF as a continuous signal. Each IR or visible scan line of the signal will last 120.0 milliseconds and will include a 5.76-millisecond sync pulse. The information will be received as a frequency modulated signal, with a frequency of 23.65 kHz corresponding to black or hot, 17.7 kHz to white or cold, and 25.3 kHz to sync tip. The information baseband will be 4.7 kHz for the visible data and 2.34 kHz for the infrared data. The SR baseband signal will consist of time-interleaved visible and infrared data.

The earth-scan portion of the IR or visible signals will begin 23 milliseconds after the sync pulse and will end 96 milliseconds after the sync pulse. The remainder of the video signal will be time shared among spacecraft clock, calibration, telemetry, and other synchronizing information.

(b) Flutter-and Wow Signal

The SR flutter-and-wow signal will be received at DAPAF as a 6.25-kHz subcarrier, frequency modulated by the flutter-and-wow of the spacecraft and ground station tape recorders. The flutter-and-wow signal will be present throughtout the SR video transmission.

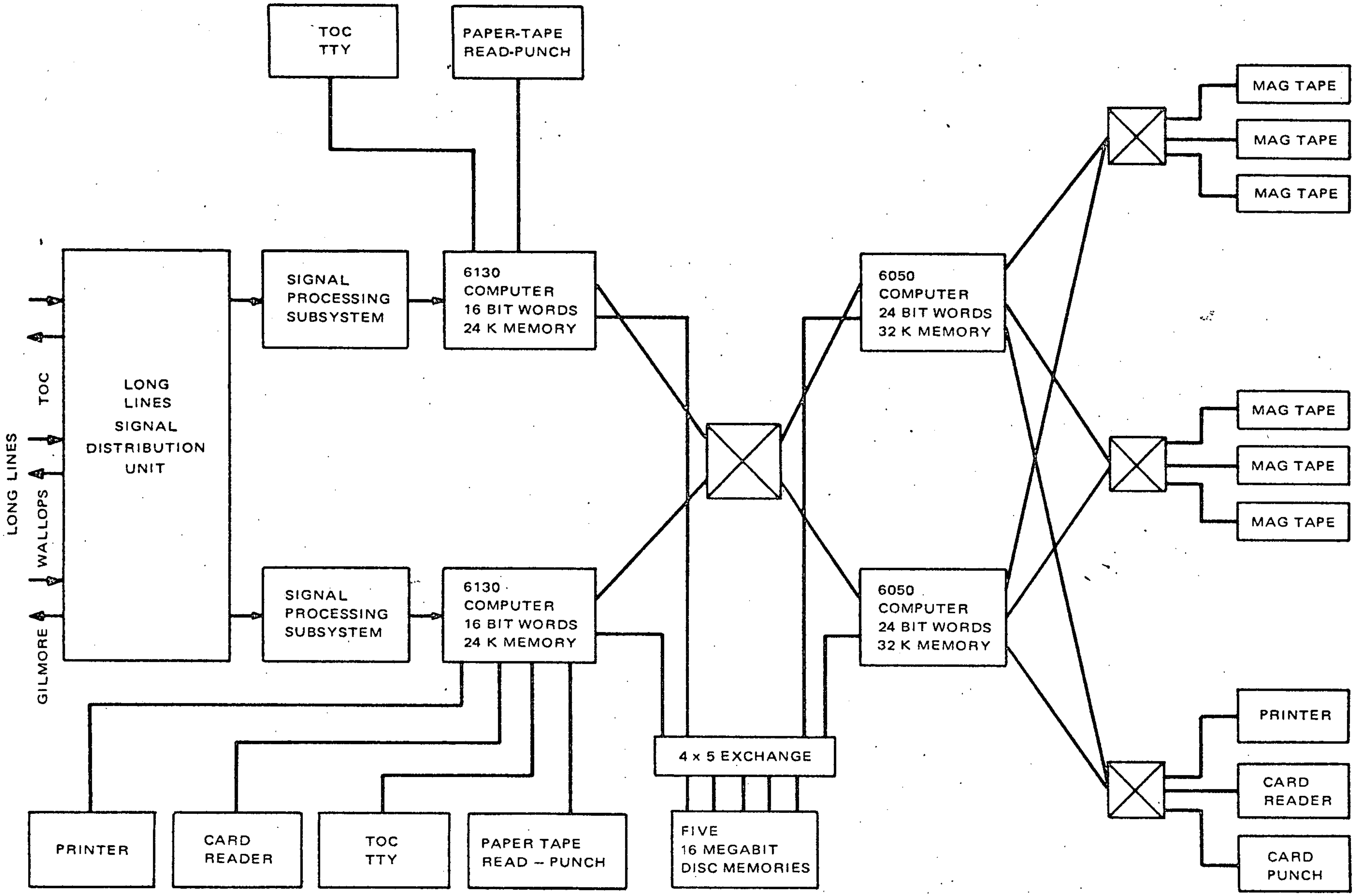

Figure XI-1. Data Processing and Analysis Facility at NESC, Suitland, Md., Block Diagram

(2) VHRR DATA

(a) Video Signal

The VHRR data will be received at DAPAF as a continuous signal, and will be followed by several frames of spacecraft time code. In the normal mode of operation of the spacecraft, the VHRR signal will consist of time-interleaved visible and infrared (IR) data. Each IR or visible scan line of the signal will last 600 milliseconds and will include a 6.8-millisecond sync pulse. In the backup mode of operation of the spacecraft, only IR or visible channel data will be present and the data will include the backscan period of the sensor. The information will be received as a frequency-modulated signal, with a frequency of 25.6 kHz corresponding to white or cold and sync tip, and a frequency of 18.4 kHz corresponding to black or hot. The information baseband will be 4.4 kHz for both IR and visible signals.

The time code will contain 24 return-to-zero bits and will be repeated at least 3 times following the VHRR data readout. The code will not be coherent with VHRR signal timing. The rate will be 15 bits per second and the duration of a bit will be 66.7 milliseconds. The first bit of the code will be the most significant digit, and the time-code resolution will be 0.25 second.

(b) Flutter-and-Wow Signal

The VHRR flutter-and-wow signal will be received at DAPAF as a 6.25 kHz subcarrier, frequency modulated by the flutter-and-wow of the spacecraft and ground station tape recorders. The flutter-and-wow signal will be present throughout the VHRR video transmission.

(3) DIGITAL DATA

The digital data is a continuous data stream containing interleaved VTPR sensor data, SPM sensor data, digital housekeeping telemetry data, spacecraft time code data, and digital synchronizing information. The digital data will be received at DAPAF as a translated signal spectrum covering a band from 14 to 28 kHz, plus a pilot tone at 30 kHz.

At DAPAF, the signal will be translated back to baseband, in frequency and phase synchronism, by means of phase-locked-loop techniques using the pilot tone as reference. The resultant baseband signal will be a band-limited, split-phase-change (SØC or bi-phase), digital signal. The bit rate will be 10.667 kb/s and the time for one bit period will be 93.75 microseconds. Significant spectrum components will cover the band from 2 to 16 kHz. This

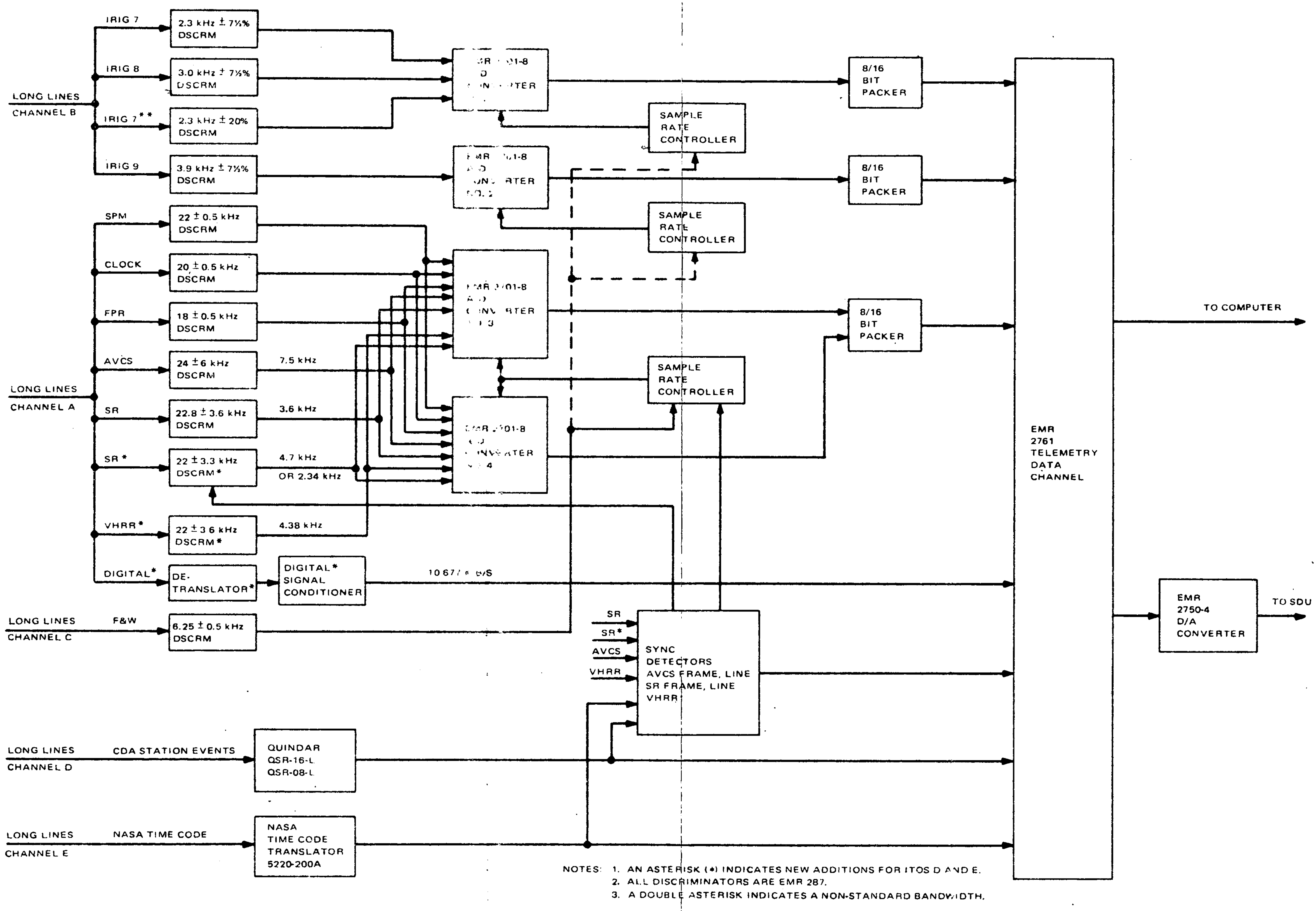

Figure XI-2. DAPAF Signal Processing Subsystem, Block Diagram digital signal must be conditioned to restore the digital waveshape and remove the transmission link noise and jitter by a general purpose signal conditioner* to permit interfacing with the analysis computers.

The received digital data stream will have the same format as described in Section VII, paragraph D. of this report, except that the direction of the time scale will be reversed because the playback direction of the spacecraft recorder is opposite to the record direction; also the bit rate will be faster by a factor of 20.833 due to the playback speed of tape recorder.

(4) BEACON DATA

As in TIROS M/ITOS-1, the ITOS D and E beacon data will be carried on two multiplexed subcarriers centered at 2.3-and 3.9-kHz. The lower frequency subcarrier will be deviated up to ±20 percent by attitude sensor signals the upper frequency subcarrier will contain housekeeping telemetry and other data and will be deviated up to ±7.5 percent (IRIG channel 9).

(5) CDA STATION-EVENTS SIGNALS

During satellite interrogations, command program and CDA station events will be received as commutated signals modulating subcarriers centered at 2.4 and 1.3 kHz, respectively. This transmission will be identical to that currently received during TOS and TIROS M/ITOS-1 interrogations

c. NEW FACILITIES

For ITOS D and E, the signal processing subsystem at DAPAF will require the additional equipment described in the following paragraphs.

(1) SR DEMODULATOR

This is a discriminator of essentially the same type as presently used for SR data (EMR 287), except that it has an input bandwidth of 14-to 30-kHz, and an output bandwidth of 4.7 kHz for the visible data and 2.34 kHz for the IR data. Since visible and IR data will be received in line-by-line interleaved form, some form of gating and output selection arrangement controlled by the sync detectors will be required for optimum signal-to-noise recovery of the two types of signals.

*Typical conditioners of this type are EMR models 2720 or 2721 or Dynatronics type BSC-7B.

(2) VHRR DEMODULATOR

This is a discriminator of essentially the same type as presently used for SR or AVCS data, except that it has an input bandwidth of 14-to 30-kHz, and an output bandwidth of 4.38 kHz.

(3) DIGITAL TRANSLATOR

This is a simple double-balanced-mixer translator with a phased-lock-loop system for acquiring the pilot tone signal transmitted with the digital data over the long lines. The function of the translator is to recover the digital signal, in frequency and phase coherence, after transmission through the long lines as a translated spectrum.

(4) DIGITAL SIGNAL CONDITIONER

This is a standard PCM signal conditioner whose function is to restore the waveshape of the digital signal and remove the transmission-link noise and jitter prior to interfacing with the analysis computers.

C. COMMAND AND DATA ACQUISITION STATIONS

1. General

The two CDA stations, located at Gilmore Creek, Alaska, and Wallops Island, Virginia, will function primarily as relay stations between TOC, TEC/TTCC, DAPAF, and the satellite. Operating in conjunction with the associated data acquisition facility, the CDA stations will perform the following functions:

- Receive the command programs teletyped to them from TOC and, when the satellite comes within communications range, transmit the commands as frequency-shift-keyed (FSK) audio signals modulating an RF command carrier frequency,
- Receive and record on magnetic tape the video, flutter-and-wow, digital, and telemetered data transmitted by the satellite, relaying the telemetered data in real time (as it is received at the station) to TOC, TEC/TTCC, and DAPAF, and
- Play back the video, flutter-and-wow, and digital data after the satellite pass and transmit it to DAPAF through the long lines for processing.

ITOS D and E additions to the existing CDA stations will be incorporated without compromising the operational capability of the stations.

2. Data Acquisition Facilities

The data acquisition facilities (DAF) at Wallops Island and Gilmore Creek provide the RF communications links between the satellite and the CDA stations. The DAP equipment used with ITOS D and E is the same as that used with TIROS M/ITOS-1. These include a command transmitter operating at 148 MHz, and polarization-diversity receiving systems capable of operating at 1700 MHz for video reception, 137.5 MHz for direct SR reception, and 136.77 MHz for beacon reception, in conjunction with the necessary antenna and antenna tracking systems.

In addition to providing the CDA stations with demodulated subcarriers, the DAF's will provide AGC voltages indicative of received signal strength for use by the CDA stations in identifying the start of useful data reception.

3. Ground Station Redundancy

Redundancy is provided in the CDA stations wherever an electronic failure could result in loss of information. Parallel channels are provided up to and including the magnetic tape recorders. Beyond the recorders, redundancy is not considered necessary, since information can always be recovered by replaying the recorders.

Two complete command programmers ensure command capability. In addition, the program of commands to the satellite can be set up by either of two methods, (1) the primary method uses the automatic teletype tape-reading system, or (2) the secondary method uses manual switches on the front panels of both programmer racks.

4. Radio Frequency Equipment

a. INTRODUCTION

The transmitters, receivers, antennas, and antenna tracking systems necessary for establishing the rf communications link between the satellite and the ground are installed at the DAF associated with each CDA station.

b. COMMAND LINK

The power of the ground transmitter is 1 kilowatt; the antenna gain is 12.0 db, and the line losses do not exceed 3 dB. The frequency of operation is 148.56 MHz ±0.001 percent.

The present GDA stations have facilities for modulating and controlling the transmitter. The modulation input to the transmitter is one of two tone-pair oscillators, designated tone pair A and tone pair B. Each pair contains an enable-tone oscillator and an FSK voltage-controlled oscillator. The nominal signal level at the CDA/DAF interface is 0.25 volt rms into an impedance of 100 ohms, unbalanced with respect to ground.

The control and indicator interface signals are listed in Table XI-1.

TABLE XI-1. CONTROL AND INDICATOR INTERFACE

Function	Nature of Interface Signal	Path
Command Transmitter Ready	28-volt indicator	DAF to CDA
Command Transmitter On	28-volt control	CDA to DAF
Command Transmitter Plate Signal On	28-volt indicator	DAF to CDA
Power Transmitted	28-volt indicator	DAF to CDA
Select Antenna or Dummy Load	28-volt control	CDA to DAF
Antenna Selected	28-volt indicator	DAF to CDA
Dummy Load Selected	28-volt indicator	DAF to CDA

A command rf signal, from the antenna feed, samples the transmitted signal to verify the data. The frequency is 148 MHz and the amplitude is -113 dBm to -27 dBm at an impedance of 50 ohms.

c. BEACON DATA LINK

The beacon receiver is required to receive the beacon transmission from the spacecraft and extract the composite subcarrier modulation for processing at the CDA station. The antenna gain is 27.6 dB. The phase lock, carrier tracking receiver has a predetection tracking bandwidth of 2 kHz and a noise figure of 6 dB. The signal at the DAF/CDA interface will be a composite subcarrier with a nominal amplitude of 3 volts peak-to-peak at an impedance of 75 ohms, unbalanced with respect to ground. The frequency spectrum of the signal will be 1.6 to 4.4 kHz. This equipment is already installed at the DAF.

The signals listed below are also provided by the beacon receiver:

a. Horizontally Polarized Receiver AGC

(1) Voltage range: 0 to 8 volts.

(2) Corresponding rf signal strength: Thermal noise to -25 dBm.

b. Vertically Polarized Receiver AGC

(1) Voltage range: 0 to 8 volts.

(2) Corresponding rf signal strength: Thermal noise to -25 dBm.

d. REAL-TIME VHF LINK

The real-time VHF link uses a Nems-Clarke 1432 fm receiver. The input will be at 137.5 MHz; the signal at the DAF/CDA interface will be a 2.4-kHz subcarrier, amplitude modulated with SR data at an amplitude of 3 volts peak-to-peak and an impedance of 75 ohms. This equipment is already installed at the DAF.

The signals listed below are also provided from the real-time VHF receiver:

a. Horizontally Polarized Receiver AGC

(1) Voltage range: 0 to 8 volts.

(2) Corresponding rf signal strength: Thermal noise to -25 dBm.

b. Vertically Polarized Receiver AGC

(1) Voltage range: 0 to 8 volts.

(2) Corresponding rf signal strength: Thermal noise to -25 dBm.

e. S-BAND PLAYBACK LINK

The S-band playback link is the same as that used for TIROS M/ITOS-1 operations. The received frequency will be in the 1690- to 1710-MHz band. The information signal from the spacecraft, which consists of a composite subcarrier in the 11- to 501- kHz band, will frequency modulate the carrier to produce a peak deviation of ±925 kHz. The antenna gain is 47.7 dB, and the preamplifier front end noise figure is 2.2 dB. The receiver will extract the composite subcarrier from the transmission and provide a signal of 3 volts peak-to-peak amplitude at 75-ohm impedance (unbalanced) at the DAF/CDA interface. The frequency bandwidth will be the composite subcarrier band of 11 to 501 kHz.

The following signals are also provided from the S-band receivers:

a. Horizontally Polarized Receiver AGC

(1) Voltage range: 0 to 8 volts.

(2) Corresponding rf signal strength at receive input: Thermal noise to -25 dBm.

b. Vertically Polarized Receiver AGC

(1) Voltage range: 0 to 8 volts.

(2) Corresponding rf signal strength at receive input: Thermal noise to -25 dBm.

5. Video Equipment

a. INTRODUCTION

The video handling section of the CDA station will receive and process the 11- to 501-kHz composite signal transmitted from the satellite. This composite signal will contain the information shown below:

Information	No. of Channels
SR Video	2
SR Flutter and Wow	2
VHRR Video	1
VHRR Flutter and Wow	1
VHRR Flutter and Wow	1
Digital Data	2
Pilot Tones	2

The individual subcarriers will be extracted from the composite signal by the CDA station demultiplexers and recorded on magnetic tape recorders. After each satellite pass, the information will be retransmitted to DAPAF via the long lines. The limited capacity of the long lines necessitates the sequential transmission of the video data; however, each video channel will be transmitted simultaneously with its associated flutter-and-wow signal. The CDA station will process the video data (e.g., by replaying the recorders at a reduced speed) to produce compatibility between the frequency characteristics of the video signals and the long lines.

Redundant demultiplexers and recorders will be provided to minimize the possibility of loss of information. Oscilloscope display of the received subcarriers and of the demodulated signals for monitoring purposes will be included.

Figure XI-3 shows in simplified form the handling of the S-band video data at the CDA stations.

b. DEMULTIPLEXING

Table XI-2 shows the function, input characteristics, and output characteristics for each of the signals present on the 12- to 501-kHz composite subcarrier received at the CDA station from DAF.

Figure XI-4 is a block diagram of the ITOS D and E demultiplexer. Two phase-locked oscillators are required to lock onto and track the two transmitted pilot tones. These phase-locked oscillators, one at 300 kHz and the other at 450 kHz, provide references tones which are indentical in frequency and phase with the tones that are used in the spacecraft multiplexer to translate the various information-signal spectra to their assigned frequency allocations.

The VHRR video is frequency-doubled prior to recording, to facilitate its eventual transmission over the long lines.

Also, a new rack will be added between the present demultiplexer rack and the tape recorders in order to accommodate the two new ITOS D and E demultiplexer chassis. This is illustrated in Figure XI-5.

c. TAPE RECORDERS

All data transmissions from the TOS and ITOS (including ITOS D and E) satellites are permanently recorded on magnetic tape by a recording system comprising four 14-channel magnetic tape recorders, and associated control circuits. The use of two recorders during signal reception, each of which records identical data, provides an increased degree of reliability in recording all useful data. During all recording operations, the tape recorders are operated at a speed of 60 inches per second in order to provide sufficient frequency response. The use of four recorders makes it possible to simultaneously record data from a satellite and retransmit previously recorded data from another satellite down the long lines.

C4

TABLE XI-2. DEMULTIPLEXER FUNCTIONAL PARAMETERS

Signal	Input Spectral Characteristics: Bandwidth (kHz)	Input Spectral Characteristics: Relative Amplitude* (Ratio)	Translated Spectral Bandwidth (kHz)	Post-Translation Processing	Output Spectral Bandwidth (kHz)
SRR-A F&W	11.9-13.1	25	na	f x 2	24.3-25.7
SRR-B F&W	24.3-25.7	25	na	na	24.3-25.7
VHRR Video	38.5-137.5	160	na	f x 2	112-240
SRR-A Video	180-214	160	56-120	na	56-120
300 kHz Pilot Tone	298-302	25	na	na	**
Digital A	284-316	80	2-16	na	2-16
SRR-B Video	356-420	285	56-120	na	56-120
450 kHz Pilot Tone	448-452	35	na	na	**
Digital B	452-466	80	2-16	na	2-16
VHRR F&W	499.2-500.8	50	49-51	na	49.2-50.8

*Input to demultiplexer is 3 volts peak-to-peak at an impedance of 75 ohms.
**The pilot tones shall be used in the demultiplexer to translate the other frequency spectra. They are not supplied as outputs.

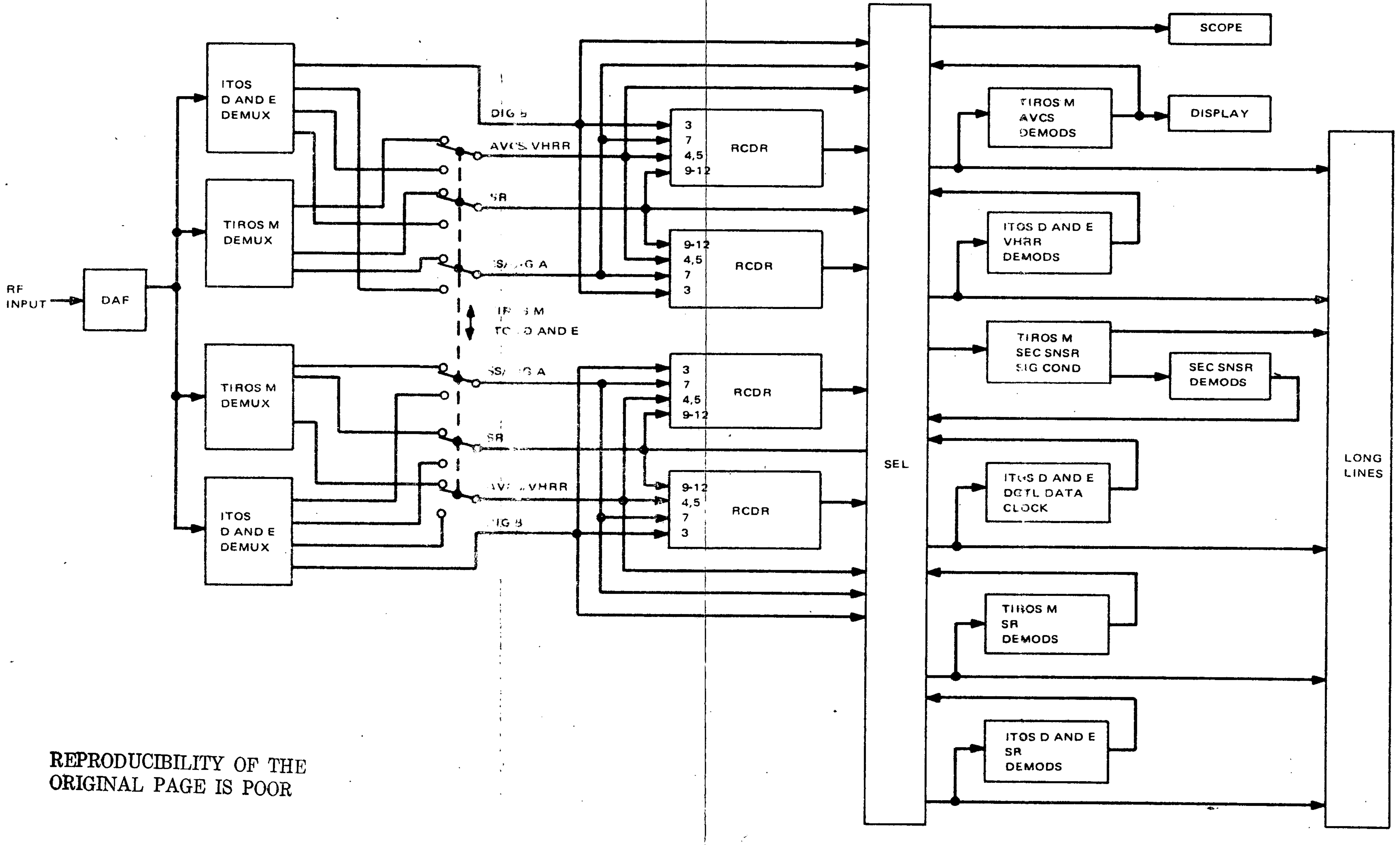

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Figure XI-3. S-Band Data Handling of CDA Stations, Block Diagram

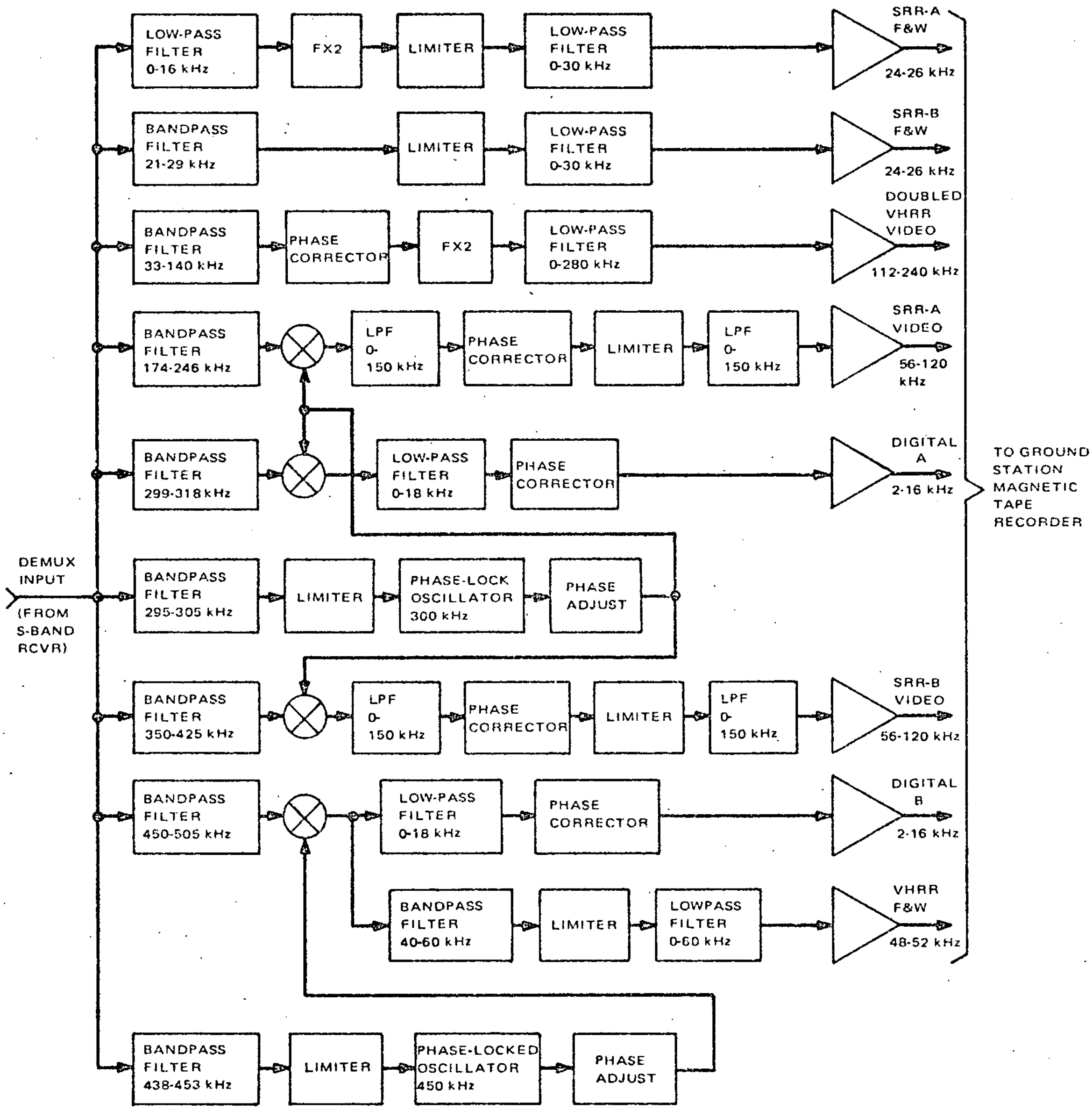

Figure XI-4. Demultiplexer, Block Diagram

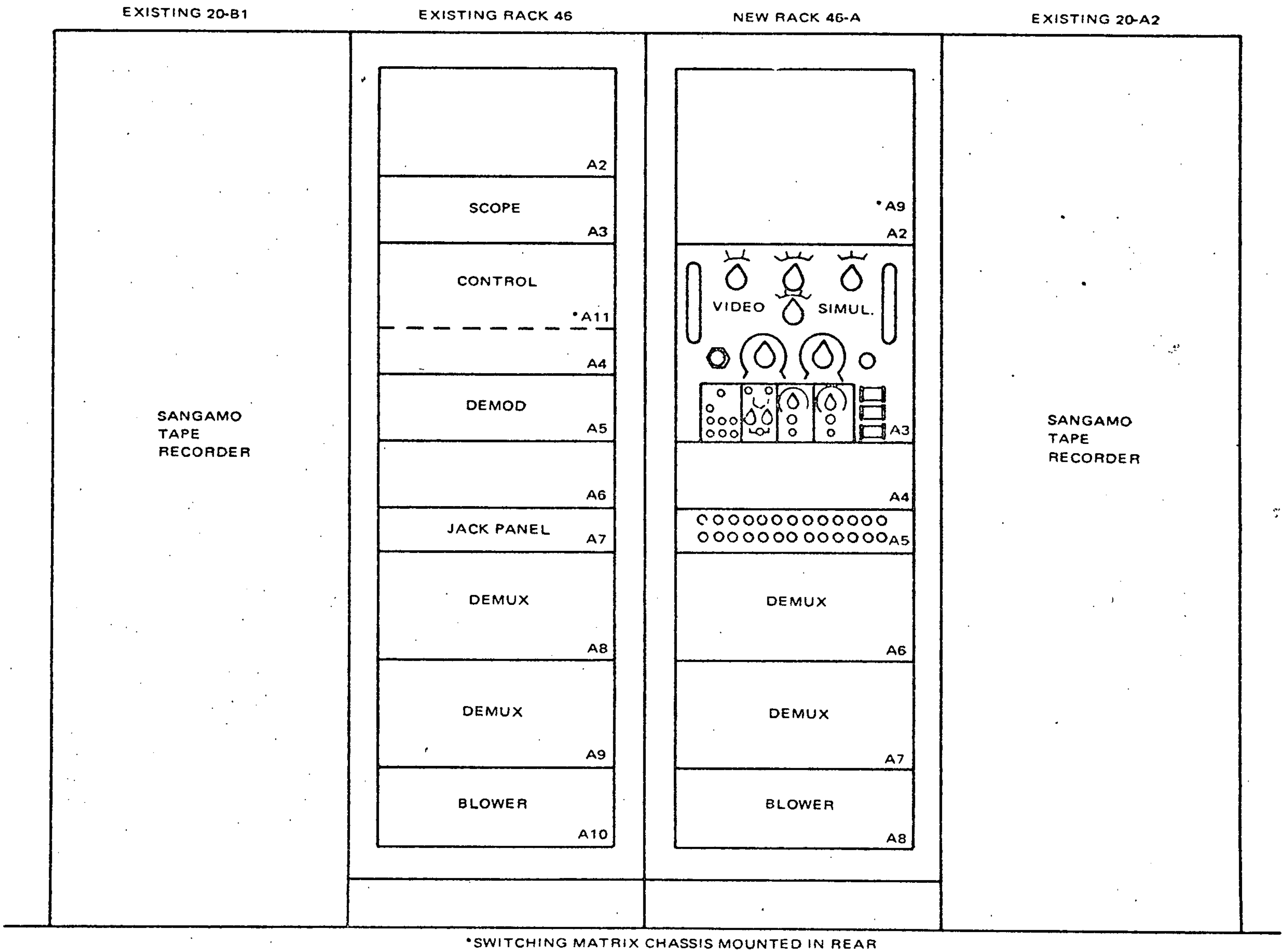

Figure XI-5. New Rack Configuration to Accommodate ITOS D and E Demultiplexer Chassis

The recorder channel assignments for the TOS, TIROS M/ITOS-1, and ITOS D and E data are given in Table XI-3. Channels 4 and 5 were selected for ITOS D and E VHRR-video and flutter-and-wow data, respectively, because the signal processing to the long lines uses the same hardware as that used for the AVCS data from TIROS M/ITOS-1, ITOS A, B, and C. Channels 9 through 12 were selected for the digital data in order to minimize the station modifications necessary to accommodate this data. Channel 2, which records time-shared real-time SR and APT data, is retained, however, it records only SR data fro ITOS D and E.

An additional channel may be obtained for future needs by simply multiplexing the data being recorded on channels 13 and 14 and recording on a single channel.

Switching, which is controlled by the master selection switch at the station control panel (rack 26), will route the TOS, TIROS M/ITOS-1, and ITOS D and E data to the appropriate channels of the tape-recorders.

d. LONG LINES INTERFACE

The existing long line facilities and channel characteristics will remain unchanged for ITOS D and E. The data handling channels and the data which will be processed down each channel is given in Table XI-4.

e. A-SCAN DISPLAY OF DATA

An oscilloscope display of the data being recorded as well as the data being processed into the long lines is provided in the existing stations. The data is demodulated for a display of the baseband signals by plug-in discriminations, most of which are housed in rack 46.

(1) S-BAND DATA

Six new demodulators and a phase-lock-loop circuit will be added to rack 46, to demodulate ITOS D and E data. The TIROS M/ITOS-1 demodulators will be retained. The following paragraphs discuss the ITOS D and E requirements. A comparison between the characteristics of the TIROS M/ITOS-1 and ITOS D and E demodulator requirements is made in Table XI-5.

(a) SR Data

SR video and flutter-and-wow data is demodulated directly for baseband display. Since the center carrier of both the video and flutter-and-wow data being recorded is roughly twice that of TIROS M/ITOS-1 (flutter-and-wow data is exactly twice) two new demodulators are required for ITOS D and E. However, the recorders play back into the long lines at one quarter the record

TABLE XI-3. TAPE RECORDER CHANNEL ASSIGNMENTS

Channel	TOS	TIROS M/ITOS-1, ITOS A, B, and C	ITOS D and E
1	NASA 28-bit timecode	NASA 28-bit timecode	NASA 28-bit timecode
2	APT Subcarrier	APT Subcarrier	Real-Time SR
3	AVCS Subcarrier	—	Digital Channel B
4	AVCS Video (doubled)	AVCS Video (doubled)	VHRR Video (doubled)
5	AVCS F&W	AVCS F&W	VHRR F&W
6	Beacon Subcarriers	Beacon Subcarriers	Beacon Subcarriers
7	—	Secondary Sensor	Digital Channel A
8	*	*	*
9	—	SR Video 1	SR Video-A
10	—	SR F&W 1	SR F&W-A
11	—	SR Video 2	SR Video-B
12	—	SR F&W 2	SR F&W-B
13	—	Command Events	Command Events
14	—	CDA F&W	CDA F&W

*Used for servo reference or pilot tone on Sangamo recorders at Gilmore Creek CDA station.

TABLE XI-4. LONG LINE CHANNEL DATA

Channel	Bandwidth (kHz)	ITOS D and E Data	Recorder Playback
A	13-30	VHRR video	7.5 in/s
		SR video	15.0 in/s
		Digital data*	60.0 in/s
B	1.4 to 4.4	Real time beacon	Real time
C	4.3 to 7.4	VHRR F&W	7.5 in/s
		SR F&W	15.0 in/s
D	0.3 to 3.4	Beacon	7.5 in/s
		Command events	Real time
		Station events	Real time

*Includes VTPR, SPM, housekeeping telemetry, and spacecraft time code data in a single digital bit stream. The recorder playback is a 10.667 kb/s bit stream which is translated using a 30 kHz pilot tone to fit into the long line channel.

TABLE XI-5. DEMODULATOR SIGNAL CHARACTERISTICS

Data		TIROS M/ITOS-1, ITOS A,B, and C (kHz)	ITOS D and E (kHz)
SR DT* Video	Center Freq	45.6	88.0
	Deviation	±7.2	±13.25
	Baseband	7.2	18.75
	Total Spectrum	31.2 to 60.0	56 to 120.0
SR ST* Video	Center Freq	22.8	22.0
	Deviation	±3.6	±3.3
	Baseband	3.6	4.7
	Total Spectrum	15.6 to 30.0	14.0 to 30.0
SR DT* F&W	Center Freq	12.5	25.0
	Deviation	±125 Hz	±500 Hz
	Baseband	2.0	500 Hz
	Total Spectrum	10.125 to 14.625	24.0 to 26.0
SR ST* F&W	Center Freq	6.25**	6.25
	Deviation	±62 Hz	±125 Hz
	Baseband	1.0	125 Hz
	Total Spectrum	5.25 to 7.25	6.0 to 6.5
VHRR DT* Video	Center Freq	172.0**	176.0
	Deviation	±16.0	±29.0
	Baseband	60	35.0
	Total Spectrum	96.0 to 248.0	112.0 to 240.0
VHRR ST* Video	Center Freq	22.25**	22.0
	Deviation	±2.0	±3.6
	Baseband	7.5	4.4
	Total Spectrum	12.0 to 31.0	14.0 to 30.0

TABLE XI-5. DEMODULATOR SIGNAL CHARACTERISTICS (Continued)

Data		TIROS M/ITOS-1, ITOS A,B, and C (kHz)	ITOS D and E (kHz)
VHRR DT* F&W	Center Freq	50.0**	50.0
	Deviation	±500 Hz	±500 Hz
	Baseband	500 Hz	500 Hz
	Total Spectrum	49.0 to 51.0	49.0 to 51.0
VHRR ST* F&W	Center Freq	6.25**	6.25
	Deviation	±62 Hz	±62 Hz
	Baseband	62 Hz	62 Hz
	Total Spectrum	6.2 to 6.3	6.125 to 6.375
Digital Data (DT and ST)		---	10.667 kb/s

* DT is direct time; ST is slow time.

**AVCS demodulators.

speed as opposed to one-half the record speed for TIROS M/ITOS-1. The resultant center carrier is within the range of the existing demodulators. However, in the case of the video data, baseband data above 3.6 kHz will be attenuated up to 7dB at 4.7 kHz by the rolloff (42 dB/octave) of the discriminator output filter.

(b) VHRR Data

VHRR video and flutter-and-wow data is directly demodulated for baseband display. The center frequencies of the video data, both that being recorded and that being played back into long lines is very close to that of the TIROS M/ITOS-1 AVCS video. However, the deviation of the VHRR data is almost twice. This makes the AVCS demodulators, which are located in rack 27, unusable. As a result, two new VRR video demodulators will be added to rack 46.

The center frequencies, deviations, and baseband characteristics of the two VHRR flutter-and-wow demodulators are within the range of their AVCS counterparts. However, the demodulators are located in rack 27, which is part of the hard-copy AVCS data display equipment. This equipment will not be used with ITOS D and E. In order to make the ITOS D and E station operation independent of this equipment, two new flutter-and-wow demodulators will be added in rack 46.

(c) *AVCS Data*

The TIROS M/ITOS-1 AVCS demodulators located in rack 27, will be retained for TIROS M/ITOS-1 station operation.

(d) *Digital Data*

The digital data is a 10.667 kb/s biphase digital signal. The data being played back into the long lines is translated to fit the wideband channel of the long lines by a 30-kHz pilot tone. Phase-lock-loop circuits, which provide a bit rate clock, will be used as an oscilloscope sweep sync for an "eye pattern" display of the data. The clear area within the eye pattern is a measure of such parameters as signal-to-noise, jitter, and intersymbol interference.

(e) *Real-Time VHRR Data*

The real-time VHRR data is not processed by the CDA station under the terms of the present contract.

(2) *BEACON DATA*

The beacon data will be displayed in the same manner as TIROS M/ ITOS-1.

(3) *REAL-TIME SR DATA*

Real-time SR data will be processed, like TIROS M/ITOS-1 via the VHF transmission link. The baseband of the ITOS D and E data, at 900 Hz, is twice that of TIROS M/ITOS-1. In addition, the TIROS M/ITOS-1 demodulator was designed to be loaded by a high impedance and is not compatible for use with a strip chart recorder, which has a relatively low impedance. A new demodulator will be added to rack 46 to provide oscilloscope and strip chart recorder display of the baseband signal.

f. CHART RECORDER DISPLAY OF DATA

S-band and real-time SR data is not normally displayed on chart recordings. Beacon data will be displayed in the same manner as the TIROS M/ITOS-1 beacon data.

D. PROGRAMMING COMMANDS AND EQUIPMENT

1. Satellite Commands

a. GENERAL

Commands for programming the TIROS M/ITOS-1 and ITOS D and E satellite instrumentation are transmitted from the CDA stations to the satellites in the form of audio frequency tones which amplitude modulate a radio frequency command carrier. Each command transmission to the satellite consists of a 5.35-second transmission of a continuous, analog, audio frequency "enable" tone, required as part of the access sequence for command reception, followed by a digital address and one or more sequences of commands. These sequential commands are formed by frequency-shift-keying a second audio tone, the FSK tone, to form the binary "1's" and binary "0's" that make up the individual satellite commands.

The satellite commands fall into two classifications: direct commands and remote commands. The command structures and additional command requirements for ITOS D and E are described in the following paragraphs.

b. DIRECT COMMANDS

The direct commands consist of the following: a sync pulse that resets the satellite decoder circuits; an address portion consisting of a 12-bit code that uniquely identifies the satellite for which the command is intended; a second sync pulse; and a 13-bit instructional command that either selects a satellite component for operation or performs an on/off type function. The structure of the direct command is a 2-out-of-12 code plus a command termination bit. For the ITOS satellites, the command capacity has been doubled by the use of 2 sets of commands which are differentiated by a one-position shift in the satellite address.

c. REMOTE COMMANDS

Remote commands are similar to direct commands in that they contain a sync pulse, satellite address portion, a second sync pulse, and a direct command portion. However, in the remote command, the direct command portion selects one of the two programmer words, and is immediately followed by 28 bits of programmer-loading data. This data contains a program of operations for either the satellite-borne sensor subsystems or dynamics control subsystem, to be implemented in areas remote from the CDA station.

d. ADDITIONAL COMMAND REQUIREMENTS

Listed below are the additional commands which will be added for commanding the ITOS D and E satellite:

- Five key-enabled commands;

  VHRR Motor 1 off,

  VHRR Motor 2 off, and

  Deploy Solar Panels.

- Inhibit automatic updating when programmer 1 word contains a rephasing word.
- Inhibit automatic updating when programmer 2 word contains a telemetry random-access message.

2. Equipment Modifications

The changes required in the existing station equipment, to implement the additional commands for ITOS D and E listed in paragraph 1. d, are described in the following paragraphs.

a. COMMAND RACK 35, DRAWER D

(1) KEY-ENABLED COMMAND CIRCUITS

Circuitry which enables the transmission of certain direct commands only when a key operated switch is enabled, exists in drawer D of the command rack (35). Additional decode gates, one for each function; will be added to the direct command register in drawer D, to incorporate the ITOS D and E key enabled commands.

(2) INHIBIT AUTOMATIC UPDATE CIRCUITS

In order to inhibit the automatic update under the specified conditions, decoding and inhibit gates will be added to drawer D of the command rack (35). The contents of the direct command register determines which message programmer, 1 or 2 in drawer A, is loaded into the remote command register. Decode gates on both registers will determine that either a rephasing word was loaded from 1 or a random access message from 2, and will inhibit strobe gates on the update pulse counters.

b. BEACON EQUIPMENT

The beacon receiving equipment and the beacon data-processing equipment will receive, record, and process the beacon transmissions from the ITOS D and E spacecraft exactly as with TIROS M/ITOS-1, ITOS A, B and C.

c. STATION CONTROL EQUIPMENT

(1) STATION CONTROL PANEL

Overall control of the CDA station operating modes and facilities for monitoring the status of major subsystems in the station is incorporated in the switches and indicators located on the station control panel, rack 26. A master switch presently provides for selection between TOS and TIROS M/ITOS-1 operations, automatically switching the station's spacecraft command and data recording equipment to the appropriate station hardware.

The master selection switch will be modified to add the automatic insertion of hardware appropriate to the processing of data for ITOS D and E only. Functions applying only to ITOS D and E are:

- Connection of recorder channels 3-5, 7, and 9-12 to the output of the ITOS D and E demultiplexer. The recorder channel assignments for TOS, TIROS M/ITOS-1, ITOS A, B, and C, and ITOS D and E are given in Table XI-3.
- Inclusion of the following functions in the command programmer.
  a. Inhibit automatic updating of programmer 1 register when it contains a rephasing word.
  b. Inhibit automatic update on telemetry random access message in programmer 2's register.

(2) RECORDER PLAYBACK CONTROLS

Local control of playback of the tape recorders into the long lines is incorporated in the switches and indicators located in rack 46. The recorder to be used and the type of data to be played back into the long lines are selected by switches. The designated recorder channels are automatically connected to the appropriate long line channels. In some cases, data processing is required prior to long line channel feed. Sensing assures that the correct recorder speed has been selected. An incorrect speed selection is displayed on a warning light.

The recorder playback controls will be modified as follows:

a. Additon of VHRR data selection. Since the VHRR data is stored on the same recorder channels, processed via the same long line channels, and played at the same speed as TIROS M/ ITOS-1, ITOS A, B, and C AVCS data, the new function will simply be a parallel control to AVCS data selection. Figure XI-6 is a modified block diagram of the VHRR signal processing.

b. Addition of digital A data selection. This new function will switch channel 7 of the recorder (secondary sensor data for TIROS M/ITOS-1, ITOS A, B, and C) via a frequency translator to the long lines wideband channel. Recorder playback speed to 60 in/s. Figure XI-7 is a modified block diagram of the digital data signal processing.

c. Addition of digital B data selection. This new function will switch channel 3 of the recorder via the fraquency translator (b. above) to the long line wideband channel (see Figure XI-7). Recorder playback speed is 60 in/s.

d. Addition of SR A and SR B data selection. The ITOS D and E SR data is stored on the same recorder channels and processed via the same long lines as the SR data of TIROS M/ITOS-1, ITOS A, B, and C. The recorder playback speed, however, is 15 in/s as opposed to 30 in/s for TIROS M/ITOS-1, ITOS A, B, and C. Figure XI-8 is a modified block diagram of the scanning radiometer signal processing.

(3) OSCILLOSCOPE DISPLAYS

The data which is being recorded and that which is being played back into the long lines is demodulated and displayed on oscilloscopes, one of which is in rack 46. A local control panel selects the data to be displayed.

The controls will be modified to process the ITOS D and E data via 6 new demodulators for SR and VHRR data and a clock frequency extractor for digital data. A detailed description of this equipment was given earlier in the system design report.

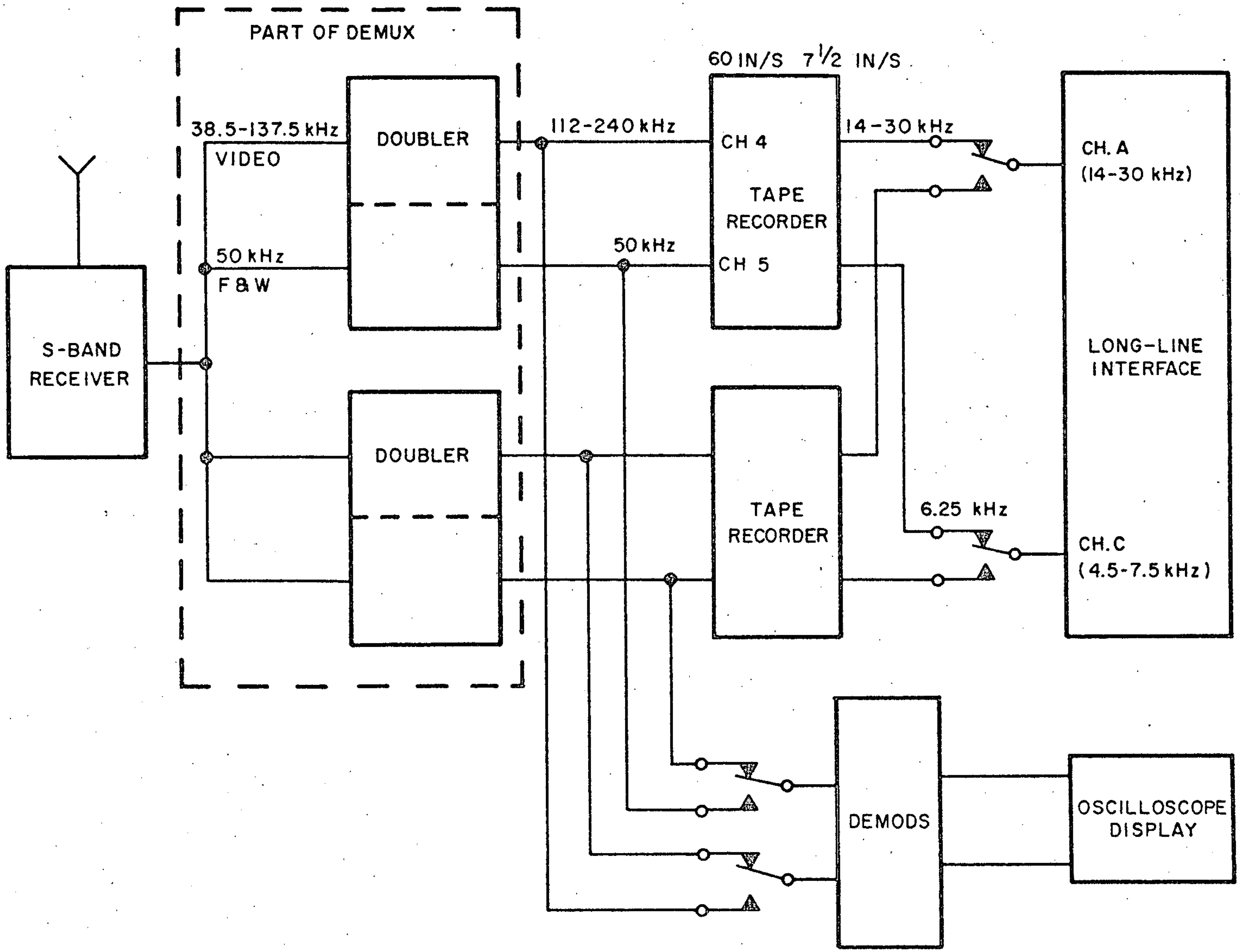

Figure XI-6. Ground Processing of VHRR Signal, Modified Block Diagram

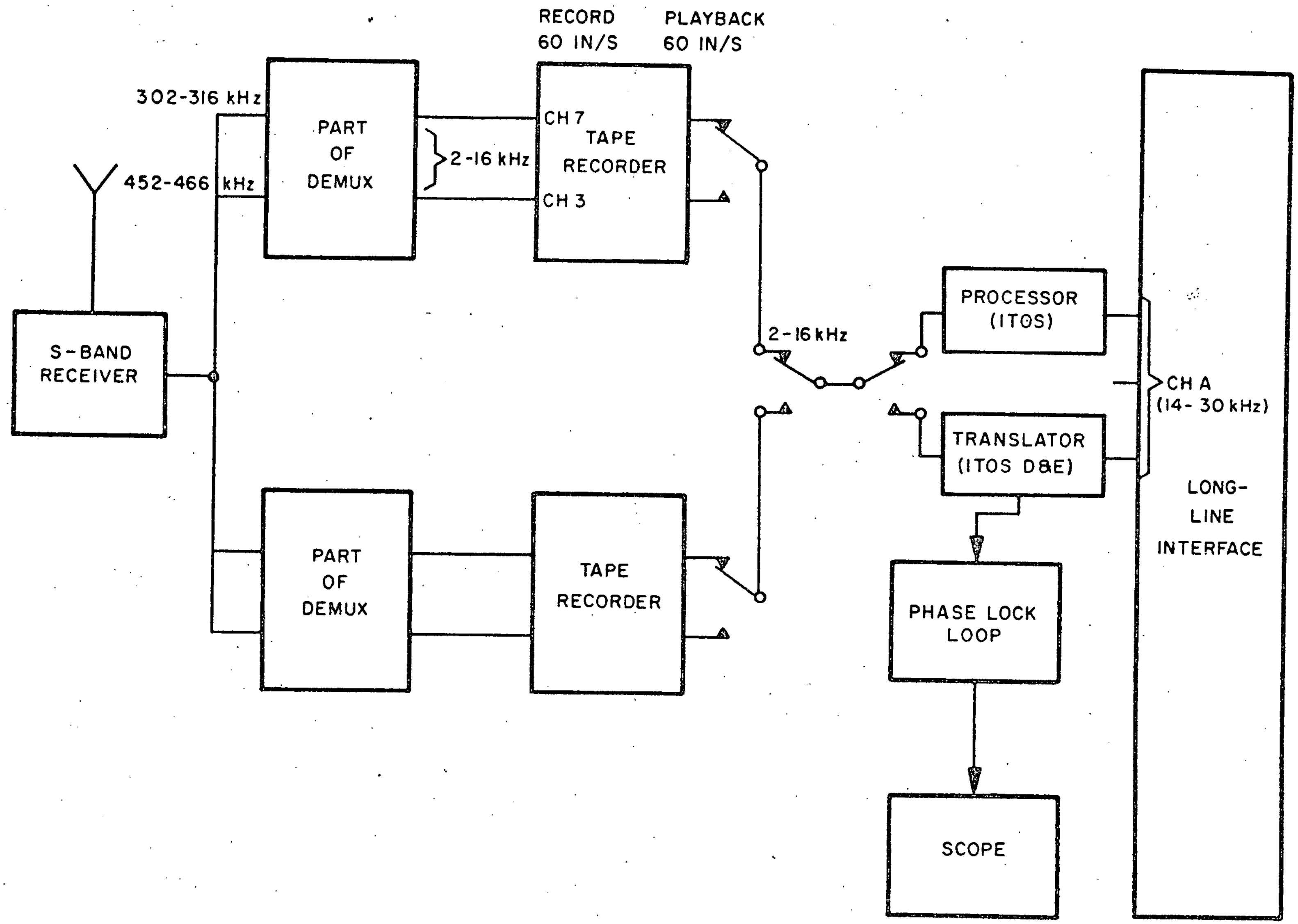

Figure XI-7. Ground Processing of Digital Data Signals, Modified Block Diagram

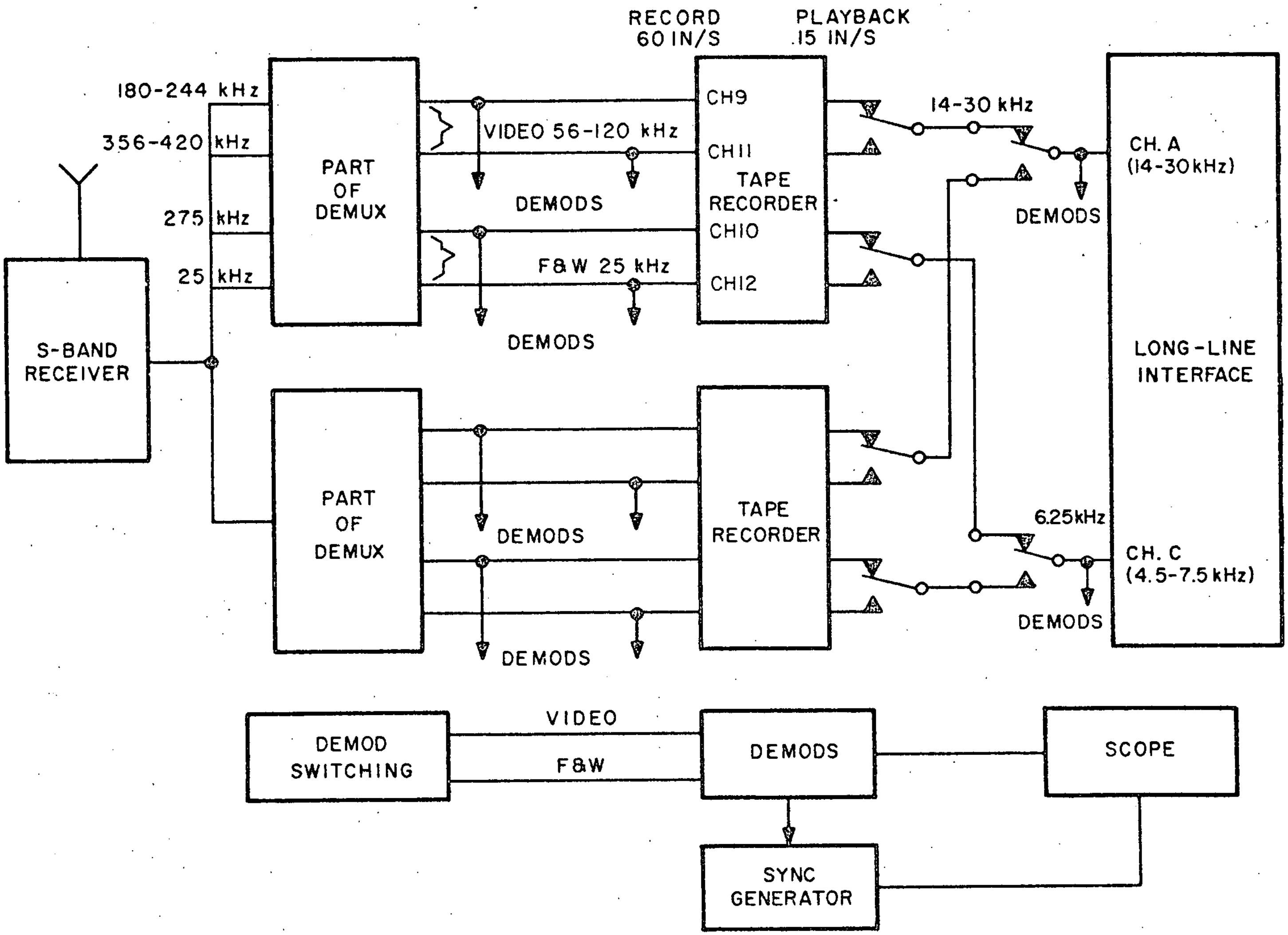

Figure XI-8. Ground Processing of Scanning Radiometer Signal, Modified Block Diagram

3. Additional Equipment

The additional equipment required for the ITOS D and E spacecraft necessitates the addition of one rack of equipment, rack 46A. The new rack will incorporate two demultiplexers and the associated monitor and control switching facilities. Refer to Figure XI-5 for the new rack configuration.

E. LONG LINES

1. General

The ITOS D and E long line system is the same as that used for TIROS M/ITOS-1, ITOS A, B, and C, and TOS. It consists of two 48-kHz wideband channels, one from Gilmore Creek to NESC/Suitland and the other from Wallops Island to NESC/Suitland (see Figure XI-9). Both channels provide full duplex service. A complete terminal and a hot spare are located at Gilmore Creek and at Wallops Island. At NESC in Suitland, Maryland, there are two terminals as well as a hot spare which can be switched to either the Gilmore Creek or the Wallops Island terminal.

A complete, direct, receive-only terminal is provided at GSFC for each of the two 48-kHz channels. For backup, suitable switching permits either terminal to be switched to either channel. There is no GSFC transmission capability via the wideband link.

At Offutt AFB, Nebraska, a complete receive-only terminal is provided for each of the two 48-kHz wideband channels. The switching arrangement is similar to that at GSFC. This terminal will receive the Gilmore Creek CDA signals directly and the Wallops Island CDA signals after retransmission from NESC/Suitland.

2. Channel Allocation

The 48-kHz wideband signal is divided into 7 channels as shown in Figure XI-10. Of the 7 channels, F and G are used for voice communication, E is an alternate voice or teletype link, and A through D are data channels. Channels E, F, and G transmit at 0.3 to 3.4 kHz; the characteristics of the 4 data channels are given in Table XI-6.

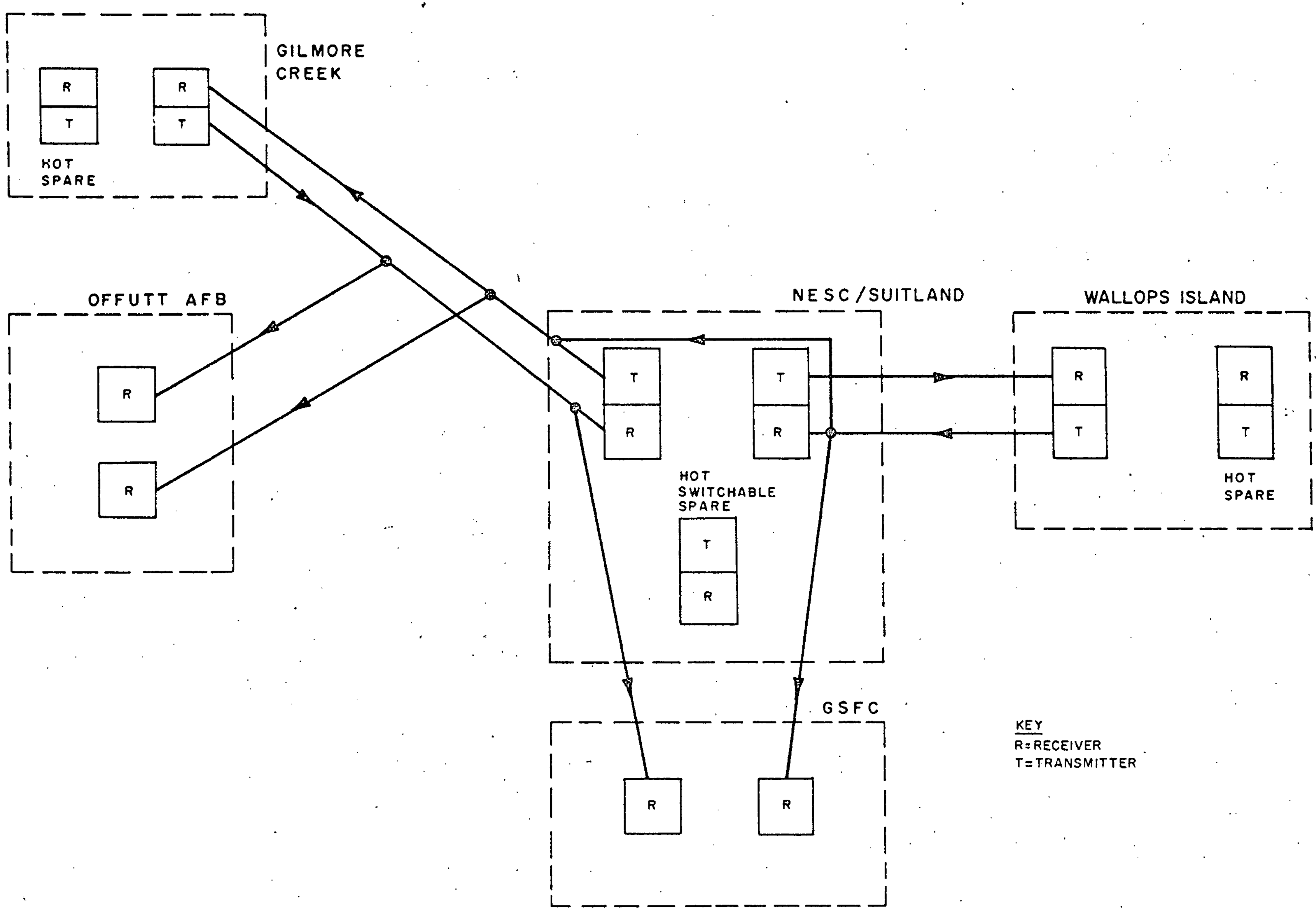

Figure XI-9. Long Lines Communications System

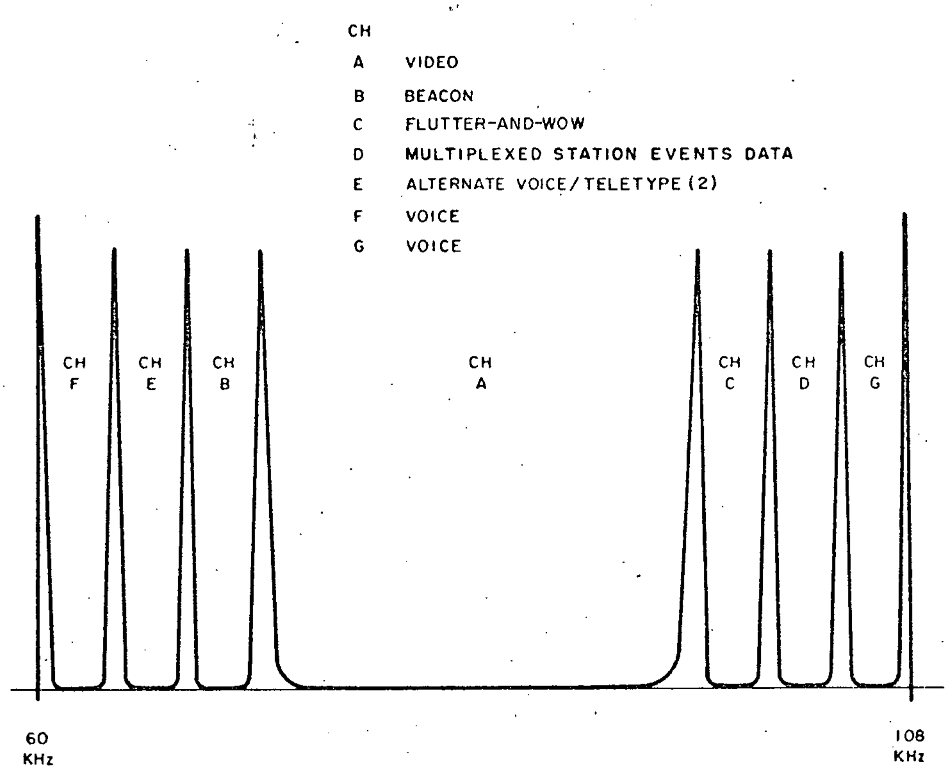

Figure XI-10. Long Lines Channel Allocations

TABLE XI-6. CHARACTERISTICS OF LONG LINES DATA CHANNELS

Channel	Transmission Frequency (kHz)	Function	
		TIROS M/ITOS-1 ITOS A, B, and C	ITOS D and E
A	14 - 30	AVCS video, SR video, or Secondary sensor data	SR video Digital Data, or VHRR Video*
B	1.3 - 4.4	Composite beacon sub-carrier (IRIG channel 9 and nonstandard channel 4)	Composite beacon sub-carrier (IRIG channel 9 and nonstandard channel 4)
C	4.3 - 7.4	AVCS flutter-and-wow or SR flutter-and-wow	SR flutter-and-wow or VHRR flutter-and-wow*
D	0.3 - 3.4	Station events	Station events
*Not an operational requirement.			

3. Long Line Utilization

Use of one long line to transmit all the data from the CDA stations to DAPAF requires the serial transmission of information.

Figure XI-11 shows the utilization of the long line for the transmission of one and two orbits of data.

The time required to transmit one orbit of data from each information source is given below:

Data Source	Time (min)
SR	22
Digital Data	5.5
VHRR	73*

*Not an operational requirement

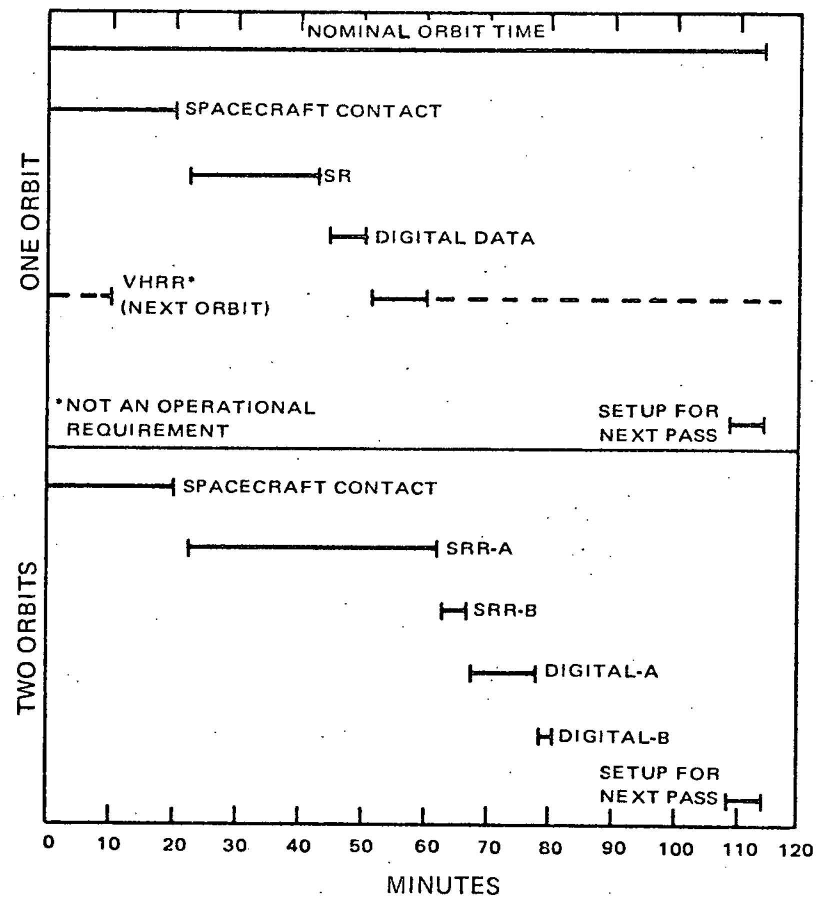

Figure XI-11. Long Line Transmission Time for One and Two Orbits

Note that, although not an operational requirement, the VHRR data from one orbit can be transmitted through the long lines by making use of the idle time of the long lines video and flutter-and-wow channels during the spacecraft pass. Use of a second CDA station recorder, to record the spacecraft playback data simultaneously with long lines playback data of the previous orbit, would be required in this case.

F. RCA ASTRO-ELECTRONICS DIVISION CHECKOUT FACILITY AND GROUND STATION

1. General

The RCA Astro-Electronics Division (AED) checkout facility and the AED ground station are each a complete set of ground support equipment, which, with some additional facilities, permit the functioning of the spacecraft to be fully checked out. Since a failure in either of the AED stations would not be operationally catastrophic, it is not necessary to include the redundant features that are incorporated in the CDA stations.

Like the CDA stations, the AED facilities must be capable of testing and operating TOS, TIROS M/ITOS-1, ITOS A, B, and C, and ITOS D and E configuration spacecraft.

Unless otherwise specified, the information in this section applies to both AED stations.

2. Radio Frequency Signal Handling

The checkout stations include equipment for converting the transmitted signals from the spacecraft into the frequency bands and signal levels present at the CDA station interfaces. Equipment for the reception of beacon data, real-time SR data, and S-band data is already installed. Facilities also exist for transmitting command data to the spacecraft.

3. Data Processing

The ITOS D and E modifications which were described in paragraph C will also be added to the AED test stations. Since these stations are not part of the operational link, as are the CDA stations, redundancy features and slow-time demodulators which monitor the data to the long lines, are not required. The modifications are summarized in the following paragraphs.

a. S-BAND DATA

- One additional ITOS D and E demultiplexer will be added. Space is available in existing rack 46.
- VHRR video and flutter-and-wow demodulators, one each, will be added for oscilloscope display of data.
- A VHRR video demodulator will be added for visicorder display of data. The 35 kHz baseband will be reduced to 4.38 kHz by an 8 to 1 reduction in record to play back speeds. The new video baseband is within the frequency response of existing station visicorders.
- SR video and flutter-and-wow demodulators, one each, will be added for oscilloscope and visicorder display of baseband data.
- The control switches and monitoring circuits associated with processing the TIROS M/ITOS-1, ITOS A, B, and C, and the ITOS D and E data via the proper demultiplexer to the correct recorder channels will be added.
- The control switches to process the data via the correct demodulators will be added.

b. BEACON DATA

The ITOS facilities will be used without change.

c. REAL-TIME SR DATA

- An am demodulator will be added to provide oscilloscope and visicorder displays of the baseband data.

4. Commands

The ITOS D and E modifications which were described in paragraph C will be added to the AED test stations.

G. LAUNCH SUPPORT STATION

Since the complement and operation of this station are almost identical to the AED test stations, the ITOS D and E modifications will be the same as those described in paragraph F.